Editor's Overview

THE 24TH ISSUE OF THE *International Productivity Monitor* (IPM) published by the Centre for the Study of Living Standards contains ten contributions. Topics covered include the World KLEMS initiative, the new concept of human capital productivity, a symposium on the measurement of multifactor productivity in Canada, the long-term outlook for productivity growth in Canada, methodologies for the estimation of industry contributions to aggregate labour productivity growth, and the political economy of economic and productivity growth.

Advances in our understanding of productivity trends require better data. A major initiative in this area is the World KLEMS project, which generates data sets for inputs of capital (K), labour (L), energy (E), materials (M) and services (S) at the industry level for countries around the world. In the lead article, **Dale W. Jorgenson** from Harvard University, author of many seminal papers on productivity topics and leader of the World KLEMS initiative, shows how these data sets provide a framework for productivity measurement and analysis at the industry level, filling a void in the system of national accounts. Using KLEMS data for the United States for the 1947-2010 period, he provides a detailed examination of the sources of economic growth, shedding light on the roles played by IT-producing, IT-using, and non-IT industries in the growth process.

The concept of human capital, defined as the discounted value of future earnings, has a long history in economics. But human capital has never been directly linked to productivity. In the second article, **Barbara Fraumeni** from the University of Southern Maine and the China Center for Human Capital and Labour Market Research, and an expert in the human capital field, makes a pioneering attempt to bring the concepts of human capital and labour productivity together by introducing a new term, human capital productivity, defined as the ratio between an index of discounted future output and an index of human capital. While still in its very early stages of conceptual development and without empirical estimates, the concept of human capital productivity may contribute significantly to our understanding of the role human capital plays in potential output growth.

Official estimates of business sector multifactor productivity (MFP) growth in Canada paint a dismal picture. Statistics Canada reports that MFP advanced at a meager 0.28 per cent average annual rate over the 1961-2011 period and that the level of MFP was actually lower in 2011 than in 1977. MFP growth is often considered a proxy for the pace of innovation in an economy, or at least the rate of disembodied technical change. Given the major new technologies that have been introduced over the last one third of a century, many find it difficult to accept that MFP growth has been negative. To address the question of the accuracy of official MFP estimates, this issue of the IPM features a symposium on the measurement of MFP in Canada.

In the first article of the symposium, **Erwin Diewert** from the University of British Columbia and the University of New South Wales, a world expert in productivity measurement, and **Emily Yu** from the Department of Foreign Affairs and International Trade put forward new estimates of MFP growth for the Canadian business sector, finding that MFP actually grew at a 1.03 per cent average annual rate between 1961 and 2011. This 0.75 percentage point differential with the official MFP growth rate is accounted for by significantly lower capital services growth: 3.0 per cent versus 4.8 per cent. They make the case that the Statistics Canada capital services growth is implausibly high.

In the second article in the symposium, **Wulong Gu** from Statistics Canada responds to Diewert and Yu by identifying three methodological choices these authors made that account for the discrepancy in capital services growth: the use of a top-down approach to the aggregation of assets in contrast to the bottom up approach used by Statistics Canada; the assumption that the real rate of return is equalized across assets, in contrast to Statistics Canada's assumption that the nominal rate of return is equalized; and the use of a much smaller list of assets. Gu argues that Statistics Canada estimates follow international practices adopted by other statistical agencies in order to make MFP estimates internationally comparable.

In a rejoinder to Gu, **Erwin Diewert** agrees that his use of the top-down approach involves some aggregation bias that the bottom-up approach avoids and notes that he would have preferred to have used this latter approach if more detailed data had been publically available. The ability of outside researchers to replicate Statistics Canada's MFP estimates should be encouraged as this can serve as a check on the reliability of the official estimates. Diewert also shows that Statistics Canada's assumption that expected capital gains equal ex post capital gains can lead to negative user costs of capital, which are not plausible.

The symposium contains two additional contributions to the debate. In the first, **Paul Schreyer** from the OECD notes that there is no single method for the calculation of the user cost of capital, and hence capital services, that constitutes an international standard. He argues that it is worth pursuing this objective and states that the OECD is willing to contribute. He also makes a useful distinction between effective productivity growth and underlying productivity growth. The former adds up industry productivity growth while the latter includes the reallocation effects related to a departure from the assumption of efficient input markets, that is inputs growing more rapidly in those industries that pay relatively higher prices for those inputs than other industries. Schreyer points out that the large reallocation effects found for Canada by Gu suggest significant productivity gains could be realized through more efficient resources reallocation.

In the second, **Michael Harper**, formerly with the U.S. Bureau of Labor Statistics (BLS), and **Alice Nakamura** and **Lu Zhang** from the University of Alberta discuss the BLS approach to MFP measurement, and compare this approach to that taken by Statistics Canada. They note that transparency has been a key hallmark of the BLS approach and that the agency has worked closely and shared data with other government departments and academic economists interested in MFP and that this interaction with data users has proven very beneficial to everyone involved. They also note that the BLS uses a pragmatic mixture of exogenous and endogenous rates of return in its estimation of the user cost of capital. This means that the MFP estimates produced by Statistics Canada and the BLS are not strictly speaking comparable given that Statistics Canada uses endogenous rates of return.

The articles in the symposium greatly advance our understanding of the measurement of multifactor productivity in Canada. The symposium highlights the sensitivity of capital services estimates and hence MFP estimates, to the assumptions related to the user cost of capital, particularly the treatment of the rate of return. The importance of transparency in the construction of MFP estimates is also a key theme of the symposium. Everyone benefits from researchers outside Statistics Canada having access to data that allow them to replicate the official estimates. Stronger measured MFP growth arising from slower capital services growth means that capital intensity growth is weaker. This changes the relative importance of the two main sources of labour productivity growth (MFP and capital deepening). There is no effect on labour productivity growth.

Labour productivity growth in Canada has averaged well less than 1 per cent since 2000. Whether this pace continues, or whether productivity growth returns to the faster pace of the pre-2000 period, will be crucial for the economic destiny of the country. In the eighth article, **Peter Jarrett** from the OECD provides a relatively optimistic long-term outlook for productivity in Canada based on an OECD modeling exercise. While admitting that the factors that explain the poor productivity performance of the 2000s are poorly understood, he sees output per worker growth averaging 1.7 per cent per year over the next half century, nearly double the rate for the 2000s, as the Canadian economy returns to its long-term labour productivity growth path.

Productivity analysis normally includes the estimation of sectoral contributions to aggregate labour productivity growth. Unfortunately, there is no unique way to decompose productivity growth into its sectoral or industry components. Results can vary significantly depending on the choice of decomposition formula. In the ninth article, **Ricardo de Avillez** from the Centre for the Study of Living Standards reviews three decomposition formulas, arguing that all three provide significant, and complementary, insights into the role industries play in adding to or subtracting from overall productivity growth. A particularly interesting finding refers to the oil and gas sector, which is found to have made a large positive contribution, or a negative contribution, to aggregate labour productivity growth depending on whether oil and gas prices increases are included, or excluded, from the decomposition formula.

One of the most influential books on economics published in 2012 has been *Why Nations Fails: The Origins of Power, Prosperity and Poverty* by Daron Acemoglu from MIT and James Robinson from Harvard University. The book argues that it is man-made economic and political institutions that underlie economic success, including productivity performance. In the summer of 2012, **Christopher Ragan** from McGill University interviewed both authors. The final article is an edited transcript of that interview.

The World KLEMS Initiative

Dale W. Jorgenson[1]
Harvard University

ABSTRACT

The objective of this article is to provide an overview of the World KLEMS Initiative, which brings together EU KLEMS, Latin America KLEMS, and Asia-KLEMS. This project generates KLEMS data sets, consisting of inputs of capital (K) and labour (L) at the industry level, together with inputs of energy (E), materials (M) and services (S), for countries around the world. Growth of output, inputs, and productivity at the industry level is critical to understanding changes in the structure of an economy, especially the relative importance of different industries and different inputs. The article illustrates the insight into the growth process provided by the KLEMS framework by analyzing the sources of economic growth in the United States over the 1947-2010 period, including contributions to growth from IT-producing and IT-using and non-IT-using industries as well as college and non-college labour.

RÉSUMÉ

Un aperçu de l'initiative World KLEMS, qui regroupe EU-KLEMS, LA-KLEMS, et Asia-KLEMS, est présenté dans cet article. Cette initiative génère des ensembles de données, formés d'intrants de capital (K) et de travail (L pour Labour) au niveau des industries, et d'intrants d'énergie (E), de matières (M) et de services (S) pour des pays partout dans le monde. La croissance de la production, des intrants et de la productivité au niveau des industries est essentielle pour comprendre les changements structurels d'une économie, en particulier l'importance relative de différentes industries et de différents intrants. Cet article illustre ce que le cadre KLEMS peut nous apprendre sur le processus de croissance en analysant les sources de la croissance économique aux États-Unis pendant la période 1947 à 2010, y inclus la contribution à la croissance des industries qui produisent des TI, qui utilisent des TI et qui n'en utilisent pas, ainsi que celle de la main-d'œuvre ayant effectué des études collégiales et de la main-d'œuvre n'en ayant pas fait.

THE WORLD KLEMS INITIATIVE was established at the First World KLEMS Conference, held at Harvard University on August 19-20, 2010. The purpose of this Initiative is to generate KLEMS data sets, consisting of inputs of capital (K) and labour (L) at the industry level, together with inputs of energy (E), materials (M) and services (S), for countries around the world. These data sets will provide the framework for analyzing the sources of economic growth at the industry level and will fill a void in systems of national accounts. Growth of output, inputs, and productivity at the industry level is also critical to understanding changes in

1 Dale W. Jorgenson is the Samuel W. Morris University Professor with the Department of Economics at Harvard University. I am grateful to Marcel Timmer and Bart van Ark for joining me in launching the World KLEMS Initiative. I am also indebted to Mun Ho and Jon Samuels for their collaboration on the new KLEMS data set for the United States for 1947-2010 described below. Finally, I would like to thank Andrew Sharpe and members of the International Advisory Committee for the journal for their helpful suggestions. Email: djorgenson@fas.harvard.edu.

the structure of an economy especially the relative importance of different industries and different inputs. Furthermore, international comparisons of level differences based on purchasing power parities of outputs and inputs at the industry level provide a second focus for KLEMS research. These comparisons are essential in assessing changes in comparative advantage and formulating growth policy.

The EU (European Union) KLEMS study provides industry-level data on the sources of growth for 25 of the 27 EU member countries.[2] Two volumes have been published on the results of the study. Marcel Timmer, Robert Inklaar, Mary O'Mahony, and Bart van Ark (2010 and 2011) describe the data sets and analyze the sources of economic growth in Europe at the industry level. These data sets are essential for tracing the slowdown in European economic growth that preceded the current financial and fiscal crisis to slower productivity growth and lower levels of investment in information technology. The EU KLEMS project also includes data sets for Australia, Canada, Japan, Korea, and the United States. Matilde Mas and Robert Stehrer (2012) present international comparisons within Europe and between Europe and advanced economies in Asia and North America. As European policy-makers focus on removing barriers to the revival of economic growth, international differences in the sources of growth have become central to the development of new directions for policy.

The Second World KLEMS Conference was held at Harvard University on August 9-10, 2012. The conference included reports on recent progress in the development of KLEMS data sets, as well as extensions and applications.[3] Regional organizations in Asia and Latin America have now joined the European Union in supporting research on KLEMS data sets. Due to the growing recognition of the importance of KLEMS data, an effort is underway to extend the KLEMS framework to emerging and transition economies. These include Argentina, Brazil, Chile, China, India, Indonesia, Mexico, Russia, Turkey, and Taiwan. Brazil, Russia, India, and China have been widely recognized as future leaders in the growth of the world economy.

The Latin American chapter of the World KLEMS Initiative, LA-KLEMS, was established in December 2009 at a conference at ECLAC, the Economic Commission for Latin America and the Caribbean. This chapter is coordinated by ECLAC and includes seven research organizations in four leading Latin American countries – Argentina, Brazil, Chile, and Mexico.[4] Mario Cimoli, Andre Hofman, and Nanno Mulder (2010) summarize the results of the initial phase of the LA-KLEMS project.

The Asian chapter of the World KLEMS Initiative, Asia-KLEMS, was founded in December 2010 and the first Asia-KLEMS Conference was held at the Asian Development Bank Institute in Tokyo in July 2011.[5] The Asia-KLEMS Commit-

2 Updated data are available for the EU countries are posted on the EU KLEMS website: http://www.euklems.net/

3 The conference program and presentations are available at: http://www.economics.harvard.edu/faculty/jorgenson/WorldKLEMS.

4 Additional information about LA-KLEMS is available on the project website: http://www.cepal.org/cgi-bin/getprod.asp?xml=/la-klems/noticias/paginas/4/40294/P40294.xml&xsl=/la-klems/tpl-i/p18f-st.xsl&base=/la-klems/tpl-i/top-bottom.xsl. An overview of LA-KLEMS is presented by Hofman (2012).

5 Additional information about Asia-KLEMS is available on the project website: http://asiaklems.net/1_1.html. An overview of Asia-KLEMS is presented by Pyo (2012). Updated data for Australia, Canada, Japan, Korea, and the United States– the original participants in the EU KLEMS study from outside the European Union–are posted on the World KLEMS website: http://www.worldklems.net/. As data become available from the Asia-KLEMS and LA-KLEMS projects, they will also be posted on the World KLEMS website. More details are given by Timmer (2012).

tee includes representatives of major Asian countries, including China, India, Japan, South Korea, and Singapore.

International comparisons of patterns of output, inputs, and productivity are very challenging, but have become crucial to growth strategy in an increasingly globalized world economy. Research on international supply chains has established the need for integration of KLEMS data sets with information on trade. The World Input-Output Database (WIOD) augments industry-level data sets for the countries of the World KLEMS Initiative with data on international trade among these countries. This project has produced a database that includes industry-level patterns of production and trade for all of the participating countries. The World Input-Output Database is a key resource for empirical research on international trade and the process of globalization.[6]

The New Framework for Productivity Measurement

The traditional approach to productivity measurement has been greatly enhanced by the KLEMS accounting framework and the focus of productivity measurement has shifted from the economy as a whole to individual industries.[7] Paul Schreyer's (2001) OECD *Productivity Manual* has established international standards for economy-wide and industry-level productivity measurement.[8] The hallmarks of the new framework for productivity measurement are constant quality indexes of capital and labour services at the industry level and indexes of energy, materials, and services inputs constructed from a time series of input-output tables.

The first data set containing time series data on output, capital, labour, and intermediate inputs, and productivity for all industries in the United States was constructed by Dale Jorgenson, Frank Gollop, and Barbara Fraumeni (1987). This study provided annual data for the period 1948-1979 and was recognized as the international standard in Paul Schreyer's (2001) *OECD Productivity Manual*. Dale Jorgenson, Mun Ho, and Kevin Stiroh (2005) updated the data set and revised it to include data on investment in information technology. This demonstrated the importance of KLEMS data in understanding the IT investment boom and provided the framework for the KLEMS data sets and international comparisons for Europe, Japan, and the United States presented in Jorgenson (2009).

The key idea underlying a *constant quality index of labour input* is to capture the heterogeneity of different types of labour inputs. Hours worked for each type of labour input are combined into a constant quality index of labour input, using labour compensation per hour as weights.[9]

Similarly, a *constant quality index of capital input* deals with the heterogeneity among different types of capital inputs. These capital inputs are combined into a constant quality index, using prices of the inputs with rental prices as weights, rather than the asset prices used in measuring capital stocks. The KLEMS accounting framework employs the concept of the cost of capital introduced by Jorgenson (1963). This makes it possible to incorporate differences among depreciation rates on different assets, as well as variations in returns due to the tax treatment of

6 Information about WIOD is available on the project website: http://www.wiod.org/participants/index.htm. The relationship between WIOD and World KLEMS is discussed by Timmer (2012).

7 A detailed survey of recent research on sources of economic growth is given in Jorgenson (2005). A survey of earlier research is given in Jorgenson (1990).

8 A brief history of World KLEMS is presented by Schreyer (2012).

9 Constant quality indexes of labour input for the United States at the industry level are discussed in detail by Jorgenson, Gollop, and Fraumeni (1987:69-108 and 261-300) and Jorgenson, Ho, and Stiroh (2005:201-290).

different types of capital income, into the rental prices. These prices also include asset-specific inflation rates that are particularly important in analyzing the impact of investments in information technology.[10]

The new framework for productivity measurement has posed the challenge of developing a system of production accounts for individual sectors of the U.S. economy. This is a set of accounts for outputs of individual industries as well as inputs of capital and labour services and intermediate goods for these industries in current and constant prices. The basic accounting identity for each industry is that the value of output is equal to the sum of values of the inputs. A complete system of production accounts for the U.S. economy was constructed by Jorgenson, Gollop, and Fraumeni (1987). The system incorporates a time series of input-output tables in current and constant prices.[11]

Finally, industry-level data on output, inputs and productivity are linked to aggregate data on the sources of economic growth by means of the *production possibility frontier* introduced by Jorgenson (1966). This allows for joint production of consumption and investment goods from capital and labour services. Nicholas Oulton (2007) demonstrates that Robert Solow's (1960) model of embodied technical change is a special case of the model proposed by Jorgenson (1966). Jeremy Greenwood and Per Krussell (2007) employ Solow's one-sector model, replacing constant quality price indexes for investment goods with "investment-specific" or embodied technical change. The deflator for the single output is used to deflate both consumption and investment, while separate deflators are provided for consumption and investment in the systems of national accounts discussed below.

The new framework for productivity growth measurement was adopted by the Panel to Review Productivity Statistics of the National Research Council, chaired by Albert Rees. The Rees Report of 1979, *Measurement and Interpretation of Productivity*, became the cornerstone of this new measurement framework for the official productivity statistics. This was implemented by the Bureau of Labor Statistics (BLS), the U.S. government agency responsible for these statistics. Under the leadership of Jerome Mark and Edwin Dean, the BLS Office of Productivity and Technology undertook the construction of a production account for the U.S. economy with measures of capital and labour inputs and total factor productivity, renamed *multifactor productivity*.[12]

New Architecture

Dale Jorgenson and Steven Landefeld (2006) have developed a new architecture for the U.S. national income and product accounts (NIPAs) that includes prices and quantities of capital services for all productive assets in the U.S. economy. The incorporation of the price and quantity of capital services into the *System of National Accounts 2008* was approved by the United Nations Statistical Commission at its February-March 2007 meeting (United Nations *et.al.*, 2009). Schreyer, then head of national accounts at the OECD, prepared an OECD

10 Constant quality indexes of capital input for the United States at the industry level are presented by Jorgenson, Fraumeni, and Gollop (1987:109-140 and 267-300), and by Jorgenson, Ho, and Stiroh (2005:147-200).

11 Details on the construction of the time series of input-output tables are presented by Jorgenson, Gollop and Fraumeni (1987:149-182), and Jorgenson, Ho, and Stiroh (2005:87-146).

12 A detailed history of the BLS productivity measurement program is found in Dean and Harper (2001). The BLS (1983) framework was based on GNP rather than NNP and included a constant quality index of capital input. A constant quality index for labour input was incorporated in 1993 (BLS, 1993). The expert advisory group for the *OECD Productivity Manual* was chaired by Edwin Dean, then Associate Commissioner for Productivity at the BLS and leader of the successful effort to implement the Rees report (Rees, 1979).

Manual, *Measuring Capital*, published in 2009. This provides detailed recommendations on methods for the construction of prices and quantities of capital services. In effect, the UN Statistical Commission reversed the position of the *System of National Accounts 1993*, which had stated that it was impossible to decompose income from capital (called net operating surplus) into price and quantity components (United Nations *et.al.*, 1993:403).

The *SNA 2008* (United Nations *et.al.*, 2009:415) estimates of capital services are described as follows:

> By associating these estimates with the standard breakdown of value added, the contribution of labour and capital to production can be portrayed in a form ready for use in the analysis of productivity in a way entirely consistent with the accounts of the System.

The measures of capital and labour inputs in the prototype system of U.S. national accounts presented by Jorgenson and Landefeld (2006) are consistent with the *OECD Productivity Manual*, *SNA 2008*, and the OECD Manual, *Measuring Capital*. The volume measure of input is a quantity index of capital and labour services, while the volume measure of output is a quantity index of investment and consumption goods. Productivity is the ratio of output to input.

The new architecture for the U.S. national accounts was endorsed by the Advisory Committee on Measuring Innovation in the 21st Century Economy to the U.S. Secretary of Commerce: [13]

> The proposed new 'architecture' for the NIPAs would consist of a set of income statements, balance sheets, flow of funds statements, and productivity estimates for the entire economy and by sector that are more accurate and internally consistent. The new architecture will make the NIPAs much more relevant to today's technology-driven and globalizing economy and will facilitate the publication of much more detailed and reliable estimates of innovation's contribution to productivity growth.

In response to the Advisory Committee's recommendations, the Bureau of Economic Analysis (BEA) and the BLS have produced an initial set of multifactor productivity estimates integrated with the NIPAs. Data on capital and labour inputs are provided by the BLS. The results are reported by Michael Harper, Brent Moulton, Steven Rosenthal, and David Wasshausen (2009) and will be updated annually.[14] This is a critical step in implementing the new architecture. Estimates of productivity are essential for projecting the potential growth of the U.S. economy, as demonstrated by Jorgenson, Ho, and Stiroh (2008). The omission of productivity statistics from the NIPAs and the 1993 SNA has been a serious barrier to assessing potential growth.

Measuring Productivity at the Industry Level

Reflecting the international consensus on productivity measurement at the industry level, the Advisory Committee on Measuring Innovation in the 21st Century Economy to the U.S. Secretary of Commerce (2008:7) recommended that the BEA should:

> Develop annual, industry-level measures of total factor productivity by restructuring the NIPAs to create a more complete and consistent set of accounts integrated with data from other statistical agencies to allow for the consis-

13 The Advisory Committee was established on December 6, 2007, with ten members from the business community, including Carl Schramm, President and CEO of the Kauffman Foundation and chair of the Committee. The Committee also had five academic members, including the author . The Advisory Committee met on February 22 and September 12, 2007, to discuss its recommendations. The final report was released on January 18, 2008.

14 The most recent data set is available at: http://www.bea.gov/national/integrated_prod.htm.

tent estimation of the contribution of innovation to economic growth.

The principles for constructing industry-level production accounts are found in Fraumeni, Harper, Powers, and Yuskavage (2006). Disaggregating the production account by industrial sector requires the fully integrated system of input-output accounts and accounts for gross product originating by industry as described by Lawson, Moyer, Okubo, and Planting (2006), and Moyer, Reinsdorf, and Yuskavage (2006). Moyer (2012) described plans to integrate the BEA's industry data with the NIPAs, beginning with the benchmark revision of 2013, at the Second World KLEMS Conference. The NIPAs and the 2007 benchmark input-output table will be prepared within the same framework. The annual input-output data will be revised periodically along with the NIPAs and will form a continuous time series. The annual input-output data are employed in the industry-level production accounts presented by Susan Fleck, Steven Rosenthal, Matthew Russell, Erich Strassner, and Lisa Usher (2012) in their paper for the Second World KLEMS Conference, "A Prototype BEA/BLS Industry-Level Production Account for the United States." This covers the period 1998-2010 for the 65 industrial sectors used in the NIPAs.[15] The capital and labour input are provided by the BLS, while the data on output and intermediate inputs are generated by the BEA.

Industry-level production accounts are now prepared on a regular basis by national statistical agencies in Australia, Canada, Denmark, Finland, Italy, the Netherlands, and Sweden as well as the United States. Augmented by production accounts from the EU KLEMS project described by Timmer, Inklaar, O'Mahony, and van Ark (2010), these accounts can be used in international comparisons of patterns of structural change like those presented by Jorgenson and Timmer (2011). The World KLEMS Initiative will make it possible to extend these comparisons to numerous countries around the world, including important developing and transition economies.

A Prototype Industry-Level Production Account for the United States, 1947-2010

To illustrate the application of KLEMS data sets, I will summarize the prototype production account for the United States for 1947-2010 constructed by Jorgenson, Ho and Samuels (2012b). The incorporation of data on labour and capital inputs in constant prices into the national accounts is described in Chapters 19 and 20 of the *System of National Accounts 2008*, published in 2009. Jorgenson and Schreyer (2012) have shown how to integrate a complete system of production accounts at the industry level, such as provided by KLEMS data sets, into the *System of National Accounts 2008*. The lengthy time series is especially valuable for comparing recent changes in the sources of economic growth with longer term trends.

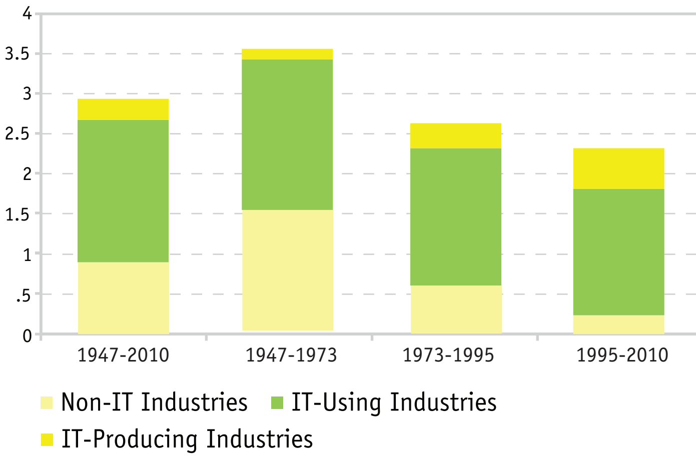
In December 2011, the BEA released a new industry-level data set. This has a number of features that are useful in constructing KLEMS data sets. The data set employs the North American Industry Classification System (NAICS). The NIPAs have been based on NAICS since the benchmark revision of 2003. The new industry data set integrates three separate industry programs: benchmark input-output tables released every five years, annual input-output tables, and gross domestic product by industry, also released annually. The annual input-output tables and gross domestic product by industry form consistent time series. The input-output tables provide data on the output side of the national

15 The most recent date set is availbale at: http://bea.gov/industry/index.htm#integrated.

Chart 1

Contributions of Industry Groups to Value Added Growth in the United States, 1947-2010

(percentage points per year)



accounts along with intermediate inputs in current and constant prices.

Mark Planting, formerly head of the input-output accounts at the BEA, has developed a time series of input-output tables in current prices covering the 1947-1997 period on a NAICS basis. This incorporates all earlier benchmark input-output tables for the United States, including the first benchmark table for 1947. The BEA has linked these input-output tables to the official tables for 1998-2010. Jorgenson, Ho, and Samuels (2012b) have constructed input-output tables in constant prices for 1947-2010 on a NAICS basis. This data set incorporates input-output tables in constant prices from Jorgenson, Gollop, and Fraumeni (1987) for 1948-1979, from Jorgenson, Ho, and Stiroh (2008) for 1977-2000, and from Jorgenson, Ho, and Samuels (2012a) for 1960-2007.[16] We incorporate data on capital and labour inputs in constant prices from the same sources to obtain an industry-level production account for the United States covering the period 1947-2010. This KLEMS data set is consistent with the BEA's annual input-output tables for 1998-2010.

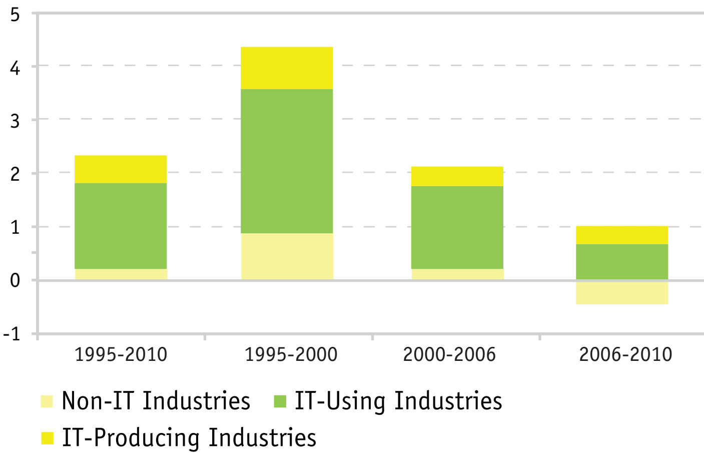
I will illustrate the application of the prototype industry-level production account by analyzing postwar U.S. economic history for three broad periods. These are the postwar recovery, 1947-1973; the big slump following the energy crisis of 1973, 1973-1995; and the period of growth and recession, 1995-2010. To provide more detail on the period of growth and recession, I will consider the sub-periods 1995-2000, 2000-2005, and 2005-2010 – the investment boom, the jobless recovery, and the great recession.

The NAICS industry classification includes the industries identified by Jorgenson, Ho, and Samuels (2012b) as IT-producing industries, namely, computers and electronic products and two IT-services industries, information and data processing and computer systems design. Jorgenson, Ho and Samuels have classified industries as IT-using if at least 15 per cent of capital input in the industry was associated with IT equipment and software in 2005. This sector now comprises about 45 per cent of the U.S. economy. The IT-producing industries include about 3 per cent, while non-IT industries make up the remainder.[17] The IT-using industries are mainly in trade and services, while most manufacturing industries are in the non-IT sector. The NAICS industry classification provides much more detail on services and trade, especially the industries that are intensive users of IT. I will begin by discussing the results for the IT-producing sectors, now defined to include the two IT-service sectors.

16 Data for 1960-2007 are posted on the World KLEMS website: http://www.worldklems.net/data/index.htm.

17 The three industry categories are mutually exclusive. There are 3 IT-producing industries, 34 IT-using industries and 30 non-IT industries. More details are found at: http://www.economics.harvard.edu/faculty/jorgenson/files/12_0425_WIOD.pdf.

Chart 2
Contributions of Industry Groups to Value Added Growth in the United States, 1995-2010
(percentage points per year)



The contribution of each industry to value added is the growth rate of value added for the industry, weighted by its share in value added for the economy as a whole. Prices of computers and electronic products have declined rapidly, relative to the GDP deflator, since the commercialization of the electronic computer in 1959. This trend accelerated with the switch from vacuum tubes to semiconductors around 1970. The two IT-services sectors have had declining prices, relative to the GDP deflator, since around 2000. Chart 1 reveals a steady increase in the share of IT-producing industries in value added since 1947. This is paralleled by a decline in the contribution of the non-IT industries, while the share of IT-using industries has remained relatively constant. Chart 2 decomposes the growth of value added for the period 1995-2010. The contributions of the IT-producing and IT-using industries peaked during the investment boom of 1995-2000 and have declined since then. However, the contribution of the non-IT industries has also declined sharply and became negative during the great recession. Chart 3 gives the contributions to value added for the 65 individual industries over the period 1947-2010.

In order to assess the relative importance of productivity growth at the industry level as a source of U.S. economic growth, we utilize the production possibility frontier of Jorgenson, Gollop, and Fraumeni (1987:301-342) and Jorgenson, Ho, and Stiroh (2005:361-416). This gives the relationship between aggregate productivity growth and productivity growth at the industry level. The growth rate of aggregate productivity includes a weighted average of industry productivity growth rates, using an ingenious weighting scheme originated by Domar (1961). In the Domar weighting scheme the productivity growth rate of each industry is weighted by the ratio of the industry's gross output to aggregate value added. A distinctive feature of Domar weights is that they sum to more than one, reflecting the fact that an increase in the rate of growth of the industry's productivity has two effects. The first is a direct effect on the industry's output and the second an indirect effect via the output delivered to other industries as intermediate inputs.

The rate of growth of aggregate productivity also depends on the reallocations of capital and labour inputs among industries. The rate of aggregate productivity growth exceeds the Domar-weighted sum of industry productivity growth rates when these reallocations are positive. This occurs when capital and labour inputs are paid different prices in different industries and industries with higher prices have more rapid growth rates of the inputs. Under this assumption aggregate capital and labour inputs grow more rapidly than the Domar-weighted averages of industry capital and labour input growth rates, so that the reallocations are positive. When industries with lower prices for inputs grow more rapidly, the reallocations are negative.

Chart 4 shows that the contributions of IT-producing, IT-using, and non-IT industries to aggregate MFP productivity growth are similar in magnitude for the period 1947-2010.

Chart 3

Contributions of Individual Industries to Real Value Added Growth in the United States, 1947-2010

(percentage points per year)

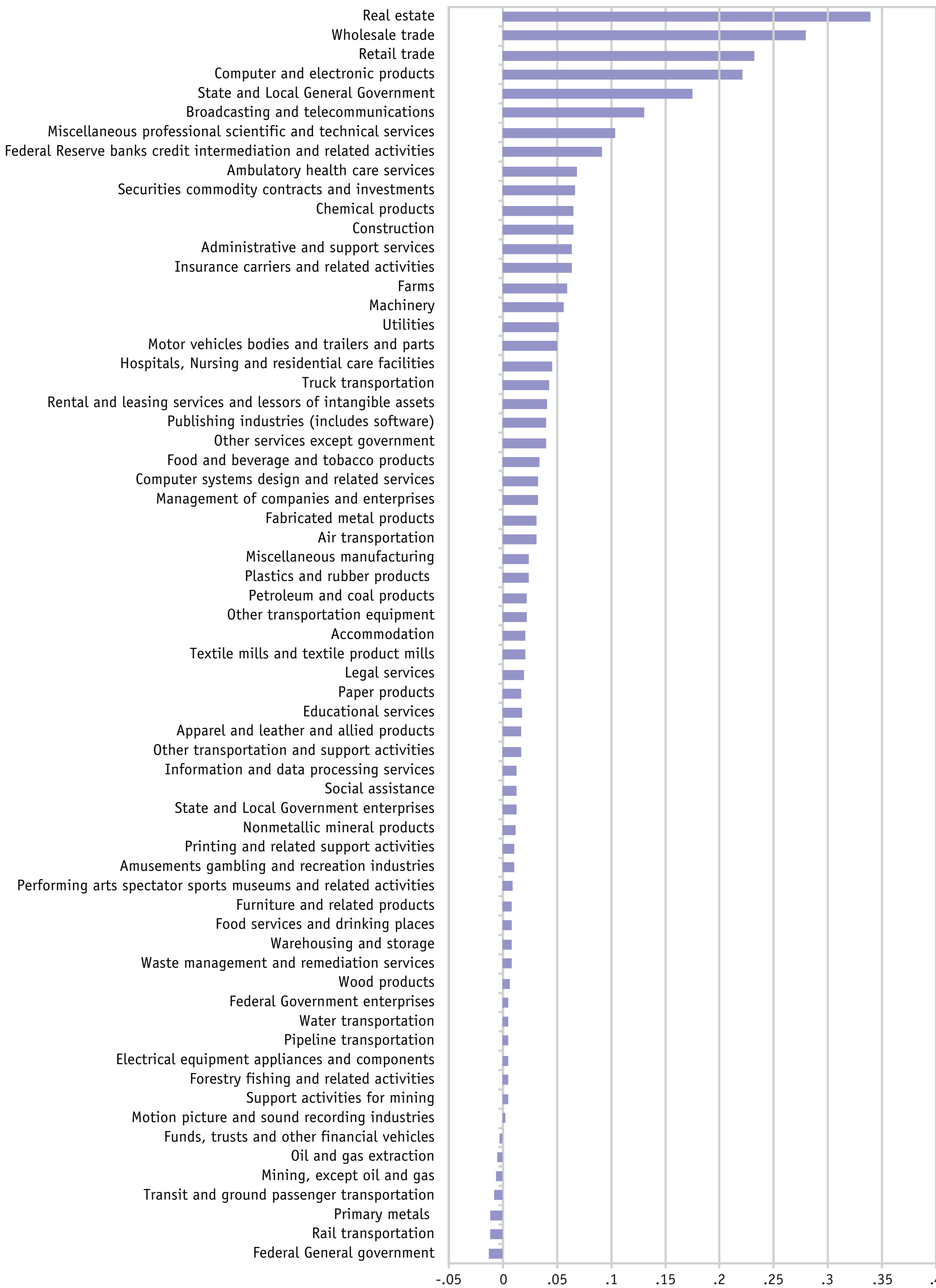


Chart 4

Contributions of Industry Groups to Multifactor Productivity Growth in the United States, 1947-2010

(percentage points per year)

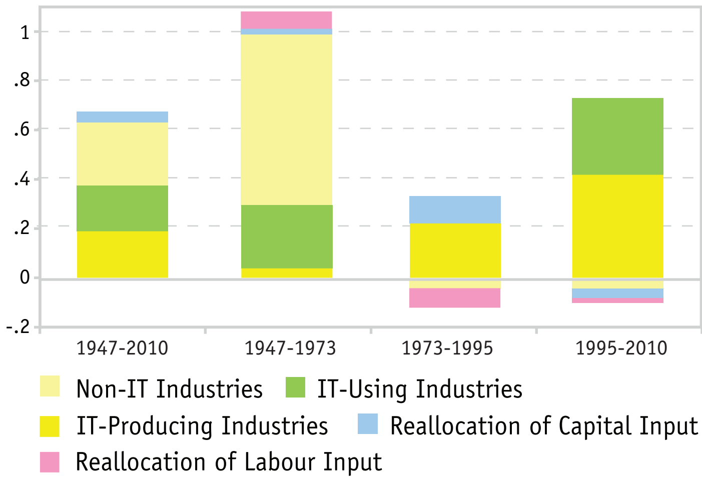
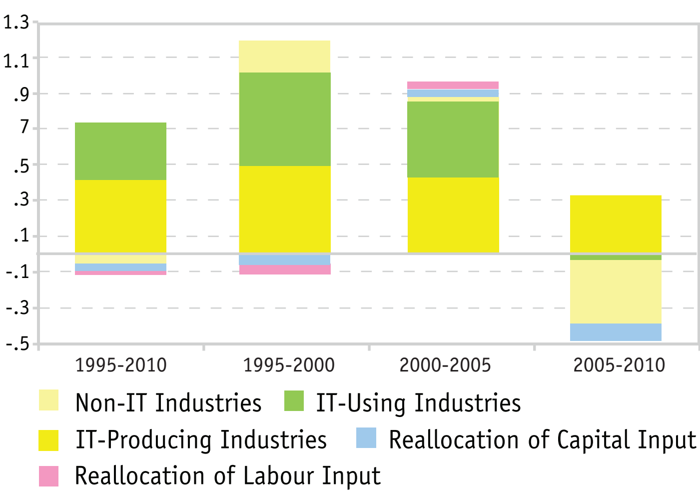


Chart 5

Contributions of Industry Groups to Multifactor Productivity Growth in the United States, 1995-2010

(percentage points per year)



The non-IT industries greatly predominated in the growth of value added during the postwar recovery, 1947-1973, but this contribution became negative after 1973. The contribution of IT-producing industries was relatively small during this period, but became the predominant source of growth during the big slump, 1973-1995, and increased considerably during the resurgence and recession of 1995-2010. The IT-using industries contributed substantially to U.S. economic growth during the postwar recovery, but disappeared during the big slump, 1973-1995, before reviving after 1995. The reallocation of capital input made a small but positive contribution to growth of the U.S. economy for the period 1947-2010, while the contribution of reallocation of labour input was negligible. Both reallocations were positive during the postwar recovery and both were negative during the resurgence and recession, but very small in magnitude.

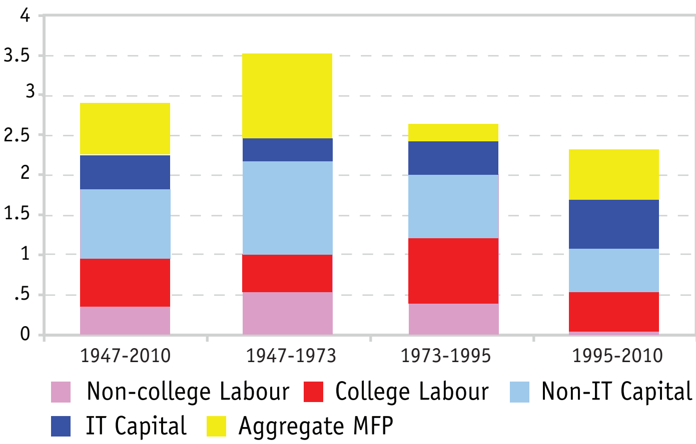
Considering the period 1995-2010 in more detail in Chart 5, the IT-producing industries were the most important source of productivity growth during the period as a whole. The contribution of these industries remained substantial during each sub-period – 1995-2000, 2000-2005, and 2005-2010 – despite the strong contraction of economic activity during the great recession of 2007-2009. The contribution of the IT-using industries was slightly greater than that of the IT-producing industries during the first two sub-periods, but become negative and small in magnitude during the period of the great recession. The non-IT industries contributed positively to productivity growth during the investment boom of 1995-2000, but were almost negligible during the jobless recovery and became substantially negative during the great recession. The contributions of reallocations of capital and labour inputs were very small and negative during the period as a whole and fluctuated from negative in 1995-2000 to positive in 2000-2005. Chart 6 gives the contributions of each of the 65 industries to multifactor productivity growth for the period as a whole. The computer and electronic products industry was the leading contributor to U.S. economic growth during this period.

Chart 6

Contributions of Individual Industries to Multifactor Productivity Growth in the United States, 1947-2010

(percentage points, per year)

Chart 7
Sources of Economic Growth in the United States, 1947-2010
(percentage points per year)



Research on the impact of investment in IT equipment and software on economic growth is summarized by Jorgenson (2009). The prices of capital inputs are essential for assessing the contribution of investment in IT equipment and software to economic growth. This contribution is the relative share of IT equipment and software in the value of output, multiplied by the rate of growth of IT capital input. A substantial part of the growing contribution of capital input in the United States can be traced to the change in composition of investment associated with the growing importance of IT equipment and software. The most distinctive features of IT assets are the rapid declines in prices of these assets, as well as relatively high rates of depreciation. The price of an asset is transformed into the price of the corresponding capital input by the *cost of capital*, introduced by Jorgenson (1963). The cost of capital includes the nominal rate of return, the rate of depreciation, and the rate of capital loss due to declining prices. The distinctive characteristics of IT prices – high rates of price decline and rates of depreciation – imply that cost of capital for the price of IT capital input is very large relative to the cost of capital for the price of non-IT capital input.

The contributions of college-educated and non-college-educated workers to U.S. economic growth is given by the relative shares of these workers in the value of output, multiplied by the growth rates of their hours worked. Personnel with a college degree or higher level of education correspond closely with "knowledge workers" who deal with information. Of course, not every knowledge worker is college-educated and not every college graduate is a knowledge worker. Multifactor productivity growth is the key economic indicator of *innovation*. Economic growth can take place without innovation through *replication* of established technologies. Investment increases the availability of these technologies, while the labour force expands as population grows. With only replication and without innovation, output will increase in proportion to capital and labour inputs. By contrast the successful introduction of new products and new or altered processes, organization structures, systems, and business models generates growth of output that exceeds the growth of capital and labour inputs. This results in growth in multifactor productivity or output per unit of input.

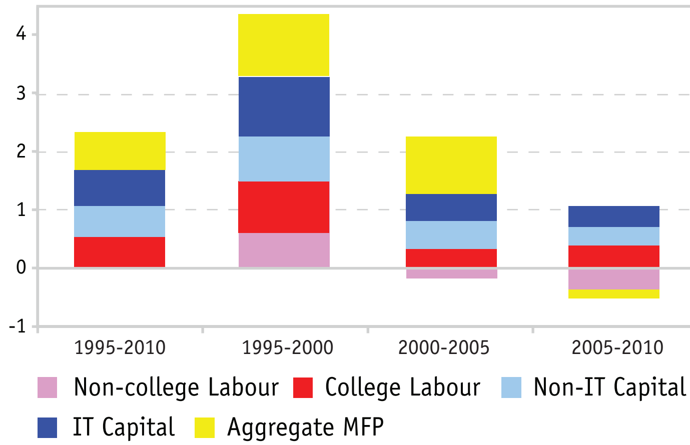
Multifactor productivity growth was identified as the predominant source of economic growth by Solow (1957). However, Chart 7 shows that the productivity growth was far less important than the contributions of capital and labour inputs. For the period 1947-2010 multifactor productivity accounts for about 20 per cent of U.S. economic growth. The contribution of capital input accounts for the largest share of growth for the period as a whole, while the contribution of labour input accounts for the rest. The great bulk of U.S. economic growth is due to replication of established technologies rather than innovation. Innovation is obviously far more challenging and subject to much greater risk. The diffusion of successful innovation requires mammoth financial commitments.

These fund the investments that replace outdated products and processes and establish new organization structures, systems, and business models. Although innovation accounts for a relatively modest portion of economic growth, this portion is vital for maintaining gains in the U.S. standard of living in the long run.

The contribution of capital input exceeded that of innovation, while the contribution of labour input was similar to that of innovation during the postwar recovery, 1947-1973. The standard explanation for the substantial importance of innovation during the period is the backlog of new technologies available at the end of World War II. During the big slump of 1973-1995, growth of inputs remained about the same. The "slump" was due to the sharp slowdown in multifactor productivity growth. The contribution of labour input increased in importance, relative to the contribution of capital input. The contributions of college-educated workers and investment in information technology grew substantially, while the contributions of non-college workers and non-information technology declined considerably. After 1995 the rate of U.S. economic growth continued to decline and the contribution of non-college workers almost disappeared. Multifactor productivity growth revived and investment in information technology became the predominant source of the contribution of capital input.

Chart 8 shows that all of the sources of economic growth we have identified contributed to the U.S. growth acceleration after 1995, relative to the big slump. Jorgenson, Ho, and Stiroh (2008) have shown that the rapid pace of U.S. economic growth after 1995 was not sustainable. After the dot-com crash in 2000 the overall growth rate dropped to well below the long-term average of 1947-2010. The contribution of investment also declined below the long-term average, but the shift from non-IT to IT capital input remained. The contribution of labour input dropped precipitously, accounting for most of the decline in economic growth during the jobless recovery. The contribution to growth by college-educated workers continued at a reduced rate, but that of non-college workers was negative. The most remarkable feature of the jobless recovery was the continued growth in multifactor productivity, indicating a continuing surge of innovation. Both IT and non-IT investment continued to contribute to U.S. economic growth during the recession period after 2005, while multifactor productivity growth became negative, reflecting a widening gap between actual and potential growth of output. The contribution of college-educated workers remained positive and substantial, while the contribution of non-college workers became strongly negative.

Chart 8
Sources of Economic Growth in the United States, 1995-2010
(percentage points per year)



Conclusion

The new framework for productivity measurement employed in constructing KLEMS data sets reveals that replication of established technologies through growth of capital and labour inputs, recently through the growth of college-educated workers and investments in both IT and Non-IT capital, explains by far the largest proportion of U.S. economic growth. International productivity comparisons reveal similar patterns for the world economy, its major regions, and leading industrialized, developing, and emerging economies (Jorgenson and Vu, 2009). Studies are now underway to extend these comparisons to individual industries for the countries included in the World KLEMS Initiative.

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New Estimates of Real Income and Multifactor Productivity Growth for the Canadian Business Sector, 1961-2011

W. Erwin Diewert[1]
University of British Columbia and University of New South Wales
Emily Yu
Department of Foreign Affairs and International Trade

ABSTRACT

Using new data from Statistics Canada, this article shows that the multifactor productivity (MFP) performance of the Canadian business sector has been reasonably satisfactory over the past half century. In particular, traditional gross income MFP growth averaged 1.03 per cent per year over the 1961-2011 period. This compares with the official Statistics Canada estimate of 0.28 per cent. The difference was mostly due to significantly higher capital input growth recorded by Statistics Canada. The study finds that quality adjusted labour input growth was the main driver of real income growth, followed by MFP growth, capital input growth, and finally by falling real import prices. The study encountered many data problems which should be addressed in future work on Canadian business sector productivity performance.

RÉSUMÉ

Utilisant de nouvelles données de Statistique Canada, cet article montre que la performance de la productivité multifactorielle (PMF) des entreprises canadiennes a été raisonnablement satisfaisante au cours du dernier demi-siècle. En particulier, la croissance traditionnelle de la PMF selon les produits bruts a été en moyenne de 1,03 % par année de 1961 à 2011, alors que l'estimation officielle de Statistique Canada est de 0,28 %. Cette différence est due surtout à la croissance beaucoup plus forte des intrants de capital enregistrée par Statistique Canada. L'étude conclut que la croissance de l'apport de travail pondérée par la qualité est le principal facteur de la croissance du revenu réel, suivie par la croissance de la PTF, la croissance des intrants de capital et, enfin, la chute du prix réel des importations. De nombreux problèmes de données qu'il faudrait résoudre dans les prochains travaux sur la performance de la productivité du secteur des entreprises canadiennes se sont présentés au cours de cette étude.

1 Erwin Diewert is Professor in the Department of Economics at the University of British Columbia and at the School of Economics at the University of New South Wales. Emily Yu is an economist at the Department of Foreign Affairs and International Trade. This article is an abridged and edited version of Diewert and Yu (2012). The financial assistance of the SSHRC is gratefully acknowledged. The first author also thanks Shutao Cao, Serge Coulombe, Don Drummond, Wulong Gu, Ulrich Kohli, Sharon Kozicki, Danny Leung, Alice Nakamura, Andrew Sharpe and Jianmin Tang for helpful comments. None of the above are responsible for any views expressed in this paper. Emails: Diewert@econ.ubc.ca; Emily.yu@international.gc.ca.

Many observers have noted that an improvement in a country's terms of trade has effects similar to an improvement in a country's productivity growth in boosting real incomes. However, it is not straightforward to work out the exact magnitude of each source of gain. A number of authors developed production theory methodologies which enable one to obtain index number estimates of the contribution of each type of gain.[2] This article applies the methodology developed in Diewert, Mizobuchi and Nomura (2005) and Diewert and Lawrence (2006) to develop estimates of the sources of real income gains in the business sector of the Canadian economy over the 1961-2011 period. Appendix 1 provides the details of the methodology and Appendix 2 describes how data for the Canadian business sector were developed from Statistics Canada sources.[3]

The first main section of the article uses data from Appendix 2 to develop conventional measures of Canadian business sector multifactor productivity (MFP) for the 1961-2011 period.[4]

MFP growth, while perhaps the most important source of growth in living standards, is not the entire story. If a country's export prices increase more rapidly than its import prices, then it is well known that this has an effect that is similar to a productivity improvement. The second section of the article measures the relative contributions of multifactor productivity improvements, changes in real export and import prices and the growth of labour and capital input to the growth of (gross) real income generated by the business sector in Canada using the methodology explained in Appendix 1.

The third section compares our estimates of MFP growth to the official MFP estimates produced by the Statistics Canada KLEMS program.[5] It should be noted that the Statistics Canada KLEMS program uses detailed industry data in order to construct MFP estimates by industry and then these industry estimates are aggregated to give total business sector estimates of MFP growth. In contrast, our approach uses aggregate estimates for the outputs produced and inputs used for the entire business sector. Thus our estimates may suffer from some aggregation bias. The final section concludes.

Output and Input Aggregates and Conventional Productivity Growth for Canada

In Appendix 2, we construct price and quantity series for 22 net outputs, 12 types of labour input and 17 types of capital input for the business sector of the Canadian economy for the years 1961-2011.[6]

The net outputs are domestic consumption (Q_1) (excluding market residential rents and the services of owner occupied housing); real sales of goods and services by the business sector to

2 See Diewert (1983), Diewert and Morrison (1986), Diewert, Mizobuchi and Nomura (2005), Diewert and Lawrence (2006), Morrison and Diewert (1990), and Kohli (1990, 2003, 2004, and 2006).

3 Appendix 1 is posted at http://www.csls.ca/ipm/24/appendix1-diewert-yu.pdf and Appendix 2 is posted at http://www.csls.ca/ipm/24/appendix2-diewert-yu.pdf.

4 Total factor productivity and multifactor productivity are the same concept. The authors have in the past used the former term. This article adopts multifactor productivity since this is the term used by Statistics Canada.

5 See Baldwin, Gu and Yan (2007) for a description of the methodology used in the KLEMS program. KLEMS stands for capital (K), labour (L), energy (E), materials (M), and services (S). For an overview of World KLEMS, see Jorgenson (2012).

6 The series are almost all chained Tornqvist indexes, not chain Fisher indexes as used by Statistics Canada. This choice is a better fit with exact index number results (Diewert and Morrison, 1986). However, the differences between the chained Fisher and Tornqvist are negligible so this is not a source of difference with KLEMS estimates.

the nonmarket sector less real sales of goods and services from the nonmarket sector to the business sector (Q_2), four types of investment goods (Q_3-Q_6), inventory change (Q_7), eight types of exports (Q_8-Q_{15}), and seven types of imports (Q_{16}-Q_{21}).[7]

The price indexes that correspond to the above quantity indexes Q_n^t are denoted as P_n^t for n = 1,..., 22 and t = 1961,..., 2011 and are listed in Appendix 2. We define the price of our consumption aggregate as $P_C^t \equiv P_1^t$.

We form a domestic output aggregate Q_D^t with corresponding price P_D^t by aggregating Q_1^t-Q_7^t.[8] Similarly, we form an export aggregate Q_X^t with corresponding price P_X^t by aggregating Q_8^t-Q_{15}^t and an import aggregate Q_M^t with corresponding price P_M^t by aggregating Q_{16}^t-Q_{22}^t.[9] Once these indexes have been constructed, a business sector aggregate output or real value added index Q_Y^t is constructed as an aggregate of Q_D^t, Q_X^t and $-Q_M^t$. The corresponding aggregate output price index is P_Y^t.[10] The price indexes P_C^t, P_D^t, P_X^t, P_M^t and P_Y^t for the 1961-2011 period are given in Table 1 and the corresponding quantity indexes Q_D^t, Q_X^t, Q_M^t and Q_Y^t are given in Table 2.

Statistics Canada has constructed detailed labour input data for the Canadian business sector for 36 types of labour for the 1961-2010 period in CANSIM Table 3830024 which we will make use of in this study. Labour input is organized according to a four way classification:

- By *education level* E. There are 3 categories in this classification: E=1 corresponds to primary or secondary education; E=2 corresponds to some or completed post-secondary education below university and E=3 corresponds to university degrees or above.
- By *age of worker* A. There are 3 categories in this classification: A=1 corresponds to 15-34 years old; A=2 corresponds to 35-54 years old and A=3 corresponds to 55 years old and over.
- By *sex* S. There are 2 categories in this classification: S=1 corresponds to a male worker and S=2 corresponds to a female worker.
- By *type of employment* T. There are 2 categories in this classification: T=1 corresponds to a paid worker and T=2 corresponds to a self employed worker.

Estimates of annual hours and total compensation are thus provided for 36 types of workers (3x3x2x2). We aggregate over the age groups using Fisher chained indexes in order to form 12 price and quantity series for labour, P_{L1}-P_{L12}

7 The 22 net outputs are: domestic consumption (Q_1) (excluding market residential rents and the services of owner occupied housing); real sales of goods and services by the business sector to the nonmarket sector less real sales of goods and services from the nonmarket sector to the business sector (Q_2) government investment (Q_3); business sector investment in residential structures (Q_4); business sector investment in machinery and equipment (Q_5); business sector investment in nonresidential structures (Q_6); inventory change (Q_7); exports of agricultural and fish products (Q_8); exports of energy products (Q_9); exports of forest products (Q_{10}); exports of industrial goods and materials (Q_{11}) (excluding energy and forest product exports); exports of machinery and equipment (Q_{12}) (excluding automotive products); exports of automotive products (Q_{13}); exports of other consumer goods (Q_{14}) (excluding automotive products); exports of services (Q_{15}); imports of agricultural and fish products (Q_{16}); imports of energy products (Q_{17}); imports of industrial goods and materials (Q_{18}) (including imports of forest products but excluding imports of energy products); Imports of machinery and equipment (Q_{19}) (excluding automotive products); imports of automotive products (Q_{20}); imports of other consumer goods (Q_{21}); and imports of services (Q_{22}).

8 P_D^t is the Törnqvist price index of P_1^t-P_7^t and Q_D^t is the corresponding implicit quantity index.

9 P_X^t and P_M^t are constructed as Törnqvist price indexes and Q_X^t and Q_M^t are the corresponding implicit quantity indexes.

10 P_Y^t is a Törnqvist price aggregate of P_D^t,P_X^t,P_M^t (with corresponding quantities Q_D^t,Q_X^t,$-Q_M^t$) and Q_Y^t is the implicit quantity index that matches up with P_Y^t.

and Q_{L1}-Q_{L12}. These series were extended to 2011 using various Statistics Canada series as explained in Appendix 2. These 12 price and quantity series for the various types of labour were aggregated into aggregate quality adjusted business sector labour input Q_L^t with corresponding price index P_L^t.[11] P_L^t is provided in Table 1 and Q_L^t is given in Table 2.

Using information on business sector capital stocks in CANSIM Table 310003, calculated estimates for the beginning of year capital stock for the business sector for the 14 types of reproducible capital assets ($Q_{K1\text{-}K14}$).[12] Using Statistics Canada balance sheet information (and other sources), we were able to construct business sector beginning of the year capital stock inputs for inventories (Q_{K15}), agricultural land (Q_{K16}) and business nonagricultural land (Q_{K17}). We also constructed estimates for the corresponding capital stock prices, P_{Kn}^t, for n = 1,...,17 and t = 1961-2011.

As explained in Appendix 2, user cost prices U_n^t for the 17 capital stock inputs were constructed, using balancing or endogenous real rates of return that made the value of net output produced by the business sector equal to the value of primary inputs used by the business sector.[13]

There is a problem with our capital input data in that the software series starts only in 1981. Our translog methodology does not work when an input is equal to 0 in one period and positive in a subsequent period. Thus we aggregated the software asset with the computer asset; i.e., we constructed a Fisher capital services aggregate of (U_8^t,U_{10}^t) and (Q_{K8}^t,Q_{K10}^t) to replace the individual services for these two assets.[14] We then constructed a business sector capital services aggregate Q_K^t by aggregating the 16 types of capital services using direct Törnqvist quantity aggregation. The corresponding capital services aggregate price is denoted as P_K^t and is listed in Table 1 while Q_K^t is listed in Table 2.

Once the labour and capital aggregates have been constructed, we can construct a direct Törnqvist quantity *input aggregate* of Q_L^t and Q_K^t which we denote by Q_Z^t, which is listed in

11 Q_L^t is now a direct Törnqvist quantity aggregate of Q_{L1}^t-Q_{L12}^t with P_L^t defined as the corresponding implicit price index. These index number conventions are necessary in order to apply the translog methodology explained in Appendix 1.

12 Office furniture (Q_{K1}); agricultural machinery (Q_{K2}); industrial machinery (Q_{K3}); automobiles (Q_{K4}); trucks (Q_{K5}); other transport equipment (Q_{K6}); other machinery and equipment (Q_{K7}); computers (Q_{K8}); telecommunications equipment (Q_{K9}); software (Q_{K10}); industrial buildings (Q_{K11}); commercial buildings (Q_{K12}); institutional buildings (Q_{K13}); and engineering construction (Q_{K14}).

13 User costs for capital inputs are meant to approximate what it would cost a business to rent or lease the services of the asset for the accounting period under consideration. The use of user costs in multifactor productivity studies dates back to the pioneering work of Jorgenson and Griliches (1967). Basically, a user cost consists of the sum of four terms: (1) the interest that could be earned if the asset were simply sold at the beginning of the period; (2) depreciation; (3) taxes that are assessed on the use of the asset plus the appropriate business income tax rate and (4) expected capital gains (or minus losses) that the asset might accrue over the accounting period. With respect to (1) we chose the interest rate to be the balancing rate of return that makes the value of inputs equal to the value of outputs; i.e. we chose an endogenous rate of return rather than an exogenous one. With respect to (4), we chose to value beginning and end of period capital stocks at the average investment prices of the period, which eliminated the capital gains term. There are problems associated with the estimation of *expected* capital gains and so our strategy avoids these problems. Jorgenson (1989) and his coworkers estimate expected capital gains (or losses) by actual gains (of losses). This strategy tends to lead to negative user costs for land assets and hugely positive user costs for computers (when statistical agencies assign large depreciation rates to computers). Statistics Canada uses the Jorgenson methodology. The issue of how exactly to construct user costs has not been definitively resolved. For further discussion on problems with constructing user costs, see Harper, Berndt and Wood (1980), Diewert (1980) (2005a), Schreyer (2009) and Inklaar (2010).

14 Fisher (1922) aggregation can deal with 0 quantities; see Diewert (1980: 498-501).

Table 2. The corresponding implicit aggregate input price index, $P_Z{}^t$, is listed in Table 1.

Note that we have also included the price of our household consumption aggregate, $P_C{}^t$, in Table 1, which will play a role in subsequent sections. The multifactor productivity level of the Canadian business sector T^t can be defined as the aggregate output, $Q_Y{}^t$ divided by aggregate input, $Q_Z{}^t$:[15]

(1) $T^t \equiv Q_Y{}^t/Q_Z{}^t$; t = 1961, ..., 2011.

Multifactor Productivity (MFP) *growth* for year t, τ^t, is defined as the productivity level in year t divided by the previous year's productivity level:

(2) $\tau^t \equiv T^t/T^{t-1}$; t = 1962, ..., 2011.

Table 2 lists the quantities that match up to the prices in Table 1 and it also lists multifactor productivity index levels and growth rates.

Our geometric or compound average rate of multifactor productivity growth over the 1961-2011 period is 1.03 per cent per year.[16] This compares with Statistics Canada's KLEMS program average multifactor productivity growth over the same years of 0.28 per cent per year, which is a rather substantial difference (0.75 percentage points per year)![17] In section three, we attempt to determine why our results are so different from the official Statistics Canada results.[18]

Over the golden years of the 1961-1973 business cycle,[19] multifactor productivity growth[20] averaged 2.67 per cent per year; over the next peak-to-peak business cycle of 1973-1981, MFP growth turned negative (-0.03 per cent per year). During the cycles of the 1980s and 1990s, MFP growth picked up, averaging 1.12 per cent per year over the 1981-1989 business cycle and 1.02 per cent over the 1989-2000 cycle. Since 2000 MFP growth has again turned slightly negative, averaging -0.04 per cent over the 2000-2008 cycle and -0.02 in the 2008-2011 period.

However, there is more to living standards growth than multifactor productivity growth: if the price of Canadian exports increases more rapidly than the price of Canadian imports, then the real income generated by the business sector should increase. This terms of trade effect is not taken into account in the above MFP productivity computations. Thus in the following section, we implement the translog real income methodology outlined in Appendix 1 to assess the contribution to Canadian living standards of improvements in Canada's terms of trade.

15 See definition (34) in Appendix 1.

16 This rate of multifactor productivity growth can be compared to the average rate of MFP growth for Australia obtained by Diewert and Lawrence (2006) using a similar methodology and over a similar period. The Diewert and Lawrence market sector average rate of MFP growth for Australia over the period 1961-2004 was 1.49 per cent per year. However, there is an upward bias in the Diewert and Lawrence results due to the fact that they used hours worked as their measure of labour input instead of a quality adjusted measure of labour input for Australia (which was not available).

17 Table 7 shows that our estimates of MFP growth exceeded those of Statistics Canada in all five peak-to-peak business cycles since 1961. The gap was greatest in the 1961-1973 period (1.47 percentage points), followed by the 1981-1989 period (0.95 points), the 1989-2000 cycle (0.56 points), the 2000-2008 cycle (0.48 points), and finally the 1973-1981 cycle (0.22 points).

18 Our measures of business sector output and capital input were different from the KLEMS measures because we excluded rental housing from our measure of value added and we excluded the residential land and residential structures inputs from our measure of capital services, whereas the KLEMS measures included rental housing in their output and capital input measures.

19 To minimize the influence of short-term cyclical factors on MFP growth, it is standard practice to calculate MFP growth rates over similar points of the business cycle, normally cyclical peaks. Peak years were 1973, 1981, 1989, 2000, and 2008.

20 All growth rates in this paragraph are average geometric growth rates over the period under consideration. The average growth rates in Table 4 are arithmetic ones (and hence are slightly higher).

Explaining Real Income Growth Generated by the Canadian Business Sector: the Gross Output Approach

The basic methodology used in this section can easily be explained in non-technical terms. The business sector faces (exogenous) domestic and international prices for the net outputs it produces: domestic outputs, exports and (minus) imports. The business sector also utilizes inputs of labour and capital in order to produce its outputs. The value of outputs produced by the business sector less the value of imports used (value added) must eventually flow back to the labour and capital primary inputs that were used to produce value added. This is the (gross) income generated by the business sector.

We divide this gross nominal income in year t by the price of consumption goods and services in year t, P_C^t, in order to turn this nominal income into *real income* ρ^t. This real income is the number of consumption bundles that *could* be purchased by the owners of the labour and capital inputs that were used in year t by the Canadian business sector. We also divide each of the prices P_D^t, P_X^t, P_M^t, P_L^t and P_K^t by the price of consumption, P_C^t, in order to form the corresponding real (that is relative to the price of consumption goods and services)[21] output and input prices facing the Canadian business sector in each year. Our estimates of the (gross) real income generated by the business sector and the corresponding real output and input prices are given in Table 3.

The gross real income generated by the Canadian business sector has grown from $29,368 million dollars worth of 1961 consumption bundles in 1961 to $182,140 million in 2011, a 6.20 fold increase. Looking at the change in real input and output prices, by 2011 the real price of domestic output had fallen to 0.972 of its starting level in 1961 (due to the fact that machinery and equipment prices have risen less rapidly than the price of consumption) and the real price of exports has risen slightly to 1.026 of the starting level. However, the real price of imports has fallen substantially to 0.653 of the starting level. The quality adjusted real wages of business sector workers have risen to 2.101 of their initial 1961 levels. The real price of capital services has risen 1.69 fold, reflecting rapidly rising prices of agricultural land and non-agricultural business land as well as upward trends in machinery and equipment depreciation rates and in real rates of return (see Appendix 2 for details).

Note that real wages, defined as the price of labour relative to the price of consumption goods and services, P_L^t/P_C^t, peaked in 1977 at 1.75 and then fell to 1.67 in 1983 (Table 3). By 2011 they had increased to 2.10, representing a 1.50 per cent average annual rate of advance since 1961. Real domestic prices, P_D^t/P_C^t, increased to 1.06 in 1974 and then dropped to 0.97 at the end of the sample period. This drop is probably due to the advent of quality adjustment of computers in the 1980s. The real price of exports, P_X^t/P_C^t, fluctuates but ends up close to unity at the end of the sample period (1.03). The real price of imports, P_M^t/P_C^t, drops substantially over the sample period, ending up at 0.63 in 2011. The real price of business sector capital services, P_K^t/P_C^t, increased to 1.52 in 1979 and then decreased to 1.09 in 1982. It stayed in the range 1.00 to 1.75 for the rest of the sample period, with large drops during recession years, which were in 1982, 1991 and 2009. This is due a decrease in the balancing real rate of return for those years.

There are six quantitative factors (α) that can be used to explain the real income ρ^t generated by the business sector in year t:

21 The series are called real because they are calculated by deflating by consumer prices.

- The price of domestic production (an aggregate of C+I+G) relative to the price of consumption in year t, P_D^t/P_C^t;
- The price of exports relative to the price of consumption in year t, P_X^t/P_C^t;
- The price of imports relative to the price of consumption in year t, P_M^t/P_C^t;
- The quantity of labour used by the business sector in year t, Q_L^t;
- The quantity of capital used by the business sector in year t, Q_K^t ;and
- The level of technology of the business sector, as proxied by multifactor productivity, in year t.

The formal model outlined in Appendix 1, based on the work of Diewert and Morrison (1986) and Kohli (1990), allows us to decompose the growth of real income from year t–1 to t, ρ^t/ρ^{t-1}, into multiplicative year to year contribution factors α_D^t, α_X^t, α_M^t, β_L^t, β_K^t and τ^t that describe the effects of changes in the six explanatory variables listed above going from year t–1 to t. The model outlined in Appendix 1 leads to the following equation which decomposes the year to year growth in real income generated by the business sector, ρ^t/ρ^{t-1}, into a product of six year to year explanatory contribution factors:[22]

(3) $\rho^t/\rho^{t-1} = \tau^t\, \alpha_D^t\, \alpha_X^t\, {}_M^t\, \beta_L^t\, \beta_K^t$; t = 1962, 1963,...,2011.

Thus if α_D^t is greater than one, this means that the domestic price of output grew faster than the price of consumption going from year t–1 to t and α_D^t measures the contribution of rising real domestic output prices to the growth in real income. Similarly, if α_X^t is greater than one, this means that Canadian export prices grew faster than the price of consumption going from year t–1 to t and α_X^t measures the contribution of rising real export prices to the growth in real income generated by the Canadian business sector. However, if α_M^t is greater than one, this means that Canadian import prices did not increase as quickly as the price of consumption going from year t–1 to t and α_M^t measures the contribution of *falling* real import prices to the growth in real income generated by the Canadian business sector. If β_L^t is greater than one, then business sector labour input increased going from year t–1 to t and β_L^t measures the contribution of the increase in labour input to the growth in real income generated by the Canadian business sector. Similarly, if β_K^t is greater than one, then business sector capital services input increased going from year t–1 to t and β_K^t measures the contribution of the increase in capital input to the growth in real income generated by the Canadian business sector. Finally, if τ^t is greater than one, then the efficiency of the Canadian business sector increased from year t–1 to t and τ^t measures the contribution of the efficiency increase or multifactor productivity growth to the growth in real income generated by the Canadian business sector. These year to year contribution factors are given in Table 4 along with the (arithmetic) averages of these contribution factors over various time periods.

Looking at the (geometric) averages given for the 1961-2011 period in Table 4, it can be seen that the (gross) real income generated by the Canadian business sector over the entire sample period grew at 3.72 per cent per year. The biggest contributor to this growth was the increase in quality adjusted labour input at 1.24 percentage points per year, responsible for 33.3 per cent of real income growth. Next was capital services growth (1.08 percentage points per year or 29.1 per cent). This was followed by MFP growth, τ^t, which contributed on average 1.03 percentage points per year (or 27.6 per cent) and declines in real import prices (0.40 percentage points per year or 10.7 per cent). Declines in real domestic

22 See the equations in Appendix 1 in order to derive this equation. All of the variables in equation (3) can be identified using the data in Appendix 2.

output prices and real export prices gave rise to negative average contribution factors, –0.051 and –0.002 percentage points per year respectively. The last column in Table 4 gives the product of the real export and real import price contribution factors, $\alpha_{XM}{}^t$, defined as:

(4) $\alpha_{XM}{}^t \equiv \alpha_X{}^t \alpha_M{}^t$.

Roughly speaking, $\alpha_{XM}{}^t$ is a *terms of trade contribution factor*; it gives the contribution to real income growth of the combined effects of real changes in the international prices facing the Canadian business sector.[23] It can be seen that the effects of changing real international prices are not negligible for Canada: on average, changing real export and import prices contributed 0.39 percentage points per year or 10.2 per cent to real income growth over the entire period.[24]

However, for shorter periods, the effects of changing real international prices can be far more important in explaining changes in the real income generated by the market sector of an economy. Thus if we restrict our attention to the period 2000-2011, it can be seen by looking at Table 4 that the effects of improvements in Canada's terms of trade are the most important explanatory factor. Thus during this period, the average annual growth in the real income generated by the Canadian business sector was 2.39 per cent per year and the following factors explained this growth rate: decreases in the real price of imports (1.23), increases in quality adjusted labour input (0.78), increases in capital services input (0.74) and increases in real domestic prices (0.03). There were negative contributors to business sector real income growth during the 2000s: decreases in MFP (-0.03) and decreases in the real price of exports (–0.36).

Thus decreases in the real price of imports proved to be the most important factor in explaining the growth in real income generated by the business sector during this period, accounting for over half (51.5 per cent) of the growth. Overall, the joint effects of changes in real export and import prices contributed about 0.86 percentage points per year on average to the growth of business sector real income during the 2000s, which was greater than the contribution of capital input over this period (which was 0.74 percentage points per year on average).[25] Thus improvements in the terms of trade largely compensated for the poor multifactor productivity performance during the 2000s, leading to an overall reasonable rate of growth for the real income generated by the Canadian business sector.

The annual change information in Table 4 can be easily converted into levels.[26] Thus let T^t, $A_D{}^t$, $A_X{}^t$, $A_M{}^t$, $B_L{}^t$, $B_K{}^t$ and $A_{XM}{}^t$ be the cumulated products of the annual link factors τ^t, $\alpha_D{}^t$, $\alpha_X{}^t$, $\alpha_M{}^t$, $\beta_L{}^t$, $\beta_K{}^t$ and $\alpha_{XM}{}^t$ respectively. Using these definitions and cumulating equations (3) leads to the following equation, which explains the cumulative growth in real gross income generated by the Canadian business sector relative to the base year 1961:

(5) $\rho^t/\rho^{1961} = T^t A_D{}^t A_X{}^t A_M{}^t B_L{}^t B_K{}^t$;
$t = 1962, 1963, \ldots, 2011$.

The cumulated variables that appear in (5) above are reported in Table 5 along with the cumulated terms of trade contribution factor, $A_{XM}{}^t$ defined to be the product of the two cumulated international price factors, $A_X{}^t$ and $A_M{}^t$.

23 Ulrich Kohli has pointed out that this is a slight abuse of terminology. Strictly speaking, the terms of trade is the price of exports over the price of imports and hence involves only two prices. Our definition of aXMt involves three prices: the price of exports, the price of imports and the price of domestic consumption. Our terms of trade contribution factor is the rate of change counterpart to Kohli's (2006: 50) *trading gains factor*.

24 Thus the contribution of falling real import prices outweighs the effects of falling real export prices.

25 These results are very similar to the results obtained for Australia using a similar framework by Diewert and Lawrence (2006). Both Australia and Canada have had very favourable changes in their terms of trade in recent years which contributed greatly to real income growth during the 2000s.

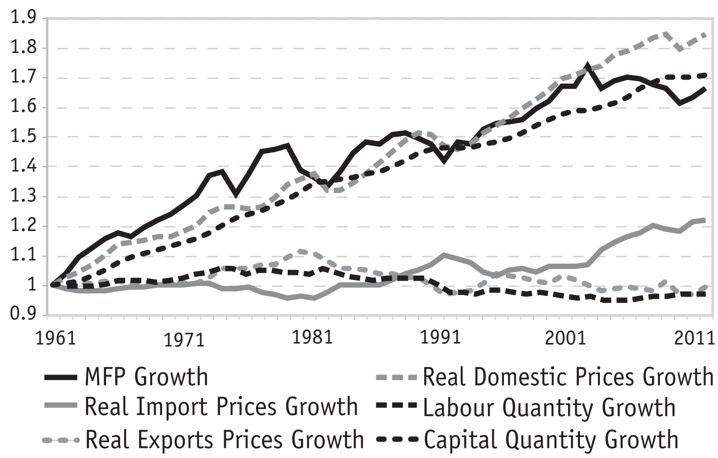
26 See equations (38) in Appendix 1 (with obvious extensions to multiple inputs and outputs).

Table 5 present the various growth factors for 6 sub-periods, including five peak-to-peak business cycles:

- The 12 golden years for the Canadian economy were 1961-1973, when the real income generated by the business sector grew by 6.73 per cent per year and MFP growth was a stellar 2.67 per cent per year;
- The 1973-1981 period, characterized by stagflation, oil shocks and rapidly increasing tax rates when the real income generated by the business sector fell to 3.38 per cent per year and MFP growth plummeted to -0.03 per cent per year;
- The 1981-1989 period when real income growth continued to fall, reaching 3.05 per cent, but MFP growth recovered to 1.12 per cent per year;
- The 1989-2000 period when real income growth again fell to 2.55 per cent, with MFP growth stable at 1.12 per cent per year;
- The 2000-2008 period when real income growth picked up to 3.22 per cent even though MFP growth turned negative (-0.04 per cent). Positive terms of trade effects accounts for this strong income growth despite the deterioration in productivity performance.
- In the 2008-2011 period, real income growth fell to 0.21 per cent per year due to the recession, with no effect on MFP growth (-0.02).

Table 5 shows that real income generated by the business sector grew 6.20 fold over the years 1961-2011. The main factors explaining this growth are growth of quality adjusted labour input (cumulative growth factor 1.85), growth of capital services (cumulative growth factor 1.71), MFP productivity increases (cumulative growth factor 1.67) and lower real import prices (cumulative growth factor 1.22). There were small negative contributions from declining real domestic output prices (cumulative growth factor 0.97) and declining real export prices (cumulative growth factor .99). [27]

Chart 1
Cumulated Contribution Factors Accounting for Real Income Growth in the Canadian Business Sector, 1961-2011
(1961=1.0)



In recent years, the real prices of Canada's raw materials exports have increased dramatically. However, these increases do not show up in the A_X^t column of Table 5; i.e., the overall real price of Canadian exports has remained relatively constant in recent years. This apparent contradiction can be explained by falling real prices for Canadian exports of manufactured goods. As already noted above, the effects of falling real import prices in recent years have been substantial. The cumulative contribution factors listed in Table 5 are plotted in Chart 1.

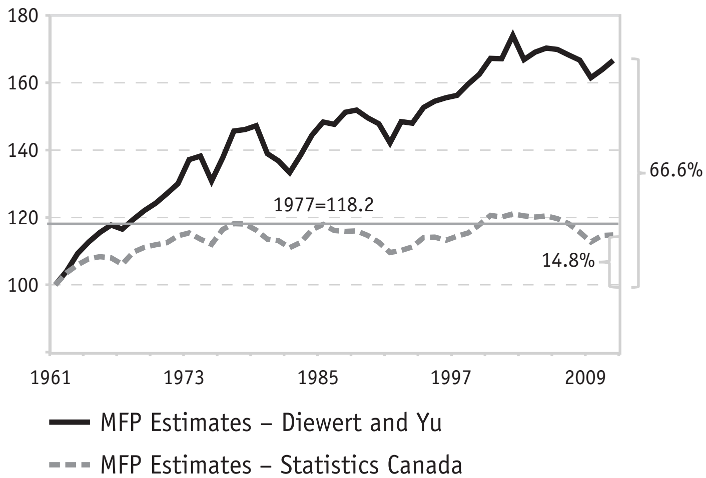
It can be seen that labour, capital and MFP growth were the main contributors to the generation of real income growth over the period 1961-2011, but that falls in import prices were an important contributory factor during the period 2002-2007.

27 This growth factor can also be expressed as compound annual growth rates, as shown in Table 5.

Chart 2

MFP Growth in the Canadian Business Sector, Comparison between Diewert and Yu and Statistics Canada, 1961-2011

(1961=100)

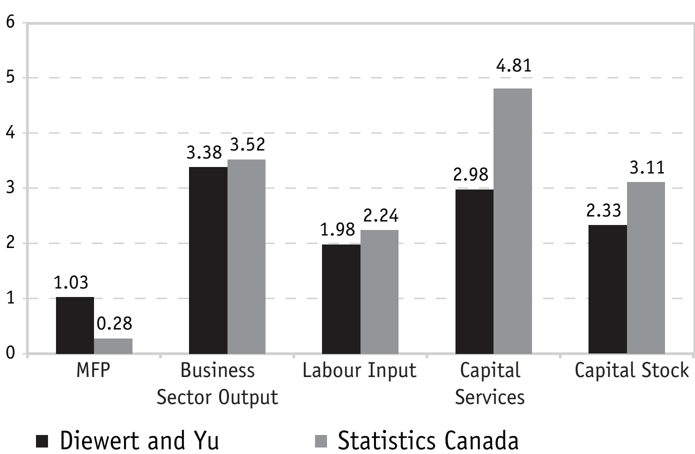


Source: Calculations by Diewert and Yu; Statistics Canada, Canadian Productivity Accounts (CANSIM Table 383-0021).

Chart 3

MFP, Output, and Input Growth in the Canadian Business Sector, 1961-2011

(compound annual growth rates, per cent)



Source: Calculations by Diewert and Yu; Statistics Canada, Canadian Productivity Accounts (CANSIM Table 383-0021).

Comparison with the KLEMS Program Multifactor Productivity Estimates

As was mentioned earlier, the Statistics Canada KLEMS program produces on a regular basis estimates of multifactor productivity growth for the Canadian business sector.[28] Earlier in the article we noted that our level of business sector MFP using our user cost framework was 1.666 in 2011 from its starting value of 1.000 in 1961 whereas the KLEMS multifactor business sector productivity was 1.148 in 2011. This implies a significant difference of 0.75 percentage points in MFP growth over half a century between the two series (1.03 per cent versus 0.28 per cent) (see Chart 2 and Table 7). It is particularly interesting to note that the level of MFP in the Statistics Canada series in 2011 was below that of 1977, indicating negative MFP growth for the last one third of a century, a period of rapid technological change (Chart 2). In this section, we will try to determine why our estimates are so different from the corresponding KLEMS program estimates.

Our measures of real business sector output, labour and capital services input are $Q_Y{}^t$, $Q_L{}^t$ and $Q_K{}^t$ and our measure of the capital stock used by the business sector is $Q_{KW}{}^t$. These estimates are found in Table 6. The KLEMS program provides index counterparts to our measures for the years 1961-2011.[29] The KLEMS program also provides nominal estimates for business sector output, labour input and capital services input for the years 1961-2008.[30] We use the initial 1961 values for the KLEMS value of business sector output, labour and capital input and scale or convert the KLEMS constant dollar estimates for all years into a constant dollar series expressed in terms

28 See Baldwin, Gu and Yan (2007) and Baldwin and Gu (2007) for a description of the methods used in this program.

29 See CANSIM Table 3830021, series V41712932, V41712949, V41713051 and V41713068 respectively.

30 See CANSIM Table 3830021, series V41713153, V41713170 and V41713228 respectively.

of 1961 dollars. These official KLEMS series are given as Q_{YO}^t, Q_{LO}^t and Q_{KO}^t in Table 6.

Table 6 and Chart 3 show that our compound average annual rate of output growth over the 1961-2011, 3.38 per cent, is slightly smaller than the KLEMS estimate of average rate of output growth, which was 3.52 per cent. This relatively small difference does not explain the large difference in rates of multifactor productivity growth (and the difference goes in the wrong direction).

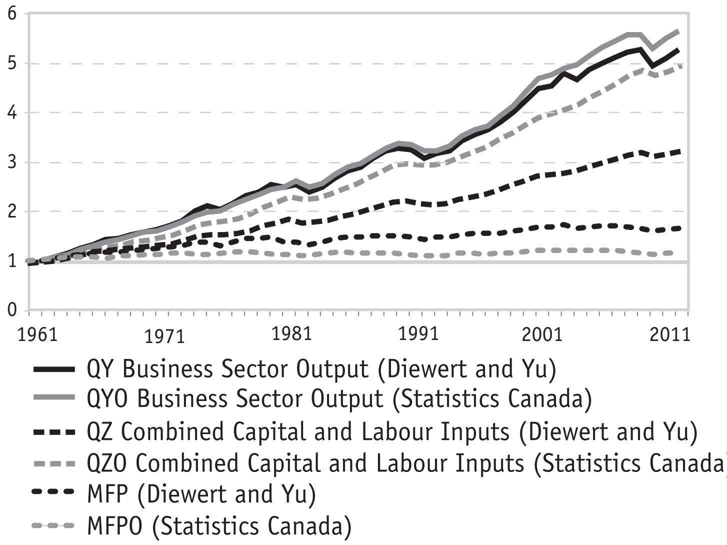
As noted earlier, our business sector output concept differs from the corresponding KLEMS concept in two ways:

- We exclude the services of both owned and rented residential housing from our output concept whereas the KLEMS program excludes only owned residential housing services; and
- We measure real inventory change as a difference in real inventory stocks whereas the KLEMS program follows national income accounting conventions and measures inventory change in a different manner.

The effect of the above two differences on output growth rates is obviously not large, resulting in our average output growth rate being fairly close to the corresponding official rate.[31]

In order to better identify sources of the differences between our multifactor productivity estimates and the official estimates, we plot our productivity level estimates (MFP) and the corresponding official ones normalized to equal one in 1961 (MFPO) in Chart 4. It can be seen that the official estimates have been essentially flat since 1972. The top two series are the output series, QY and QYO, and they are not too different. The two middle series are the total input series showing that the official aggregate input series (QZO), lies far above our counterpart series, QZ.

Chart 4
Statistics Canada and Diewert and Yu Estimates of Output, Input and Multifactor Productivity in the Canadian Business Sector, 1961-2011
(1961=1.0)

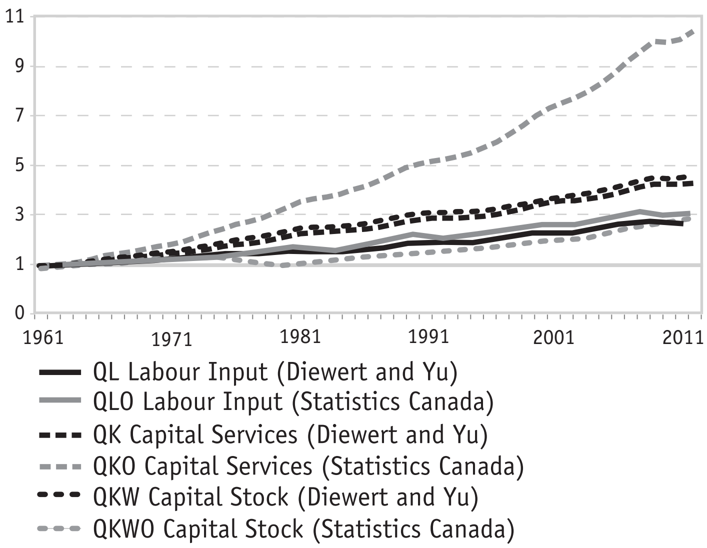


In order to identify the sources of the difference in the growth rate for aggregate input, our labour and capital services series (normalized to equal one in 1961), QL and QK, are plotted in Chart 5 with the official (normalized) series, QLO and QKO. We also plot our normalized wealth (real) capital stock, QKW, along with the counterpart official normalized wealth stock, QKWO. It can be seen that QL and QLO are reasonably close, but the official capital services series, QKO, is far above our normalized capital services series QK. It can be seen that the KLEMS capital stock series, QKWO, is also above our series QKW, but the differences in the wealth series are far smaller than the differences in the capital services series.

Our measure of quality adjusted labour grew on average at 1.98 per cent per year between 1961 and 2011, which is somewhat slower than the corresponding KLEMS rate, which was 2.24 per cent per year (Chart 3). This difference does

31 See the last column in Table 6 which lists real paid rents for the Canadian economy. They are small relative to the size of the business sector.

Chart 5
Statistics Canada and Diewert and Yu Estimates of Labour, Capital Services and Capital Stock in the Canadian Business Sector, 1961-2011
(1961=1.0)



help to explain the difference in multifactor productivity growth rates. We believe that our estimates for quality adjusted labour growth are just as credible as the KLEMS program estimates due to the difficulties in measuring the experience variable in an objective manner (which the KLEMS program uses and we do not).

However, the big explanatory factor lies in the differences in the growth of capital services: our capital services aggregate grew at the geometric rate of 2.98 per cent per year whereas the KLEMS capital services aggregate grew at 4.81 per cent per year, a massive difference of 1.83 percentage points per year! Our capital stock aggregate grew at 2.33 per cent per year and the KLEMS capital stock grew at 3.11 per cent per year, a difference of 0.78 percentage points. It is understandable why our capital stock aggregate grew more slowly than the corresponding KLEMS capital stock aggregate. Our estimates for the price of business land are likely much higher than the KLEMS estimates and we assumed no business land growth. Both factors will lead to a much lower rate of growth of the aggregate capital stock.[32]

It is possible to explain why the average growth rate of capital *services* should be faster than the average growth rate of capital *stock* components. The faster growing components of the capital stock (M&E, and especially the ICT component) have larger user costs of capital relative to the slower growing components of the capital stock (agricultural land and nonagricultural land) compared to their stock prices. Thus aggregate capital services will tend to grow faster than the corresponding aggregate capital stock.[33]

In order to obtain a rough estimate for how much of a difference in growth rates between capital stocks and services should be expected, we calculated average rates of growth over our sample period for each of our 17 capital stock components. We also calculated sample average shares for each type of capital service and for each component of the wealth stock. We calculated a share weighted average of the average rates of asset growth using average capital service shares and found that the resulting average rate of growth of capital services was 3.03 per cent per year. We then calculated a share weighted average of the average rates of asset growth using average capital stock shares and found that the resulting average rate of growth of capital stocks was 2.38 per cent per year. Thus we expect the difference between

32 It is interesting to compare these two sets of estimates of capital input and multifactor productivity growth for Canada with estimates for the United States from the Bureau of Labor Statistics. US multifactor productivity growth over the 1961-2011 was 1.15 per cent per year, similar to the estimate of Diewert and Yu for Canada (1.03 per cent) and four times the Statistics Canada estimate (0.28 per cent). US capital input growth was 3.91 per cent, mid-way between the Statistics Canada estimate (4.81 per cent) and the Diewert-Yu estimate (2.98 per cent) .

33 This observation dates back to Jorgenson and Griliches (1967) at least.

the average capital services rates of growth and the corresponding stock rates of growth to be 0.65 percentage points per year (3.03 per cent -2.38 per cent).

Recall that our average geometric rate of growth of capital services was 2.98 per cent and our average geometric rate of growth of the capital stock was 2.33 per cent per year for a difference of 0.65 percentage points per year. Thus we think that our difference between the rates of growth in the capital stock and the corresponding capital services is very reasonable. In contrast, we find the differences in the KLEMS estimates to be far too big to be credible.[34]

Part of the problem is that the KLEMS program does not provide enough detailed data for researchers outside Statistics Canada to determine the exact source of differences. Some of the differences may be due to the following factors:

- The inclusion of ex post capital gains terms in the KLEMS user cost formula. This will give high tech assets an enormous user cost (due to their rapidly declining prices) as compared to our weights.[35]
- We are using a sector wide balancing rate of return whereas the KLEMS program uses sector specific rates that could be very variable and volatile.
- The KLEMS program has access to more detailed data and so our estimates may be subject to some aggregation bias.

Conclusion

There are three major conclusions that we can draw from the above results.

First, using recent Statistics Canada data sources and a top down approach, we have shown that the MFP performance of the business sector of the Canadian economy has been reasonably satisfactory over the past 50 years. In particular, traditional gross income multifactor productivity growth averaged 1.03 percent per year over the period 1961-2011 (compared to only 0.28 per cent per year according to Statistics Canada official MFP measure). However, there have been two cyclically neutral periods (1981-1989 and 2000-2008) where the MFP productivity performance of the Canadian business sector was decidedly unsatisfactory, indeed negative.

Second, the results presented here show that over short periods of time, changes in the external price environment facing an economy can have substantial effects on living standards. Thus during the years 2000-2011, the real income generated by the Canadian business sector grew at an average rate of 2.39 percent per year and declines in real import prices contributed 1.23 percentage points to this increase, which was greater than the effects of quality adjusted labour input growth (0.78 percentage points per year), capital input (0.74 percentage points per year) and real domestic prices growth (0.03 percentage points per year).

Finally, the study uncovered many data problems which should be addressed in future work on Canadian productivity performance. In particular, the treatment of capital services by Statistics Canada needs additional documentation and experimentation, particularly with respect to the measurement of land services, the form of the user cost formula, the treatment of taxes, the determination of depreciation rates and the choice of a reference rate of return.

34 The difference between capital services and capital stock growth in the KLEMS estimates is of 1.70 percentage points, based on a capital stock growth of 3.11 per cent per year and a capital services growth of 4.81 per cent per year during the 1961-2011 period.

35 Statistics Canada's depreciation rates are not necessarily incorrect. This is a topic that requires further research.

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Table 1
Price Indexes for Canadian Business Sector Output and Input Aggregates, 1961-2011

	P_C	P_D	P_X	P_M	P_L	P_K	P_y	P_Z
	Consumption	Domestic Output	Exports	Imports	Labour	Capital Services	Business Sector Output	Combined Labour and Capital Inputs
Year	(index, 1961=1.000)							
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.006	1.007	1.030	1.058	1.038	1.039	0.999	1.038
1963	1.020	1.021	1.041	1.096	1.072	1.155	1.007	1.100
1964	1.023	1.032	1.057	1.105	1.114	1.213	1.019	1.148
1965	1.036	1.056	1.080	1.102	1.188	1.261	1.049	1.213
1966	1.074	1.096	1.125	1.119	1.266	1.340	1.097	1.292
1967	1.107	1.129	1.154	1.144	1.348	1.264	1.131	1.318
1968	1.148	1.164	1.201	1.167	1.435	1.340	1.173	1.401
1969	1.185	1.205	1.231	1.196	1.548	1.366	1.214	1.482
1970	1.215	1.242	1.267	1.220	1.645	1.409	1.256	1.560
1971	1.242	1.288	1.286	1.248	1.763	1.452	1.298	1.649
1972	1.293	1.348	1.333	1.275	1.915	1.535	1.366	1.776
1973	1.384	1.459	1.515	1.360	2.096	2.014	1.509	2.070
1974	1.582	1.674	1.913	1.646	2.424	2.404	1.752	2.422
1975	1.820	1.891	2.167	1.890	2.805	2.206	1.970	2.577
1976	1.904	1.998	2.297	1.929	3.229	2.390	2.111	2.907
1977	2.028	2.125	2.502	2.172	3.541	2.717	2.216	3.228
1978	2.190	2.291	2.738	2.417	3.711	3.052	2.374	3.467
1979	2.403	2.511	3.208	2.730	3.977	3.660	2.633	3.877
1980	2.691	2.794	3.735	2.980	4.384	3.791	3.003	4.172
1981	2.898	3.059	3.998	3.266	4.928	3.711	3.259	4.457
1982	3.166	3.316	4.089	3.439	5.470	3.460	3.494	4.657
1983	3.407	3.510	4.151	3.423	5.676	4.305	3.721	5.158
1984	3.564	3.647	4.297	3.582	5.978	4.823	3.851	5.562
1985	3.676	3.756	4.381	3.677	6.295	5.100	3.956	5.867
1986	3.756	3.844	4.371	3.744	6.487	4.992	4.015	5.929
1987	3.852	3.953	4.458	3.692	6.727	5.593	4.186	6.331
1988	3.958	4.061	4.471	3.601	7.199	5.588	4.348	6.602
1989	4.071	4.176	4.560	3.594	7.541	5.468	4.511	6.747
1990	4.302	4.335	4.529	3.644	7.853	5.342	4.647	6.870
1991	4.540	4.460	4.371	3.580	8.225	4.635	4.752	6.756
1992	4.599	4.503	4.496	3.726	8.410	5.118	4.773	7.085
1993	4.689	4.585	4.694	3.925	8.400	5.293	4.839	7.162
1994	4.718	4.659	4.973	4.161	8.331	6.119	4.915	7.503
1995	4.735	4.692	5.291	4.277	8.498	6.549	5.044	7.794
1996	4.833	4.748	5.321	4.222	8.612	6.890	5.152	8.013
1997	4.913	4.806	5.327	4.237	8.916	6.780	5.207	8.136
1998	4.978	4.872	5.316	4.380	9.196	6.687	5.170	8.252
1999	5.069	4.936	5.379	4.360	9.439	7.132	5.288	8.593
2000	5.207	5.050	5.710	4.442	9.915	8.062	5.553	9.287
2001	5.365	5.167	5.803	4.584	10.205	7.973	5.631	9.410
2002	5.434	5.248	5.689	4.615	10.375	8.594	5.625	9.789
2003	5.571	5.325	5.648	4.315	10.585	8.393	5.884	9.817
2004	5.652	5.415	5.786	4.206	10.897	9.245	6.139	10.380
2005	5.777	5.531	5.952	4.156	11.373	9.792	6.401	10.899
2006	5.880	5.662	5.975	4.117	11.913	9.778	6.590	11.196
2007	5.989	5.798	6.031	4.014	12.306	10.056	6.861	11.544
2008	6.156	5.975	6.644	4.244	12.622	10.728	7.219	12.035
2009	6.183	6.044	5.991	4.283	12.847	8.710	6.935	11.198
2010	6.255	6.094	6.123	4.103	13.034	9.764	7.202	11.804
2011	6.392	6.215	6.559	4.175	13.431	10.821	7.516	12.523
Compound Annual Growth Rates, per cent								
1961-2011	3.78	3.72	3.83	2.90	5.33	4.88	4.12	5.19
2000-2011	1.88	1.91	1.27	-0.56	2.80	2.71	2.79	2.76
1961-1973	2.74	3.20	3.52	2.59	6.36	6.01	3.49	6.25
1973-1981	9.68	9.70	12.90	11.58	11.28	7.94	10.10	10.06
1981-1989	4.34	3.97	1.66	1.20	5.46	4.97	4.15	5.32
1989-2000	2.26	1.74	2.07	1.95	2.52	3.59	1.91	2.95
2000-2008	2.12	2.13	1.91	-0.57	3.06	3.64	3.33	3.29
2008-2011	1.26	1.33	-0.43	-0.54	2.09	0.29	1.35	1.34

Table 2

Canadian Business Sector Real Output, Real Input Aggregates, and MFP Growth, 1961-2011

	Q_D	Q_X	Q_M	Q_L	Q_K	Q_y	Q_Z	T	τ
	Domestic Output	Exports	Imports	Labour	Capital Services	Business Sector Output	Combined Labour and Capital Inputs	MFP	MFP Growth
	(1)	(2)	(3)	(4)	(5)	(6)=(1)+(2)+(3)	(7)=(5)+(6)	(8)=(6)/(7)	(9)
Year	(millions, 1961 dollars)							(1961=1)	(% change)
1961	30,398	6,867	-7,897	19,240	10,128	29,368	29,368	1.000	
1962	32,414	7,195	-8,033	20,049	10,326	31,585	30,375	1.040	4.0
1963	34,157	7,832	-8,031	20,506	10,613	34,008	31,120	1.093	5.1
1964	36,431	9,105	-8,989	21,372	11,091	36,591	32,466	1.127	3.1
1965	40,024	9,418	-10,180	22,321	11,655	39,269	33,983	1.156	2.5
1966	43,167	10,696	-11,579	23,452	12,450	42,286	35,917	1.177	1.9
1967	43,510	11,827	-12,306	23,822	13,105	43,046	36,941	1.165	-1.0
1968	45,235	12,910	-13,527	23,864	13,515	44,645	37,378	1.194	2.5
1969	48,343	13,802	-15,377	24,366	13,986	46,806	38,338	1.221	2.2
1970	48,289	15,211	-15,293	24,395	14,513	48,260	38,850	1.242	1.7
1971	50,936	15,929	-16,480	24,836	14,953	50,452	39,711	1.271	2.3
1972	54,541	17,257	-18,892	25,469	15,415	53,041	40,792	1.300	2.3
1973	61,382	19,008	-21,754	26,868	16,106	58,832	42,891	1.372	5.5
1974	67,244	18,347	-23,977	27,717	17,037	61,727	44,662	1.382	0.8
1975	65,767	16,951	-23,228	27,534	18,122	59,494	45,471	1.308	-5.3
1976	69,516	18,390	-24,774	27,417	18,769	63,195	45,885	1.377	5.3
1977	72,993	19,678	-24,836	27,616	19,366	67,878	46,601	1.457	5.8
1978	74,955	21,544	-26,197	28,636	20,037	70,536	48,284	1.461	0.3
1979	80,182	22,467	-28,092	30,208	20,912	74,698	50,730	1.472	0.8
1980	79,002	22,548	-28,715	31,015	22,012	73,053	52,586	1.389	-5.7
1981	82,000	23,012	-30,716	31,669	23,302	74,433	54,414	1.368	-1.5
1982	72,384	22,882	-25,710	29,737	23,850	70,175	52,644	1.333	-2.6
1983	76,539	24,326	-28,444	29,747	24,016	73,155	52,786	1.386	4.0
1984	81,657	28,444	-33,270	30,714	24,312	78,122	54,090	1.444	4.2
1985	87,008	29,938	-35,548	31,892	24,809	82,738	55,787	1.483	2.7
1986	90,012	31,456	-37,965	33,124	25,343	85,019	57,578	1.477	-0.4
1987	96,002	32,933	-39,889	34,682	26,064	90,559	59,880	1.512	2.4
1988	102,460	35,371	-45,163	36,105	27,136	94,670	62,340	1.519	0.4
1989	106,238	35,434	-47,820	36,972	28,278	96,089	64,243	1.496	-1.5
1990	104,078	37,556	-48,551	36,814	29,056	95,610	64,682	1.478	-1.2
1991	98,192	38,167	-49,281	35,445	29,504	90,121	63,394	1.422	-3.8
1992	100,685	40,921	-51,473	35,000	29,544	93,349	62,887	1.484	4.4
1993	100,614	45,382	-55,461	35,683	29,642	94,373	63,765	1.480	-0.3
1994	105,514	51,076	-60,606	37,145	30,070	100,395	65,766	1.527	3.1
1995	107,894	55,452	-64,385	38,163	30,529	103,938	67,266	1.545	1.2
1996	110,521	58,646	-67,340	39,243	31,132	107,231	68,949	1.555	0.7
1997	118,530	63,457	-77,378	40,501	32,269	111,367	71,275	1.563	0.5
1998	122,860	69,086	-81,755	41,680	33,566	117,544	73,645	1.596	2.2
1999	127,598	76,337	-88,261	43,103	34,865	123,965	76,284	1.625	1.8
2000	134,789	83,350	-95,661	44,563	35,944	131,753	78,781	1.672	2.9
2001	135,351	80,654	-90,649	45,096	36,583	133,537	79,903	1.671	-0.1
2002	143,444	81,599	-92,347	45,811	36,720	140,604	80,788	1.740	4.1
2003	145,573	79,268	-96,341	46,610	37,380	137,165	82,214	1.668	-4.1
2004	154,248	83,281	-104,558	48,181	38,111	142,907	84,524	1.691	1.3
2005	163,288	84,847	-112,552	48,777	39,392	146,935	86,293	1.703	0.7
2006	171,384	85,213	-118,273	49,653	41,010	150,603	88,649	1.699	-0.2
2007	178,411	86,367	-125,533	50,817	42,360	153,232	91,066	1.683	-1.0
2008	184,343	82,650	-126,364	51,240	43,583	154,363	92,591	1.667	-0.9
2009	172,892	71,414	-108,643	49,049	43,323	145,283	89,970	1.615	-3.1
2010	183,521	76,559	-123,691	50,315	43,405	149,898	91,461	1.639	1.5
2011	191,904	80,232	-132,890	51,312	43,896	154,899	92,960	1.666	1.7
Compound Annual Growth Rates									
1961-2011	3.75	5.04	5.81	1.98	2.98	3.38	2.33	1.03	..
2000-2011	3.26	-0.35	3.03	1.29	1.83	1.48	1.52	-0.03	..
1961-1973	6.03	8.85	8.81	2.82	3.94	5.96	3.21	2.67	..
1973-1981	3.69	2.42	4.41	2.08	4.73	2.98	3.02	-0.03	..
1981-1989	3.29	5.54	5.69	1.95	2.45	3.24	2.10	1.12	..
1989-2000	2.19	8.09	6.51	1.71	2.20	2.91	1.87	1.02	..
2000-2008	3.99	-0.11	3.54	1.76	2.44	2.00	2.04	-0.04	..
2008-2011	1.35	-0.98	1.69	0.05	0.24	0.12	0.13	-0.02	..

Note: Since business sector and combined capital and labour input aggregates were calculated using Tornqvist indexes, they are not exactly additive.

Table 3
Gross Real Income Generated by the Canadian Business Sector and Real Output and Input Prices, 1961-2011

	r	P_D/P_C	P_X/P_C	P_M/P_C	P_L/P_C	P_K/P_C
	Real Income	**Real Domestic Prices**	**Real Exports Prices**	**Real Imports Prices**	**Real Labour Prices**	**Real Capital Services Prices**
Year	**(millions, 1961 dollars)**	**(1961=1.000)**				
1961	29,368	1.000	1.000	1.000	1.000	1.000
1962	31,346	1.000	1.024	1.051	1.032	1.033
1963	33,574	1.002	1.021	1.075	1.051	1.133
1964	36,430	1.008	1.033	1.080	1.089	1.186
1965	39,778	1.019	1.042	1.064	1.147	1.217
1966	43,178	1.020	1.047	1.042	1.179	1.248
1967	43,963	1.019	1.042	1.033	1.218	1.142
1968	45,613	1.014	1.046	1.017	1.250	1.167
1969	47,964	1.017	1.039	1.010	1.307	1.153
1970	49,880	1.022	1.043	1.004	1.354	1.160
1971	52,734	1.037	1.035	1.005	1.420	1.169
1972	56,020	1.042	1.031	0.986	1.481	1.187
1973	64,142	1.054	1.095	0.982	1.515	1.456
1974	68,360	1.058	1.209	1.041	1.532	1.519
1975	64,401	1.039	1.191	1.039	1.541	1.212
1976	70,045	1.049	1.206	1.013	1.696	1.255
1977	74,186	1.048	1.234	1.071	1.747	1.340
1978	76,445	1.046	1.250	1.103	1.695	1.394
1979	81,839	1.045	1.335	1.136	1.655	1.523
1980	81,529	1.038	1.388	1.107	1.629	1.409
1981	83,688	1.056	1.380	1.127	1.701	1.280
1982	77,448	1.048	1.292	1.086	1.728	1.093
1983	79,904	1.030	1.218	1.005	1.666	1.264
1984	84,425	1.024	1.206	1.005	1.677	1.353
1985	89,040	1.022	1.192	1.000	1.713	1.388
1986	90,893	1.024	1.164	0.997	1.727	1.329
1987	98,402	1.026	1.157	0.958	1.746	1.452
1988	103,992	1.026	1.130	0.910	1.819	1.412
1989	106,463	1.026	1.120	0.883	1.852	1.343
1990	103,284	1.008	1.053	0.847	1.825	1.242
1991	94,344	0.982	0.963	0.789	1.812	1.021
1992	96,892	0.979	0.978	0.810	1.829	1.113
1993	97,398	0.978	1.001	0.837	1.792	1.129
1994	104,594	0.988	1.054	0.882	1.766	1.297
1995	110,709	0.991	1.117	0.903	1.795	1.383
1996	114,302	0.982	1.101	0.874	1.782	1.426
1997	118,038	0.978	1.084	0.862	1.815	1.380
1998	122,079	0.979	1.068	0.880	1.847	1.343
1999	129,307	0.974	1.061	0.860	1.862	1.407
2000	140,515	0.970	1.097	0.853	1.904	1.548
2001	140,153	0.963	1.082	0.855	1.902	1.486
2002	145,551	0.966	1.047	0.849	1.909	1.582
2003	144,866	0.956	1.014	0.775	1.900	1.507
2004	155,219	0.958	1.024	0.744	1.928	1.636
2005	162,807	0.958	1.030	0.719	1.969	1.695
2006	168,802	0.963	1.016	0.700	2.026	1.663
2007	175,551	0.968	1.007	0.670	2.055	1.679
2008	180,996	0.970	1.079	0.689	2.050	1.743
2009	162,942	0.977	0.969	0.693	2.078	1.409
2010	172,597	0.974	0.979	0.656	2.084	1.561
2011	182,140	0.972	1.026	0.653	2.101	1.693
Compound Annual Growth Rates						
1961-2011	3.72	-0.06	0.05	-0.85	1.50	1.06
2000-2011	2.39	0.02	-0.60	-2.40	0.90	0.82
1961-1973	6.73	0.44	0.76	-0.15	3.52	3.18
1973-1981	3.38	0.02	2.93	1.73	1.46	-1.59
1981-1989	3.05	-0.36	-2.57	-3.01	1.07	0.60
1989-2000	2.56	-0.51	-0.19	-0.31	0.25	1.30
2000-2008	3.22	0.01	-0.20	-2.63	0.93	1.49
2008-2011	0.21	0.07	-1.67	-1.78	0.83	-0.96

Table 4

Sources of Annual Real Income Growth in the Canadian Business Sector, 1961-2011

		Contributions to Real Income Growth						
	r^t/r^{t-1}	τ	α_D	α_X	α_M	β_L	β_K	α_{XM}
	Real Income Growth	MFP Growth	Real Domestic Prices Growth	Real Exports Prices Growth	Real Import Prices Growth	Labour Quantity Growth	Capital Services Growth	Real Net Export Prices Growth
	(1)=(2)*(3)*(6)*(7)*(8)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)*(5)
Year	(growth factors)							
1962	1.067	1.040	1.000	1.005	0.987	1.027	1.007	0.992
1963	1.071	1.051	1.001	0.999	0.994	1.015	1.010	0.993
1964	1.085	1.031	1.007	1.003	0.999	1.027	1.016	1.002
1965	1.092	1.025	1.011	1.002	1.004	1.028	1.018	1.006
1966	1.085	1.019	1.001	1.001	1.006	1.032	1.024	1.007
1967	1.018	0.990	0.999	0.999	1.002	1.010	1.018	1.001
1968	1.038	1.025	0.994	1.001	1.005	1.001	1.011	1.006
1969	1.052	1.022	1.003	0.998	1.002	1.014	1.012	1.000
1970	1.040	1.018	1.006	1.001	1.002	1.001	1.013	1.003
1971	1.057	1.023	1.014	0.998	1.000	1.012	1.010	0.997
1972	1.062	1.023	1.006	0.999	1.006	1.017	1.010	1.005
1973	1.145	1.055	1.011	1.019	1.001	1.036	1.015	1.021
1974	1.066	1.008	1.004	1.033	0.980	1.020	1.021	1.012
1975	0.942	0.947	0.982	0.995	1.001	0.996	1.022	0.996
1976	1.088	1.053	1.010	1.004	1.009	0.997	1.012	1.013
1977	1.059	1.058	0.999	1.007	0.980	1.005	1.011	0.987
1978	1.030	1.003	0.998	1.004	0.989	1.024	1.012	0.994
1979	1.071	1.008	0.999	1.024	0.989	1.034	1.016	1.012
1980	0.996	0.943	0.994	1.015	1.010	1.016	1.020	1.025
1981	1.027	0.985	1.017	0.998	0.993	1.013	1.021	0.991
1982	0.925	0.974	0.992	0.975	1.014	0.960	1.008	0.989
1983	1.032	1.040	0.984	0.978	1.028	1.000	1.002	1.006
1984	1.057	1.042	0.994	0.996	1.000	1.020	1.005	0.996
1985	1.055	1.027	0.999	0.995	1.002	1.023	1.008	0.997
1986	1.021	0.996	1.002	0.990	1.001	1.024	1.008	0.992
1987	1.083	1.024	1.003	0.998	1.016	1.029	1.011	1.014
1988	1.057	1.004	1.000	0.991	1.021	1.025	1.015	1.011
1989	1.024	0.985	1.000	0.997	1.012	1.015	1.015	1.009
1990	0.970	0.988	0.982	0.977	1.017	0.997	1.010	0.993
1991	0.913	0.962	0.974	0.966	1.029	0.975	1.005	0.995
1992	1.027	1.044	0.997	1.006	0.989	0.992	1.000	0.995
1993	1.005	0.997	0.999	1.011	0.985	1.013	1.001	0.996
1994	1.074	1.031	1.010	1.026	0.975	1.026	1.005	1.000
1995	1.058	1.012	1.003	1.032	0.988	1.017	1.006	1.019
1996	1.032	1.007	0.992	0.992	1.018	1.017	1.008	1.009
1997	1.033	1.005	0.996	0.991	1.007	1.020	1.014	0.998
1998	1.034	1.022	1.000	0.991	0.989	1.018	1.015	0.980
1999	1.059	1.018	0.995	0.996	1.013	1.021	1.014	1.009
2000	1.087	1.029	0.996	1.021	1.005	1.021	1.012	1.026
2001	0.997	0.999	0.994	0.991	0.999	1.007	1.007	0.990
2002	1.039	1.041	1.003	0.980	1.003	1.010	1.001	0.984
2003	0.995	0.959	0.990	0.982	1.050	1.011	1.007	1.031
2004	1.071	1.013	1.002	1.005	1.021	1.020	1.008	1.026
2005	1.049	1.007	0.999	1.004	1.017	1.007	1.014	1.021
2006	1.037	0.998	1.005	0.993	1.013	1.011	1.017	1.006
2007	1.040	0.990	1.005	0.995	1.021	1.014	1.013	1.017
2008	1.031	0.991	1.002	1.035	0.987	1.005	1.012	1.021
2009	0.900	0.969	1.007	0.952	0.998	0.974	0.998	0.950
2010	1.059	1.015	0.997	1.004	1.026	1.016	1.001	1.030
2011	1.055	1.017	0.998	1.021	1.002	1.012	1.005	1.023

Table 4
Continued

	Real Income Growth	MFP Growth	Real Domestic Prices Growth	Real Exports Prices Growth	Real Import Prices Growth	Labour Quantity Growth	Capital Services Growth	Real Net Export Prices Growth
Average Contributions to Real Income Growth								
1961-2011	1.0372	1.0103	0.9995	0.9998	1.0040	1.0124	1.0108	1.0038
2000-2011	1.0239	0.9997	1.0003	0.9964	1.0123	1.0078	1.0074	1.0086
1961-1973	1.0673	1.0267	1.0044	1.0021	1.0006	1.0183	1.0135	1.0028
1973-1981	1.0338	0.9997	1.0001	1.0099	0.9938	1.0130	1.0170	1.0037
1981-1989	1.0305	1.0112	0.9965	0.9900	1.0118	1.0118	1.0090	1.0017
1989-2000	1.0255	1.0102	0.9949	1.0006	1.0011	1.0105	1.0081	1.0017
2000-2008	1.0322	0.9996	1.0001	0.9980	1.0138	1.0105	1.0098	1.0118
2008-2011	1.0021	0.9998	1.0006	0.9920	1.0084	1.0004	1.0010	1.0003
Average Contributions to Real Income Growth, per cent								
1961-2011	100.0	27.6	-1.5	-0.5	10.7	33.3	29.1	10.2
2000-2011	100.0	-1.4	1.1	-15.1	51.5	32.5	30.8	36.2
1961-1973	100.0	39.7	6.6	3.2	0.9	27.2	20.1	4.1
1973-1981	100.0	-1.0	0.4	29.4	-18.2	38.4	50.2	11.0
1981-1989	100.0	36.8	-11.5	-32.6	38.5	38.8	29.6	5.5
1989-2000	100.0	39.9	-20.0	2.2	4.2	41.1	31.8	6.5
2000-2008	100.0	-1.2	0.4	-6.1	42.8	32.8	30.4	36.7
2008-2011	100.0	-8.1	30.6	-382.1	399.6	17.8	45.4	14.3

Note: Percentage point contributions do not sum up exactly to real income growth because they are multiplicative.

Table 5
Cumulated Growth in Real Income and Contribution Factors in the Canadian Business Sector, 1961-2011

		Cumulative Contributions to Real Income Growth						
	r^t/r^{1961}	T	A_D	A_X	A_M	B_L	B_K	A_{XM}
	Cumulative Real Income Growth	MFP Growth	Real Domestic Prices Growth	Real Exports Prices Growth	Real Import Prices Growth	Labour Quantity Growth	Capital Quantity Growth	Real Net Exports Prices Growth
	(1)=(2)*(3)*(6)*(7)*(8)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)*(5)
Year	(index, 1961=1.000)							
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.067	1.040	1.000	1.005	0.987	1.027	1.007	0.992
1963	1.143	1.093	1.002	1.005	0.981	1.043	1.016	0.985
1964	1.240	1.127	1.008	1.008	0.980	1.071	1.033	0.987
1965	1.354	1.156	1.020	1.010	0.984	1.101	1.051	0.994
1966	1.470	1.177	1.021	1.011	0.989	1.136	1.076	1.000
1967	1.497	1.165	1.020	1.010	0.992	1.148	1.096	1.002
1968	1.553	1.194	1.014	1.011	0.996	1.149	1.107	1.007
1969	1.633	1.221	1.017	1.009	0.999	1.165	1.120	1.008
1970	1.698	1.242	1.023	1.010	1.000	1.166	1.134	1.011
1971	1.796	1.271	1.037	1.008	1.000	1.180	1.146	1.008
1972	1.908	1.300	1.043	1.007	1.006	1.200	1.157	1.013
1973	2.184	1.372	1.055	1.026	1.007	1.243	1.175	1.034
1974	2.328	1.382	1.058	1.060	0.987	1.267	1.200	1.046
1975	2.193	1.308	1.039	1.055	0.988	1.262	1.227	1.042
1976	2.385	1.377	1.050	1.059	0.997	1.259	1.242	1.056
1977	2.526	1.457	1.048	1.067	0.977	1.264	1.255	1.043
1978	2.603	1.461	1.046	1.071	0.967	1.294	1.270	1.036
1979	2.787	1.472	1.045	1.097	0.956	1.338	1.291	1.049
1980	2.776	1.389	1.038	1.113	0.966	1.360	1.317	1.075
1981	2.850	1.368	1.056	1.111	0.959	1.378	1.345	1.065
1982	2.637	1.333	1.048	1.083	0.973	1.323	1.355	1.053
1983	2.721	1.386	1.031	1.059	1.000	1.323	1.359	1.060
1984	2.875	1.444	1.024	1.055	1.000	1.349	1.365	1.055
1985	3.032	1.483	1.023	1.050	1.002	1.381	1.376	1.052
1986	3.095	1.477	1.024	1.040	1.003	1.413	1.387	1.044
1987	3.351	1.512	1.027	1.038	1.020	1.454	1.402	1.058
1988	3.541	1.519	1.027	1.028	1.040	1.491	1.423	1.070
1989	3.625	1.496	1.027	1.025	1.053	1.514	1.445	1.079
1990	3.517	1.478	1.008	1.001	1.070	1.510	1.459	1.072
1991	3.212	1.422	0.982	0.967	1.102	1.472	1.466	1.066
1992	3.299	1.484	0.979	0.973	1.089	1.460	1.467	1.060
1993	3.316	1.480	0.978	0.984	1.073	1.479	1.469	1.056
1994	3.562	1.527	0.987	1.009	1.046	1.517	1.476	1.055
1995	3.770	1.545	0.990	1.041	1.033	1.543	1.485	1.075
1996	3.892	1.555	0.982	1.032	1.051	1.570	1.496	1.085
1997	4.019	1.563	0.978	1.023	1.059	1.600	1.516	1.083
1998	4.157	1.596	0.979	1.014	1.047	1.630	1.539	1.061
1999	4.403	1.625	0.974	1.010	1.060	1.664	1.561	1.071
2000	4.785	1.672	0.970	1.032	1.066	1.698	1.579	1.099
2001	4.772	1.671	0.964	1.023	1.065	1.711	1.590	1.089
2002	4.956	1.740	0.967	1.003	1.068	1.727	1.593	1.071
2003	4.933	1.668	0.957	0.984	1.121	1.745	1.604	1.104
2004	5.285	1.691	0.959	0.990	1.144	1.781	1.616	1.132
2005	5.544	1.703	0.959	0.993	1.164	1.794	1.638	1.156
2006	5.748	1.699	0.964	0.986	1.179	1.813	1.665	1.163
2007	5.978	1.683	0.969	0.981	1.205	1.838	1.687	1.182
2008	6.163	1.667	0.971	1.016	1.189	1.847	1.707	1.207
2009	5.548	1.615	0.978	0.967	1.186	1.799	1.703	1.146
2010	5.877	1.639	0.975	0.971	1.216	1.827	1.704	1.181
2011	6.202	1.666	0.973	0.991	1.219	1.849	1.712	1.208
Compound Annual Growth Rates								
1961-2011	3.72	1.03	-0.05	-0.02	0.40	1.24	1.08	0.38
2000-2011	2.39	-0.03	0.03	-0.36	1.23	0.78	0.74	0.86
1961-1973	6.73	2.67	0.44	0.21	0.06	1.83	1.35	0.28
1973-1981	3.38	-0.03	0.01	0.99	-0.62	1.30	1.70	0.37
1981-1989	3.05	1.12	-0.35	-1.00	1.18	1.18	0.90	0.17
1989-2000	2.56	1.02	-0.51	0.06	0.11	1.05	0.81	0.17
2000-2008	3.22	-0.04	0.01	-0.20	1.38	1.05	0.98	1.18
2008-2011	0.21	-0.02	0.06	-0.80	0.84	0.04	0.10	0.03

Table 6
Comparison between Diewert and Yu and Statistics Canada Estimates of Real Output and Real Input Series, 1961-2011

	Q_Y	Q_{YO}	Q_L	Q_{LO}	Q_K	Q_{KO}	Q_{KW}	Q_{KWO}	Q_{PR}
	Business Sector Output		Labour Input		Capital Services		Capital Stock		
	Diewert and Yu	Statistics Canada	Diewert and Yu	Statistics Canada	Diewert and Yu	Statistics Canada	Diewert and Yu	Statistics Canada	Paid Rents
Year	(millions, 1961 dollars)								
1961	29,368	30,805	19,240	19,201	10,128	11,604	65,074	65,074	1,107
1962	31,585	33,059	20,049	20,025	10,326	12,054	66,186	66,820	1,149
1963	34,008	35,013	20,506	20,540	10,613	12,593	67,985	68,814	1,170
1964	36,591	37,567	21,372	21,466	11,091	13,493	70,874	72,554	1,221
1965	39,269	40,122	22,321	22,444	11,655	14,752	73,925	76,793	1,278
1966	42,286	42,827	23,452	23,577	12,450	16,281	78,410	82,029	1,337
1967	43,046	43,728	23,822	24,040	13,105	17,451	82,234	86,766	1,390
1968	44,645	46,133	23,864	24,143	13,515	18,350	84,583	90,256	1,420
1969	46,806	48,537	24,366	24,658	13,986	19,430	87,164	94,495	1,476
1970	48,260	49,889	24,395	24,761	14,513	20,599	90,627	98,733	1,530
1971	50,452	51,843	24,836	25,276	14,953	21,588	92,937	102,723	1,551
1972	53,041	54,998	25,469	26,048	15,415	23,028	94,972	107,460	1,584
1973	58,832	59,206	26,868	27,541	16,106	25,007	98,134	112,945	1,566
1974	61,727	61,310	27,717	28,519	17,037	26,986	103,385	119,677	1,558
1975	59,494	62,061	27,534	28,467	18,122	28,785	110,211	126,159	1,544
1976	63,195	66,118	27,417	28,467	18,769	30,764	112,964	132,642	1,482
1977	67,878	68,823	27,616	28,776	19,366	32,383	115,949	138,127	1,384
1978	70,536	71,979	28,636	29,960	20,037	34,092	119,537	143,363	1,322
1979	74,698	75,134	30,208	31,710	20,912	36,341	123,921	149,845	1,295
1980	73,053	76,938	31,015	32,740	22,012	38,949	130,218	156,079	1,313
1981	74,433	80,244	31,669	33,615	23,302	41,828	135,275	163,309	1,359
1982	70,175	77,088	29,737	31,968	23,850	42,817	138,323	165,802	1,410
1983	73,155	79,192	29,747	32,174	24,016	43,897	136,998	167,298	1,444
1984	78,122	84,752	30,714	33,358	24,312	45,246	137,639	169,044	1,471
1985	82,738	89,260	31,892	34,748	24,809	47,045	140,493	172,285	1,500
1986	85,019	91,514	33,124	36,241	25,343	48,844	142,988	176,523	1,539
1987	90,559	96,022	34,682	38,042	26,064	51,453	145,848	182,258	1,599
1988	94,670	100,981	36,105	39,793	27,136	54,331	150,432	189,738	1,662
1989	96,089	103,685	36,972	40,874	28,278	57,389	155,302	197,218	1,726
1990	95,610	103,235	36,814	40,874	29,056	59,368	158,744	202,703	1,798
1991	90,121	99,027	35,445	39,587	29,504	60,538	160,238	205,445	1,853
1992	93,349	99,628	35,000	39,123	29,544	61,527	158,327	205,695	1,899
1993	94,373	102,483	35,683	39,998	29,642	62,517	157,980	206,443	1,943
1994	100,395	108,795	37,145	41,543	30,070	64,496	158,425	208,437	1,982
1995	103,938	112,401	38,163	42,727	30,529	66,834	159,699	210,681	2,016
1996	107,231	114,956	39,243	43,962	31,132	69,353	162,378	213,673	2,049
1997	111,367	121,417	40,501	45,404	32,269	73,401	166,742	220,904	2,097
1998	117,544	127,127	41,680	46,845	33,566	77,269	170,681	227,386	2,139
1999	123,965	135,542	43,103	48,389	34,865	81,676	174,830	234,118	2,187
2000	131,753	144,108	44,563	50,088	35,944	85,454	178,130	241,598	2,231
2001	133,537	146,362	45,096	50,706	36,583	87,793	181,277	245,338	2,279
2002	140,604	150,269	45,811	51,478	36,720	89,952	180,822	249,327	2,341
2003	137,165	153,124	46,610	52,405	37,380	92,830	183,931	254,812	2,413
2004	142,907	158,383	48,181	54,206	38,111	96,698	185,502	261,544	2,487
2005	146,935	163,492	48,777	54,927	39,392	101,646	189,852	270,021	2,560
2006	150,603	167,850	49,653	55,905	41,010	107,223	195,631	279,994	2,638
2007	153,232	171,306	50,817	57,295	42,360	111,990	200,440	288,720	2,715
2008	154,363	171,306	51,240	57,758	43,583	116,398	205,062	295,702	2,797
2009	145,283	163,042	49,049	55,493	43,323	115,948	205,338	294,455	2,881
2010	149,898	169,203	50,315	56,935	43,405	117,477	204,637	295,452	2,966
2011	154,899	173,861	51,312	58,119	43,896	121,435	205,655	300,439	3,054
Compound Annual Growth Rates									
1961-2011	3.38	3.52	1.98	2.24	2.98	4.81	2.33	3.11	2.05
2000-2011	1.48	1.72	1.29	1.36	1.83	3.25	1.31	2.00	2.90
1961-1973	5.96	5.60	2.82	3.05	3.94	6.61	3.48	4.70	2.93
1973-1981	2.98	3.87	2.08	2.52	4.73	6.64	4.09	4.72	-1.76
1981-1989	3.24	3.26	1.95	2.47	2.45	4.03	1.74	2.39	3.03
1989-2000	2.91	3.04	1.71	1.87	2.20	3.69	1.25	1.86	2.36
2000-2008	2.00	2.18	1.76	1.80	2.44	3.94	1.78	2.56	2.87
2008-2011	0.12	0.49	0.05	0.21	0.24	1.42	0.10	0.53	2.97

Source: Calculations by Diewert and Yu; Statistics Canada, Canadian Productivity Accounts, CANSIM Table 383-0021.

Table 7
Comparison between Diewert and Yu and Statistics Canada Estimates for MFP, Labour Compensation and Capital Cost Shares in the Canadian Business Sector, 1961-2011

	Multifactor Productivity		Labour Compensation Share		Capital Cost Share	
	Diewert and Yu	Statistics Canada	Diewert and Yu	Statistics Canada	Diewert and Yu	Statistics Canada
Year	(index, 1961=1.000)		(% of business sector GDP)			
1961	1.000	1.000	66.0	62.3	34.0	37.7
1962	1.040	1.035	66.0	62.5	34.0	37.5
1963	1.093	1.059	64.0	61.5	36.0	38.5
1964	1.127	1.077	64.0	61.2	36.0	38.8
1965	1.156	1.084	64.0	61.8	36.0	38.2
1966	1.177	1.080	64.0	62.0	36.0	38.0
1967	1.165	1.061	66.0	63.5	34.0	36.5
1968	1.194	1.097	65.0	62.3	35.0	37.7
1969	1.221	1.111	66.0	63.0	34.0	37.0
1970	1.242	1.119	66.0	62.8	34.0	37.2
1971	1.271	1.125	67.0	63.1	33.0	36.9
1972	1.300	1.145	67.0	63.1	33.0	36.9
1973	1.372	1.154	63.0	61.1	37.0	38.9
1974	1.382	1.136	62.0	60.9	38.0	39.1
1975	1.308	1.120	66.0	61.6	34.0	38.4
1976	1.377	1.165	66.0	62.2	34.0	37.9
1977	1.457	1.182	65.0	62.4	35.0	37.6
1978	1.461	1.180	63.0	60.9	37.0	39.1
1979	1.472	1.162	61.0	59.4	39.0	40.6
1980	1.389	1.136	62.0	58.8	38.0	41.2
1981	1.368	1.131	64.0	60.1	36.0	39.9
1982	1.333	1.110	66.0	60.6	34.0	39.4
1983	1.386	1.126	62.0	58.2	38.0	41.8
1984	1.444	1.163	61.0	57.5	39.0	42.5
1985	1.483	1.179	61.0	58.1	39.0	41.9
1986	1.477	1.161	63.0	59.7	37.0	40.3
1987	1.512	1.159	62.0	59.4	38.0	40.6
1988	1.519	1.160	63.0	60.3	37.0	39.7
1989	1.496	1.146	64.0	60.8	36.0	39.2
1990	1.478	1.126	65.0	61.9	35.0	38.1
1991	1.422	1.096	68.0	63.5	32.0	36.5
1992	1.484	1.102	66.0	63.6	34.0	36.4
1993	1.480	1.113	66.0	62.3	34.0	37.7
1994	1.527	1.140	63.0	59.8	37.0	40.2
1995	1.545	1.142	62.0	58.9	38.0	41.1
1996	1.555	1.132	61.0	58.8	39.0	41.2
1997	1.563	1.144	62.0	59.0	38.0	41.0
1998	1.596	1.154	63.0	60.2	37.0	39.8
1999	1.625	1.178	62.0	58.8	38.0	41.2
2000	1.672	1.206	60.0	57.4	40.0	42.6
2001	1.671	1.201	61.0	58.0	39.0	42.0
2002	1.740	1.211	60.0	58.3	40.0	41.7
2003	1.668	1.205	61.0	57.1	39.0	42.9
2004	1.691	1.201	60.0	56.7	40.0	43.3
2005	1.703	1.205	59.0	56.1	41.0	43.9
2006	1.699	1.196	60.0	56.7	40.0	43.3
2007	1.683	1.182	59.0	56.8	41.0	43.2
2008	1.667	1.156	58.0	55.6	42.0	44.4
2009	1.615	1.127	63.0	..	37.0	..
2010	1.639	1.146	61.0	..	39.0	..
2011	1.666	1.148	59.0	..	41.0	..
	Compound Annual Growth Rates		Period Average			
1961-2011	1.03	0.28	63.2	60.2	36.8	39.8
2000-2011	-0.03	-0.45	59.8	56.9	40.3	43.1
1961-1973	2.67	1.20	65.2	62.3	34.8	37.7
1973-1981	-0.03	-0.25	63.6	60.8	36.4	39.2
1981-1989	1.12	0.17	62.8	59.3	37.3	40.7
1989-2000	1.02	0.46	63.5	60.4	36.5	39.6
2000-2008	-0.04	-0.52	59.8	56.9	40.3	43.1
2008-2011	-0.02	-0.24	..	..	..	..

Note: Period averages for labour compensation and capital cost shares were calculated without taking into account the last year of the previous business cycle. Furthermore, average shares were calculated for the 1961-2008 period only, since official estimates for the 2009-2011 period were not available.

Source: Calculations by Diewert and Yu; Statistics Canada, Canadian Productivity Accounts, CANSIM Table 383-0021.

Appendix 1: Explaining Real Income Growth: The Translog Approach

The Production Theory Framework

In this Appendix, we present the production theory framework used in the article "New Estimates of Real Income and Multifactor Productivity Growth for the Canadian Business Sector, 1961-2011" published in the Fall 2012 issue of the *International Productivity Monitor*.[1] The main reference is Diewert and Morrison (1986), but we also draw on the theory of the output price index, which was developed by Fisher and Shell (1972) and Archibald (1977).[2] This theory is the producer theory counterpart to the theory of the cost of living index for a single consumer (or household) that was first developed by the Russian economist, A. A. Konüs (1924). These economic approaches to price indexes rely on the assumption of (competitive) *optimizing behavior* on the part of economic agents (consumers or producers). Thus we consider only the market sector of the economy in what follows; i.e. that part of the economy that is motivated by profit maximizing behavior. In our empirical work, we define the market sector to be the Canadian business sector of the economy less the rental and owner occupied housing sectors.[3]

Initially, we assume that the market sector of the economy produces quantities of M (net)[4] outputs, $y \equiv [y_1,...,y_M]$, which are sold at the positive producer prices $P \equiv [P_1,...,P_M]$. We further assume that the market sector of the economy uses positive quantities of N primary inputs, $x \equiv [x_1,...,x_N]$ which are purchased at the positive primary input prices $W \equiv [W_1,...,W_N]$. In period t, we assume that there is a feasible set of output vectors y that can be produced by the market sector if the vector of primary inputs x is utilized by the market sector of the economy; denote this period t production possibilities set by S^t. We assume that S^t is a closed convex cone that exhibits a free disposal property.[5]

[1] This material is drawn from Diewert, Mizobuchi and Nomura (2005) and Diewert and Lawrence (2006).

[2] The theory also draws on Diewert (1983:1077-1100), Kohli (1990, 2003, 2004, and 2006), Morrison and Diewert (1990), Fox and Kohli (1998) and Chapter 24 in the IMF, ILO, OECD, Eurostat, UNECE and the World Bank (2009).

[3] The Canadian business sector excludes all of the general government sectors such as schools, hospitals, universities, defense and public administration where no independent measures of output can be obtained. For owner occupied housing, output is equal to input and hence no productivity improvements can be generated by this sector according to SNA conventions. Due to the difficulties involved in splitting up the residential housing stock into the rental and owner occupied portions, we omit the entire residential housing stock and the consumption of residential housing services in our data. However, we do include investment in residential housing, since that investment is part of the output of the market production sector.

[4] If the mth commodity is an import (or other produced input) into the market sector of the economy, then the corresponding quantity y_m is indexed with a negative sign. We will follow Kohli (1978 and 1991) and Woodland (1982) in assuming that imports flow through the domestic production sector and are "transformed" (perhaps only by adding transportation, wholesaling and retailing margins) by the domestic production sector. The recent textbook by Feenstra (2004: 76) also uses this approach.

[5] For a more explanation for the meaning of these properties, see Diewert (1974: 134). The assumption that S^t is a cone means that the technology is subject to constant returns to scale. This is an important assumption since it implies that the value of outputs should equal the value of inputs in equilibrium. In our empirical work, we use an ex post rate of return in our user costs of capital, which forces the value of inputs to equal the value of outputs for each period. The function g^t is known as the *GDP function* or the *national product function* in the international trade

Given a vector of output prices P and a vector of available primary inputs x, we define *the period t market sector GDP function*, $g^t(P,x)$, as follows:[6]

(1) $g^t(P,x) \equiv \max_y \{P\cdot y : (y,x) \text{ belongs to } S^t\}$; $t = 0,1,2, \ldots$.

Thus market sector GDP depends on t (which represents the period t technology set S^t), on the vector of output prices P that the market sector faces and on x, the vector of primary inputs that is available to the market sector.

If P^t is the period t output price vector and x^t is the vector of inputs used by the market sector during period t and if the GDP function is differentiable with respect to the components of P at the point P^t,x^t, then the period t vector of market sector outputs y^t will be equal to the vector of first order partial derivatives of $g^t(P^t,x^t)$ with respect to the components of P; i.e., we will have the following equations for each period t:[7]

(2) $y^t = \nabla_P\, g^t(P^t,x^t)$; $t = 0,1,2, \ldots$.

Thus the period t market sector supply vector y^t can be obtained by differentiating the period t market sector GDP function with respect to the components of the period t output price vector P^t.

If the GDP function is differentiable with respect to the components of x at the point P^t,x^t, then the period t vector of input prices W^t will be equal to the vector of first order partial derivatives of $g^t(P^t,x^t)$ with respect to the components of x; i.e., we will have the following equations for each period t:[8]

(3) $W^t = \nabla_x\, g^t(P^t,x^t)$; $t = 0,1,2, \ldots$.

Thus the period t market sector input prices W^t paid to primary inputs can be obtained by differentiating the period t market sector GDP function with respect to the components of the period t input quantity vector x^t.

The constant returns to scale assumption on the technology sets S^t implies that the value of outputs will equal the value of inputs in period t; i.e., we have the following relationships:

(4) $g^t(P^t,x^t) = P^t\cdot y^t = W^t\cdot x^t$; $t = 0,1,2, \ldots$.

The above material will be useful in what follows but of course, our focus is not on GDP; instead our focus is on the income generated by the market sector or more precisely, on *the real income*

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literature; see Kohli (1978 and 1991), Woodland (1982) and Feenstra (2004:76). It was introduced into the economics literature by Samuelson (1953).

[6] The function $g^t(P,x)$ will be linearly homogeneous and convex in the components of P and linearly homogeneous and concave in the components of x; see Diewert (1974: 136). Notation: $P\cdot y \equiv \sum_{m=1}^{M} P_m y_m$.

[7] These relationships are due to Hotelling (1932: 594). Note that $\nabla_P\, g^t(P^t,x^t) \equiv [\partial g^t(P^t,x^t)/\partial P_1, \ldots, \partial g^t(P^t,x^t)/\partial P_M]$.

[8] These relationships are due to Samuelson (1953) and Diewert (1974: 140). Note that $\nabla x\; g^t(P^t,x^t) \equiv [\partial g^t(P^t,x^t)/\partial x_1, \ldots, \partial g^t(P^t,x^t)/\partial x_N]$.

generated by the market sector. However, since market sector GDP (the value of market sector production) is distributed to the factors of production used by the market sector, nominal market sector GDP will be equal to nominal market sector income; i.e. from (4), we have $g^t(P^t,x^t) = P^t\cdot y^t = W^t\cdot x^t$. As an approximate welfare measure that can be associated with market sector production,[9] we will choose to measure the *real income generated by the market sector in period t*, ρ^t, in terms of the number of consumption bundles that the nominal income could purchase in period t; i.e., define ρ^t as follows:

$$\begin{aligned}(5)\ \rho^t &\equiv W^t\cdot x^t/P_C{}^t\ ; \qquad\qquad t = 0,1,2, \ldots\\ &= w^t\cdot x^t\\ &= p^t\cdot y^t\\ &= g^t(p^t,x^t)\end{aligned}$$

where $P_C{}^t > 0$ is the *period t consumption expenditures deflator* and the market sector period t *real output price* p^t and *real input price* w^t vectors are defined as the corresponding nominal price vectors deflated by the consumption expenditures price index; i.e., we have the following definitions:[10]

$$(6)\ p^t \equiv P^t/P_C{}^t\ ;\ w^t \equiv W^t/P_C{}^t\ ; \qquad\qquad t = 0,1,2, \ldots .$$

The first and last equality in (5) imply that period t real income, ρ^t, is equal to the period t GDP function, evaluated at the period t real output price vector p^t and the period t input vector x^t, $g^t(p^t,x^t)$. Thus *the growth in real income over time can be explained by three main factors: t (Technical Progress or Total Factor Productivity growth), growth in real output prices and the growth of primary inputs*. We will shortly give formal definitions for these three growth factors.

Using the linear homogeneity properties of the GDP functions $g^t(P,x)$ in P and x separately, we can show that the following counterparts to the relations (2) and (3) hold using the deflated prices p and w:[11]

$$(7)\ y^t = \nabla_p\, g^t(p^t,x^t)\ ; \qquad\qquad t = 0,1,2, \ldots ;$$
$$(8)\ w^t = \nabla_x\, g^t(p^t,x^t)\ ; \qquad\qquad t = 0,1,2, \ldots .$$

Now we are ready to define a family of *period t productivity growth factors or technical progress shift factors* $\tau(p,x,t)$:[12]

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[9] Since some of the primary inputs used by the market sector can be owned by foreigners, our measure of *domestic* welfare generated by the market production sector is only an approximate one. Moreover, our suggested welfare measure is not sensitive to the distribution of the income that is generated by the market sector.

[10] Our approach is similar to the approach advocated by Kohli (2004: 92), except he essentially deflates nominal GDP by the domestic expenditures deflator rather than just the domestic (household) expenditures deflator; i.e., he deflates by the deflator for C+G+I, whereas we suggest deflating by the deflator for C. Another difference in his approach compared to the present approach is that we restrict our analysis to the market sector GDP, whereas Kohli deflates all of GDP. Our treatment of the balance of trade surplus or deficit is also different.

[11] If producers in the market sector of the economy are solving the profit maximization problem that is associated with $g^t(P,x)$, which uses the original output prices P, then they will also solve the profit maximization problem that uses the normalized output prices $p \equiv P/P_C$; i.e., they will also solve the problem defined by $g^t(p,x)$.

(9) $\tau(p,x,t) \equiv g^t(p,x)/g^{t-1}(p,x)$; $t = 1,2, \ldots$.

Thus $\tau(p,x,t)$ measures the proportional change in the real income produced by the market sector at the reference real output prices p and reference input quantities used by the market sector x where the numerator in (9) uses the period t technology and the denominator in (9) uses the period t–1 technology. Thus each choice of reference vectors p and x will generate a possibly different measure of the shift in technology going from period t–1 to period t.

It is natural to choose special reference vectors for the measure of technical progress defined by (9): a *Laspeyres type measure* τ_L^t that chooses the period t–1 reference vectors p^{t-1} and x^{t-1} and a *Paasche type measure* τ_P^t that chooses the period t reference vectors p^t and x^t:

(10) $\tau_L^t \equiv \tau(p^{t-1},x^{t-1},t) = g^t(p^{t-1},x^{t-1})/g^{t-1}(p^{t-1},x^{t-1})$; $t = 1,2, \ldots$;
(11) $\tau_P^t \equiv \tau(p^t,x^t,t) = g^t(p^t,x^t)/g^{t-1}(p^t,x^t)$; $t = 1,2, \ldots$.

Since both measures of technical progress are equally valid, it is natural to average them to obtain an overall measure of technical change. If we want to treat the two measures in a symmetric manner and we want the measure to satisfy the time reversal property from index number theory[13] (so that the estimate going backwards is equal to the reciprocal of the estimate going forwards), then the geometric mean will be the best simple average to take.[14] Thus we define the geometric mean of (10) and (11) as follows:[15]

(12) $\tau^t \equiv [\tau_L^t \, \tau_P^t]^{1/2}$; $t = 1,2, \ldots$.

At this point, it is not clear how we will obtain empirical estimates for the theoretical productivity growth indexes defined by (10)-(12). One obvious way would be to assume a functional form for the GDP function $g^t(p,x)$, collect data on output and input prices and quantities for the market sector for a number of years (and for the consumption expenditures deflator), add error terms to equations (7) and (8) and use econometric techniques to estimate the unknown parameters in the assumed functional form. However, econometric techniques are generally not completely straightforward: different econometricians will make different stochastic specifications and will choose different functional forms. Moreover, as the number of outputs and inputs grows, it will be impossible to estimate a flexible functional form. Thus we will suggest methods for implementing measures like (12) in this Appendix that are based on exact index number techniques.

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[12] This measure of technical progress is due to Diewert and Morrison (1986; 662). A special case of it was defined earlier by Diewert (1983: 1063).
[13] See Fisher (1922: 64).
[14] See the discussion in Diewert (1997) on choosing the "best" symmetric average of Laspeyres and Paasche indexes that will lead to the satisfaction of the time reversal test by the resulting average index.
[15] The theoretical productivity change indexes defined by (10)-(12) were first defined by Diewert and Morrison (1986: 662-663) in the nominal GDP context.

We turn now to the problem of defining theoretical indexes for the effects on real income due to changes in real output prices. Define a family of *period t real output price growth factors* $\alpha(p^{t-1},p^t,x,s)$:[16]

$$(13)\ \alpha(p^{t-1},p^t,x,s) \equiv g^s(p^t,x)/g^s(p^{t-1},x)\ ; \qquad s = 1,2, \ldots .$$

Thus $\alpha(p^{t-1},p^t,x,s)$ measures the proportional change in the real income produced by the market sector that is induced by the change in real output prices going from period t−1 to t, using the technology that is available during period s and using the reference input quantities x. Each choice of the reference technology s and the reference input vector x will generate a possibly different measure of the effect on real income of a change in real output prices going from period t−1 to period t.

Again, it is natural to choose special reference vectors for the measures defined by (13): a *Laspeyres type measure* $\alpha_L{}^t$ that chooses the period t−1 reference technology and reference input vector x^{t-1} and a *Paasche type measure* $\alpha_P{}^t$ that chooses the period t reference technology and reference input vector x^t:

$$(14)\ \alpha_L{}^t \equiv \alpha(p^{t-1},p^t,x^{t-1},t-1) = g^{t-1}(p^t,x^{t-1})/g^{t-1}(p^{t-1},x^{t-1})\ ; \qquad t = 1,2, \ldots ;$$
$$(15)\ \alpha_P{}^t \equiv \alpha(p^{t-1},p^t,x^t,t) = g^t(p^t,x^t)/g^t(p^{t-1},x^t)\ ; \qquad t = 1,2, \ldots .$$

Since both measures of real output price change are equally valid, it is natural to average them to obtain an overall measure of the effects on real income of the change in real output prices:[17]

$$(16)\ \alpha^t \equiv [\alpha_L{}^t\, \alpha_P{}^t]^{1/2}\ ; \qquad t = 1,2, \ldots .$$

Finally, we look at the problem of defining theoretical indexes for the effects on real income due to changes in input quantities. Define a family of *period t real input quantity growth factors* $\beta(x^{t-1},x^t,p,s)$:[18]

$$(17)\ \beta(x^{t-1},x^t,p,s) \equiv g^s(p,x^t)/g^s(p,x^{t-1})\ ; \qquad s = 1,2, \ldots .$$

Thus $\beta(x^{t-1},x^t,p,s)$ measures the proportional change in the real income produced by the market sector that is induced by the change in input quantities used by the market sector going from period t−1 to t, using the technology that is available during period s and using the reference real output prices p. Each choice of the reference technology s and the reference real output price

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[16] This measure of real output price change was essentially defined by Fisher and Shell (1972: 56-58), Samuelson and Swamy (1974: 588-592), Archibald (1977: 60-61), Diewert (1980: 460-461 and 1983:1055) and Balk (1998: 83-89). Readers who are familiar with the theory of the true cost of living index will note that the real output price index defined by (13) is analogous to the Konüs (1924) *true cost of living index* which is a ratio of cost functions, say $C(u,p^t)/C(u,p^{t-1})$ where u is a reference utility level: g^s replaces C and the reference utility level u is replaced by the vector of reference variables x.

[17] The indexes defined by (13)-(16) were defined by Diewert and Morrison (1986: 664) in the nominal GDP function context.

[18] This type of index was defined as a true index of value added by Sato (1976: 438) and as a real input index by Diewert (1980: 456).

vector p will generate a possibly different measure of the effect on real income of a change in input quantities going from period t−1 to period t.

As usual, it is natural to choose special reference vectors for the measures defined by (17): a *Laspeyres type measure* $\beta_L{}^t$ that chooses the period t−1 reference technology and reference real output price vector p^{t-1} and a *Paasche type measure* $\beta_P{}^t$ that chooses the period t reference technology and reference real output price vector p^t:

$$(18)\ \beta_L{}^t \equiv \beta(x^{t-1},x^t,p^{t-1},t-1) = g^{t-1}(p^{t-1},x^t)/g^{t-1}(p^{t-1},x^{t-1})\ ; \qquad t = 1,2, \ldots ;$$
$$(19)\ \beta_P{}^t \equiv \beta(x^{t-1},x^t,p^t,t) = g^t(p^t,x^t)/g^t(p^t,x^{t-1})\ ; \qquad t = 1,2, \ldots .$$

Since both measures of real input growth are equally valid, it is natural to average them to obtain an overall measure of the effects of input growth on real income:[19]

$$(20)\ \beta^t \equiv [\beta_L{}^t\, \beta_P{}^t]^{1/2}\ ; \qquad t = 1,2, \ldots .$$

Recall that market sector real income for period t was defined by (5) as ρ^t equal to nominal period t factor payments $W^t \cdot x^t$ deflated by the household consumption price deflator $P_C{}^t$. It is convenient to define γ^t as the *period t chain rate of growth factor for real income*:

$$(21)\ \gamma^t \equiv \rho^t/\rho^{t-1}\ ; \qquad t = 1,2, \ldots .$$

The Translog GDP Function Approach

We now follow the example of Diewert and Morrison (1986: 663) and assume that the log of the period t (deflated) GDP function, $g^t(p,x)$, has the following translog functional form:[20]

$$(22)\ \ln g^t(p,x) \equiv a_0{}^t + \sum_{m=1}^M a_m{}^t \ln p_m{}^t + (1/2) \sum_{m=1}^M\sum_{k=1}^M a_{mk} \ln p_m{}^t \ln p_k{}^t + \sum_{n=1}^N b_n{}^t \ln x_n{}^t + (1/2)\sum_{n=1}^N\sum_{j=1}^N b_{nj} \ln x_n{}^t \ln x_j{}^t + \sum_{m=1}^M\sum_{n=1}^M c_{mn} \ln p_m{}^t \ln x_n{}^t\ ; \qquad t = 0,1,2, \ldots .$$

Note that the coefficients for the quadratic terms are assumed to be constant over time. The coefficients must satisfy the following restrictions in order for g^t to satisfy the linear homogeneity properties that we have assumed in section 2 above:[21]

$$(23)\ \sum_{m=1}^M a_m{}^t = 1 \text{ for } t = 0,1,2, \ldots;$$
$$(24)\ \sum_{n=1}^N b_n{}^t = 1 \text{ for } t = 0,1,2, \ldots;$$
$$(25)\ a_{mk} = a_{km} \text{ for all } k,m\ ;$$

[19] The theoretical indexes defined by (17)-(20) were defined in Diewert and Morrison (1986: 665) in the nominal GDP context.

[20] This functional form was first suggested by Diewert (1974: 139) as a generalization of the translog functional form introduced by Christensen, Jorgenson and Lau (1971). Diewert (1974: 139) indicated that this functional form was flexible.

[21] There are additional restrictions on the parameters which are necessary to ensure that $g^t(p,x)$ is convex in p and concave in x. Note that when we divide the original prices by one of the prices, then one of the scaled prices will be identically equal to one and hence its logarithm will be identically equal to zero.

(26) $b_{nj} = b_{jn}$ for all n,j ;
(27) $\sum_{k=1}^{M} a_{mk} = 0$ for m = 1,...,M ;
(28) $\sum_{j=1}^{N} b_{nj} = 0$ for n = 1,...,N ;
(29) $\sum_{n=1}^{N} c_{mn} = 0$ for m = 1,...,M ;
(30) $\sum_{m=1}^{M} c_{mn} = 0$ for n = 1,...,N .

Diewert and Morrison (1986: 663) showed that[22] if g^{t-1} and g^t are defined by (22)-(30) above and there is competitive profit maximizing behavior on the part of all market sector producers for all periods t, then

(31) $\gamma^t = \tau^t\, \alpha^t\, \beta^t$; t = 1,2, ...

where γ^t, τ^t, α^t and β^t are defined above by (21), (12), (16) and (20) respectively. In addition, Diewert and Morrison (1986: 663-665) showed that τ^t, α^t and β^t could be calculated using empirically observable price and quantity data for periods t−1 and t as follows:

(32) $\ln\alpha^t = \sum_{m=1}^{M} (1/2)[(p_m^{t-1}y_m^{t-1}/p^{t-1}\cdot y^{t-1}) + (p_m^t y_m^t/p^t\cdot y^t)] \ln(p_m^t/p_m^{t-1})$
$= \ln P_T(p^{t-1},p^t,y^{t-1},y^t)$;
(33) $\ln\beta^t = \sum_{n=1}^{N} (1/2)[(w_n^{t-1}x_n^{t-1}/w^{t-1}\cdot x^{t-1}) + (w_n^t x_n^t/w^t\cdot x^t)] \ln(x_n^t/x_n^{t-1})$
$= \ln Q_T(w^{t-1},w^t,x^{t-1},x^t)$;
(34) $\tau^t = \gamma^t/\alpha^t\, \beta^t$

where $P_T(p^{t-1},p^t,y^{t-1},y^t)$ is the Törnqvist (1936) and Törnqvist and Törnqvist (1937) output price index and $Q_T(w^{t-1},w^t,x^{t-1},x^t)$ is the Törnqvist input quantity index.

Equations (31) are in rates of growth. It is possible to obtain counterparts to these equations in a levels form as follows. Thus we can express the level of real income in period t in terms of an *index of the technology level* or of Total Factor Productivity in period t T^t, of the *level of real output prices* in period t A^t, and of the *level of primary input quantities* in period t, B^t.[23] Thus we use the growth factors τ^t, α^t and β^t as follows to define the levels T^t, A^t and B^t:

(35) $T^0 \equiv 1$; $T^t \equiv T^{t-1}\, \tau^t$; t = 1,2, ... ;
(36) $A^0 \equiv 1$; $A^t \equiv A^{t-1}\alpha^t$; t = 1,2, ... ;
(37) $B^0 \equiv 1$; $B^t \equiv B^{t-1}\beta^t$; t = 1,2, ...

Using the above definitions and the exact equations (31), we can establish the following exact relationship for the level of real income in period t, ρ^t, and the period t levels for technology, real output prices and input quantities:

(38) $\rho^t/\rho^0 = T^t\, A^t\, B^t$; t = 1,2, ...

[22] Diewert and Morrison established their proof using the nominal GDP function $g^t(P,x)$. However, it is easy to rework their proof using the deflated GDP function $g^t(p,x)$ using the fact that $g^t(p,x) = g^t(P/P_C,x) = g^t(P,x)/P_C$ using the linear homogeneity property of $g^t(P,x)$ in P.
[23] This type of levels presentation of the data is quite instructive when presented in graphical form. It was suggested by Kohli (1990) and used extensively by him; see Kohli (2003 and 2004) and Fox and Kohli (1998).

The Translog GDP Function Approach and Changes in the Terms of Trade

For some purposes, it is convenient to decompose the aggregate period t contribution factor due to changes in all deflated output prices α^t into separate effects for each change in each output price. Similarly, it can sometimes be useful to decompose the aggregate period t contribution factor due to changes in all market sector primary input quantities β^t into separate effects for each change in each input quantity. In this section, we indicate how this can be done, making the same assumptions on the technology that were made in the previous section.

We first model the effects of a change in a single (deflated) output price, say p_m, going from period t−1 to t. Counterparts to the theoretical Laspeyres and Paasche type price indexes defined by (14) and (15) above for changes in all (deflated) output prices are the following *Laspeyres type measure* $\alpha_{Lm}{}^t$ that chooses the period t−1 reference technology and holds constant other output prices at their period t−1 levels and holds inputs constant at their period t−1 levels x^{t-1} and a *Paasche type measure* $\alpha_{Pm}{}^t$ that chooses the period t reference technology and reference input vector x^t and holds constant other output prices at their period t levels:

$$(39)\ \alpha_{Lm}{}^t \equiv g^{t-1}(p_1{}^{t-1},...,p_{m-1}{}^{t-1},p_m{}^t,p_{m+1}{}^{t-1},..., p_M{}^{t-1},x^{t-1})/g^{t-1}(p^{t-1},x^{t-1});\ m = 1,...,M;\ t = 1,...;$$
$$(40)\ \alpha_{Pm}{}^t \equiv g^t(p^t,x^t)/g^t(p_1{}^t,...,p_{m-1}{}^t,p_m{}^{t-1},p_{m+1}{}^t,..., p_M{}^t,x^t)\ ; \qquad m = 1,...,M;\ t = 1,2, ...$$

Since both measures of real output price change are equally valid, it is natural to average them to obtain an *overall measure of the effects on real income of the change in the real price of output m*:[24]

$$(41)\ \alpha_m{}^t \equiv [\alpha_{Lm}{}^t\, \alpha_{Pm}{}^t]^{1/2}\ ; \qquad m = 1,...,M\ ;\ t = 1,2, ...$$

Under the assumption that the deflated GDP functions $g^t(p,x)$ have the translog functional forms as defined by (22)-(30) in the previous section, the arguments of Diewert and Morrison (1986: 666) can be adapted to give us the following result:

$$(42)\ \ln\alpha_m{}^t = (1/2)[(p_m{}^{t-1}y_m{}^{t-1}/p^{t-1}\cdot y^{t-1}) + (p_m{}^t y_m{}^t/p^t\cdot y^t)]\ \ln(p_m{}^t/p_m{}^{t-1})\ ; \qquad m = 1,...,M\ ;\ t = 1,2, ...$$

Note that $\ln\alpha_m{}^t$ is equal to the mth term in the summation of the terms on the right hand side of (32). This observation means that we have the following exact decomposition of the period t aggregate real output price contribution factor α^t into a product of separate price contribution factors; i.e., we have under present assumptions:

$$(43)\ \alpha^t = \alpha_1{}^t\alpha_2{}^t...\ \alpha_M{}^t\ ; \qquad t = 1,2, ...$$

The above decomposition is useful for analyzing how real changes in the price of exports (i.e. a change in the price of exports relative to the price of domestic consumption) and in the price of

[24] The indexes defined by (39)-(41) were defined by Diewert and Morrison (1986: 666) in the nominal GDP function context.

imports impact on the real income generated by the market sector. In the empirical illustration which follows later, we let M equal three. The three net outputs are:

- Domestic sales (C+I+G);
- Exports (X) and
- Imports (M).

Since commodities 1 and 2 are outputs, y_1 and y_2 will be positive but since commodity 3 is an input into the market sector, y_3 will be negative. Hence an increase in the real price of exports will *increase* real income but an increase in the real price of imports will *decrease* the real income generated by the market sector, as is evident by looking at the contribution terms defined by (42) for m = 2 (where $y_m^t > 0$) and for m = 3 (where $y_m^t < 0$).

As mentioned above, it is also useful to have a decomposition of the aggregate contribution of input growth to the growth of real income into separate contributions for each important class of primary input that is used by the market sector. We now model the effects of a change in a single input quantity, say x_n, going from period t−1 to t. Counterparts to the theoretical Laspeyres and Paasche type quantity indexes defined by (18) and (19) above for changes in input n are the following *Laspeyres type measure* β_{Ln}^t that chooses the period t−1 reference technology and holds constant other input quantities at their period t−1 levels and holds real output prices at their period t−1 levels p^{t-1} and a *Paasche type measure* β_{Pn}^t that chooses the period t reference technology and reference real output price vector p^t and holds constant other input quantities at their period t levels:

$$(44)\ \beta_{Ln}^t \equiv g^{t-1}(p^{t-1},x_1^{t-1},...,x_{n-1}^{t-1},x_n^t,x_{n+1}^{t-1},..., x_N^{t-1})/g^{t-1}(p^{t-1},x^{t-1})\ ;\quad n = 1,...,N;\ t = 1,2, ...\ ;$$

$$(45)\ \beta_{Pn}^t \equiv g^t(p^t,x^t)/g^t(p^t,x_1^t,...,x_{n-1}^t,x_n^{t-1},x_{n+1}^t,..., p_N^t)\ ;\qquad n = 1,...,N;\ t = 1,2, ...\ .$$

Since both measures of input change are equally valid, as usual, we average them to obtain *an overall measure of the effects on real income of the change in the quantity of input n*:[25]

$$(46)\ \beta_n^t \equiv [\beta_{Pn}^t\,\beta_{Pn}^t]^{1/2}\ ;\qquad n = 1,...,N\ ;\ \ t = 1,2, ...\ .$$

Under the assumption that the deflated GDP functions $g^t(p,x)$ have the translog functional forms as defined by (22)-(30) in the previous section, the arguments of Diewert and Morrison (1986; 667) can be adapted to give us the following result:

$$(47)\ \ln\beta_n^t = (1/2)[(w_n^{t-1}x_n^{t-1}/w^{t-1}\cdot x^{t-1}) + (w_n^t\,x_n^t/w^t\cdot x^t)]\ \ln(x_n^t/x_n^{t-1});\ n = 1,...,N\ ;\ t = 1,2, ...\ .$$

Note that $\ln\beta_n^t$ is equal to the nth term in the summation of the terms on the right hand side of (33). This observation means that we have the following exact decomposition of the period t aggregate input growth contribution factor β^t into a product of separate input quantity contribution factors; i.e., we have under present assumptions:

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[25] The indexes defined by (52)-(54) were defined by Diewert and Morrison (1986: 667) in the nominal GDP function context.

(48) $\beta^t = \beta_1{}^t\beta_2{}^t \ldots \beta_N{}^t$; $t = 1,2, \ldots$.

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Appendix 2: Business Sector Data on Outputs and Inputs for Canada, 1961-2011

Introduction

The Appendix discusses the underlying data used to measure multifactor productivity growth in the article "New Estimates of Real Income and Multifactor Productivity Growth for the Canadian Business Sector, 1961-2011" published in the Fall 2012 issue of the *International Productivity Monitor*. Our approach is to use Statistics Canada information on the outputs produced by the Canadian business sector from the national accounts along with Statistics Canada information on labour and capital inputs used by the business to construct "top down" measures of the multifactor productivity performance of the Canadian business sector.[1] We also make extensive use of Statistics Canada's National Balance Sheet estimates for information on various capital inputs used by the business sector along with the more disaggregated information on business sector investment and capital stocks that is listed in CANSIM Table 310003. Our business sector labour information for 36 types of labour for the years 1961-2011 comes from CANSIM Table 3830024.

The present approach to productivity measurement is an aggregate "top down" approach as opposed to the usual industry "bottom up" approach which makes use of detailed data on inputs used and outputs produced by industrial sectors and aggregates up sectoral productivity growth rates in order to obtain national business sector estimates.[2] With reliable data, the two approaches should give very similar answers.[3] Unfortunately, data on industry inputs and outputs are not likely to be as reliable as the corresponding national data for a variety of reasons[4] so it is useful to provide a check on the industry approach to productivity measurement by using the national aggregate approach.

There is another reason for undertaking a productivity study using final demand data and this reason is that the effects of changes in a country's terms of trade can be measured in this framework whereas these effects cannot be measured in the industry accounts framework using the System of National Accounts 1993 (SNA 1993) (Eurostat, IMF, OECD, UN and World Bank, 1993, chapter 15). In particular, the Input Output accounts as outlined in Table 15.1 in the SNA 1993 do not show the role of international trade in goods and services by industry. Exports and imports enter the main supply and use tables (Table 15.1) as additions (or subtractions) to total net supply or to total domestic final demand in the familiar C+I+G+X−M setup. This means that Table 15.1 in the main production accounts of *SNA 1993* does not elaborate on which

[1] The present data base was constructed from national accounts information that was available prior to the recently released revised national accounts data. Our reason for not using the newly revised data is that the trade data were extensively revised, but the new data only extended back to 1981 whereas our present data base extends back to 1961.

[2] The bottom up approach is used by the Statistics Canada KLEMS program; see Baldwin, Gu and Yan (2007) for an overview and Baldwin and Gu (2007) for additional information on the construction of the Statistics Canada KLEMS capital services aggregates.

[3] In fact, if indirect tax effects could be ignored and if nominal and real input output tables were perfectly consistent, the two approaches should give exactly the same answer; see Chapter 19 in the IMF, ILO, OECD, Eurostat, UNECE and the World Bank (2004), Diewert (2005c and 2006) and Moyer, Reinsdorf and Yuskavage (2006).

[4] For a detailed discussion of these reasons, see Diewert (2001).

industries are actually using the imports or on which industries are actually doing the exporting by commodity.[5] Thus at present, data difficulties prevent us from looking at the effects of changes in the terms of trade using the bottom up industry aggregation approach.

Diewert and Lawrence (2000) undertook a study of Canada's business sector productivity using the national approach for the years 1962-1996 and Diewert (2002) extended their data to cover the years 1962-1998. Diewert (2008) updated these early studies that used the top-down approach, noting that there were some differences in his study compared to the earlier studies:

- Statistics Canada provided new data on national expenditure aggregates back to 1961 using annual *chained* index numbers and so it was no longer necessary to work with the old fixed base data on the most disaggregated level possible and then use chain indexes to aggregate up these data.

- Statistics Canada also provided new data on the outputs produced and inputs used by the Canadian business sector back to 1961 using chained Fisher indexes as part of their KLEMS productivity measurement program. In particular, Statistics Canada provided new estimates of labour input, which were a major improvement over the estimates of labour input used by Diewert and Lawrence.

- Diewert and Lawrence (2000) worked with a rather narrow definition of the government sector; their definition included only the public administration industry. In Diewert (2008), the Statistics Canada definition of the non-business sector was used (except that Diewert also added the residential rental housing industry to the non-business sector). The Statistics Canada definition of the non-business sector includes the general government sector and the publicly funded defense, hospital and education sectors in the non-business sector.[6] Since output in the non-business sector is measured by input, the use of the broader definition of the government sector should lead to higher estimates of productivity growth in the business sector compared to the estimates tabled in Diewert and Lawrence (2000) and Diewert (2002).

- Statistics Canada reorganized its information on indirect taxes (less subsidies) into two categories: taxes that fall primarily on outputs and taxes that fall primarily on inputs. This new information was very useful in making adjustments to output prices for indirect tax effects.[7]

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[5] It should be noted that *SNA 1993* does have a recommended optional Table 15.5 which is exactly suited to our present needs; i.e. this table provides the detail for imports by commodity and by industry. However, *SNA 1993* does not provide a recommendation for a corresponding commodity by industry table for exports. The situation is remedied in *SNA 2008* but statistical agencies generally do not have the data base to construct these detailed export and import matrices by industry and commodity. Thus for Canada, the necessary detailed trade data by industry and commodity are not publically available.

[6] The non-business sector consists of the following industries: (1) Government funding of hospitals; (2) Government funding of residential care; (3) Government funding of universities; (4) Government funding of other education; (5) Defense services; (6) Other municipal government services; (7) Other provincial government services and (8) Other federal government services.

[7] In early studies of the Total Factor Productivity of an economy like those done by Solow (1957) and Jorgenson and Griliches (1967), outputs were priced at final demand prices, which include indirect taxes. However, Jorgenson and

However, since Diewert (2008) appeared, there has been a substantial revision of the Statistics Canada data used in his study. Thus the *IPM* article uses more recent published Statistics Canada data as well as some unpublished disaggregated capital data made available to us from the Statistics Canada KLEMS database.[8] Note that the business sector used here differs from the Statistics Canada business sector in that we have excluded all residential housing services (Owner Occupied Housing services plus Rental Housing services) from our business aggregate whereas Statistics Canada includes the services of rental housing in its business aggregate.[9]

The main conceptual changes in our present data base from the data tabled in Diewert (2008) are as follows:

- The trade data were disaggregated;

- Machinery and equipment investment in Diewert (2008) has been disaggregated into 10 types of machinery and equipment and 4 types of structure using the information in CANSIM Table 310003;

- We used the Statistics Canada KLEMS data on the price of inventory stocks in the present study whereas before, we used another Statistics Canada price series to value inventory stocks;

- The depreciation rates for the 10 types of machinery and equipment and the 4 types of structure were re-estimated using information on capital stocks and investments contained in CANSIM Table 310003;

- We were able to construct disaggregated estimates for the price and quantity of 36 types of labour for the years 1961-2011 using information from CANSIM Table 3830024. These 36 types of labour were aggregated to form quality adjusted aggregate labour price and quantity series. The resulting business sector labour aggregate should be comparable to the KLEMS program labour aggregate.

In section 2 of this Appendix, we will list the basic final demand expenditure series that were used in this study. Section 3 lists the prices and quantities for the 36 types of business sector labour input that are available in three published business sector measures of quality adjusted

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Griliches (1972; 85) noted that this treatment was not consistent with competitive price taking behavior on the part of producers, since producers do not derive any benefit from indirect taxes that fall on their outputs and thus these taxes should be removed.

[8] These data were downloaded on October 1, 2012.

[9] Our reason for excluding the services of rental housing from our business sector aggregate is due to the lack of accurate data on residential structures investment on rental housing and the lack of information on the quantity and value of land that is occupied by rental housing. Our measure of business sector labour input is the conceptually the same as that used by the Statistics Canada KLEMS program since we ignore the labour inputs used by the residential rental market. In practice, our labour estimates for the business sector (which are based on CANSIM Table 3830024) turn out to be substantially different from the KLEMS estimates. Our output measures and capital services input measures also differ from the corresponding KLEMS estimates because we have dropped rental housing inputs and outputs from our definition of the business sector.

labour input for the Canadian business sector that are available on CANSIM Table 3830024. Section 4 studies the problems associated with forming estimates for capital inputs. Section 5 concludes by forming estimates of tax rates on primary inputs. This information is used to calculate estimates of balancing after tax real rates of return. Then this information is used along with the information developed in previous sections in order to calculate user costs for 17 classes of capital input: 10 types of machinery and equipment, 4 types of nonresidential structures, agricultural land, nonagricultural and nonresidential business land and inventories. Section 6 concludes with some observations on the weak points in the data and recommendations for further work on developing a set of productivity accounts for Canada.

Estimates of Canadian Final Demand Expenditures

Much of the information tabled in this section was downloaded from CANSIM Table 3800002, Gross Domestic Product; Expenditure Based. The July 17, 2012 version of these data were used, using the Statistics Canada online data service CANSIM, which were listed as quarterly data. If the quarterly data were seasonally adjusted, then the data for a year were summed and divided by 4 in order to obtain annual data. If the quarterly data were not seasonally adjusted, then they were simply summed in order to obtain annual data. In what follows, we will use the CANSIM individual series label to identify the exact series used.

The first two series are Personal Expenditures on Goods and Services in current and constant chained 2002 dollars, CANSIM Series V498087 and V1992044 respectively. Dividing the current dollar series V_{CT} by the constant dollar series Q_{CT} gives us an implicit price series P_{CT} for (total) personal consumption.

We would like to exclude the imputed expenditures on Owner Occupied Housing (OOH) from the above series since there is no possibility of productivity gains occurring in this sector. However, if we exclude imputed rent from the business sector output series, we also need to exclude the services of the owner occupied housing capital stock as an input into the business sector. Unfortunately, we are not able to construct a reliable measure of the Owner Occupied Housing capital stock from available data; we can only construct a more reliable residential housing capital stock which includes the housing capital stock that is rented. We also were not able to split residential land input into reliable owner occupied and rental components.[10] Hence we excluded both imputed and paid rents from our list of business sector outputs and we excluded the entire residential housing stock and the associated land as an inputs into the business sector.[11] Information on current dollar expenditures on imputed rents and paid rents ($V_{IMR}{}^t$ and $V_{PR}{}^t$) for the years 1961-2011 is available from CANSIM Series V498532 and

[10] The determination of the structures and land inputs into the production of rented residential housing is a difficult task since the investment data on residential housing is not decomposed into owned and rented investments. This lack of information was also a problem for the Statistics Canada KLEMS program: "Data on investment in rental residential buildings are not available. For the annual MFP programs, we divide the total investment in residential building into rental building and owner-occupied dwelling using paid rents for rental buildings and imputed rents for owner occupied dwelling as the split ratios. The investment in residential buildings and paid and imputed rents are available from the Income and Expenditure Accounts. On average, we find that about 30 per cent of total rents are paid rents and the remaining 70 per cent are imputed rents." Baldwin, Gu and Yan (2007: 43).

[11] This means our productivity estimates will be biased downward slightly since the labour inputs that are used in the rental housing market are incorrectly included in our estimates of labour input.

V498533 respectively. The corresponding information on chained 2002 constant dollar expenditures on imputed rents and paid rents (Q_{IMR} and Q_{PR}) is available from CANSIM Series V1992078 and V1992079 only for the years 1981-2011. We divide V_{IMR} by Q_{IMR} and V_{PR} by Q_{PR} in order to form price index series for imputed and paid rents, P_{IMR} and P_{PR} for the years 1981-2011.

From the Input-Output accounts, we can obtain alternative estimates for the value of imputed rents for owner occupied dwellings, V_{OOH}^t, for the years 1961-2008 from CANSIM Series V3859926. We can also obtain alternative series for the value of imputed rents for owner occupied dwellings, V_{OOH1}^t, from CANSIM Series V334072 and we can obtain the corresponding constant 1992 dollar estimates Q_{OOH1}^t from CANSIM Series V328857 for the years 1961-1997. We used these two series to form a price series for owner occupied housing rents, P_{OOH}^t, for the years 1961-1997. We divided the earlier more accurate value series V_{OOH} by P_{OOH} to form Q_{OOH} for the years 1961-1997. The Q_{OOH} series was extended from 1997 to 2006 using CANSIM Series V14183160 from CANSIM Table 3790018 which had estimates in chained 1997 dollars for owner occupied housing. The Q_{OOH} series was further extended from 2006 to 2011 using the chained 2002 dollar estimates from Series V41881435 using CANSIM Table 3790027. Using this Q_{OOH} series, we were able to construct the implicit price index for imputed owner occupied housing rents, P_{OOH}, for 1961-2008 by dividing V_{OOH} by Q_{OOH}. P_{OOH} was extended to cover the years 2009-2011 by using the movements in P_{IMR}. Finally, V_{OOH} was extended to cover the years 2009-2011 by multiplying together P_{OOH}^t times Q_{OOH}^t. We decided to use the industry oriented V_{OOH}^t series rather than the final demand oriented series V_{IMR}^t so that our business sector output concept would better align with the Statistics Canada KLEMS output aggregate.

Recall that we had a paid rent value series V_{PR}^t that covered the years 1961-2011 but the corresponding price series P_{PR}^t covered only the years 1981-2011. We linked P_{PR} to P_{OOH}^t at 1981 to obtain continuous price series for paid rents for the years 1961-2011.[12] The resulting imputed and paid rent series are listed in Table 1 below.

Recall the price and quantity series, P_{CT} and Q_{CT}, for a consumption aggregate (which includes all rents, paid and imputed) along with the two price and quantity series for imputed and paid rents in Table 1 (all tables are found at the end of the Appendix). We changed the sign of the rent quantity series from plus to minus and then calculated a chained Fisher net consumption aggregate by aggregating all consumption (plus sign for these quantities) and rents (negative signs for these quantities). The resulting price and quantity series should closely approximate the price and quantity of consumption excluding housing services. However, the price series includes indirect taxes (less subsidies) on outputs but for productivity measurement purposes, as mentioned earlier, these tax wedges should be excluded. Statistics Canada has a series for indirect taxes less subsidies on products V_{IT}^t, CANSIM II series V1997473, for the years 1961-2011. We subtracted two other tax series from this indirect tax series because these other tax series will be taken into account separately in the price of exports of goods (this is the Oil Export Tax series, CANSIM series V499746) and in the price of imports of goods (this is the Customs Import Duties series, CANSIM series V499741). The resulting indirect taxes less subsidies on

[12] Thus we are assuming that the price movements in paid rents for the years 1961-1981 followed the movements in imputed rents for those years.

products (less trade taxes) series was used to remove the tax wedges on the price of consumption series. The resulting prices and quantities of consumption, P_C^t and Q_C^t, are listed in Tables 2 and 3.

We turn our attention to the investment components of final demand. Current dollar government gross fixed capital formation is available as CANSIM series V498093 for the years 1961-2011. The corresponding chained 2002 dollar series is CANSIM II series V1992050 and we use these two series to form price and quantity series for general government sector investment, P_{IG}^t and Q_{IG}^t, which are listed in Tables 2 and 3 below.[13]

The current and constant chained dollar series for the years 1961-2011 for residential structures investment can be obtained as CANSIM series V498096 and V1992053 respectively, the current and constant 2002 chained dollar series for nonresidential structures investment can be obtained as CANSIM series V498098 and V1992053 respectively and the current and constant chained dollar series for machinery and equipment investment can be obtained as CANSIM series V498099 and V1992056 respectively. The resulting price and quantity series are denoted by P_{IR}^t, P_{IN}^t, Q_{IR}^t, Q_{IN}^t and are listed in Tables 2 and 3 below. These Tables also include the price and quantity of inventory change, P_{II}^t and Q_{II}^t, the price and quantity of business sector net deliveries to the non-business sector, P_{GN}^t and Q_{QN}^t, the export and import price indexes P_X^t and P_M^t and the corresponding quantity indexes Q_X^t and Q_M^t but the description of how these series were constructed is deferred until later.

With the exceptions of Q_{GN} and Q_M, all of the quantities listed in Table 3 can be regarded as outputs produced by the business sector and sold to final demanders. However, the business sector also sells goods and services to the non-business sector and it also purchases smaller amounts of goods and services from the non-business sector. We now describe how we formed price and quantity estimates for the net sales of the business sector to the non-business sector, Q_{GN}.

For the years 1961-2011 from the National Income and Expenditure Accounts, CANSIM II series V498092; Government Current Expenditure on Goods and Services, Table 3800002, we have estimates of total government gross current expenditures on goods and services (less sales of goods and services to the business sector) in current dollars. From the same Table and for the same years, CANSIM II series V1992049; Government Current Expenditure on Goods and Services, Table 3800002, we have estimates of total government gross current expenditure on goods and services (less sales of goods and services to the business sector) in chained 2002 dollars. We use these two series to form price and quantity series for final demand government sector net expenditures on goods and services, P_G^t and Q_G^t, which are listed in Table 4.

Recall that the Statistics Canada KLEMS productivity program business sector value added aggregate *includes* rental residential housing but *excludes* the services of owned residential housing (whereas our business sector value added aggregate *excludes* all forms of residential rents). The Industry Division of Statistics Canada produces yet another business sector estimate

[13] The price series for investment should be adjusted for indirect taxes that fall on investment outputs. Since these taxes are relatively small and it is difficult to collect consistent information on these taxes over our sample period, we neglect these indirect tax wedges on investment components of final expenditure.

of nominal and real value added (at factor cost) which *includes* all residential rents, both imputed and paid. We will denote this value added aggregate by $V_B{}^t$ in year t. Statistics Canada also produces a companion non-business sector value added aggregate (at factor cost) which we will denote by $V_N{}^t$ in year t. If the value of indirect taxes less subsidies on products for year t, $V_{IT}{}^t$, is added to the sum of these two industry value added aggregates, we get an estimate of the value of GDP at final demand prices in year t; i.e., we have the following identity:

(1) $V_B{}^t + V_N{}^t + V_{IT}{}^t = V_{GDP}{}^t$.

We will now describe how we formed estimates for $V_B{}^t$ and $V_N{}^t$ along with the corresponding price and quantity decompositions. From Table 3790024, Gross Domestic Product (GDP) at Basic Prices in Current Dollars, SNA, Benchmark Values, Special Industry Aggregations Based on the North American Industry Classification System (NAICS), we can obtain the $V_B{}^t$ series (series title is Canada: Business Sector Industries) for the years 1961-2008 from CANSIM II Series V3860037. From the same Table 3790024, we can obtain the $V_N{}^t$ series (series title is Canada: Non-Business Sector Industries) for the years 1961-2008 from CANSIM II Series V3860040. We can obtain price indexes $P_B{}^t$, $P_N{}^t$ and quantity indexes $Q_B{}^t$, $Q_N{}^t$ for $V_B{}^t$ and $V_N{}^t$ for the years 1961-1997 by using the series V334562, V335071, V334565 and V335074 from CANSIM Table 3790002, Gross Domestic Product (GDP) at Factor Cost, System of National Accounts Benchmark Values by Industry (Special Aggregations).

These series give business and non-business sector value added at basic prices in current dollars and in constant 1992 dollars. Using CANSIM Table 3790020, we can find estimates for $Q_B{}^t$ (Series V14182646) and for $Q_N{}^t$ (Series V14182651) in chained 1997 dollars for the years 1997-2006. The Q_B series can be extended to 2011 by aggregating the monthly data in CANSIM Table 3790027, Series V41881176, which has the title: Gross Domestic Product at Basic Prices, by North American Industry Classification System, Canada, Seasonally Adjusted at Annual Rates, Chained 2002 Dollars, Business Sector Industries. The Q_N series can be extended to 2011 by aggregating the monthly data in CANSIM Table 3790027, Series V41881179. Thus we now have enough information to define the $P_B{}^t$ and $P_N{}^t$ series through to 2008. We extend the price series $P_N{}^t$ from 2008 using an implicit price index for government goods and services, $P_G{}^t$, which was constructed using CANSIM Table 3800002, Series V498092 in current dollars and Series V1992049 for chained 2002 dollars, $Q_G{}^t$, which are listed in Table 4. It turns out that the total of $V_B{}^t$ and $V_N{}^t$ is available in CANSIM Series V3860274. Canada, Gross Domestic Product (GDP) at Basic Prices in Table 3800030: GDP and GNP at Market Prices and Net National Income at Basic Prices. Thus we have enough information to deduce the price $P_B{}^t$ and the value of business sector output $V_B{}^t$ for the years 2009-2011.The business and nonbusiness sector price and quantity series, $P_B{}^t$, $P_N{}^t$ and $Q_B{}^t$, $Q_N{}^t$ are listed in Table 4 below.

Recall the GDP identity defined by (1) above, which expressed the nominal value of GDP, $V_{GDP}{}^t$, at final demand prices as being equal to the value added of the Industry Division business sector value added at basic prices, $V_B{}^t$, plus non-business sector value added, $V_N{}^t$, plus the value of indirect taxes less subsidies on products, $V_{IT}{}^t$. We can also express the value of GDP at final demand prices as the familiar sum of final demand values; i.e. as the following sum of final demand expenditures on consumption plus investment plus government expenditures on goods and services plus exports less imports:

(2) $V_{GDP}^t = V_{CT}^t + V_I^t + V_G^t + V_X^t - V_M^t$.

Define a new consumption aggregate at basic prices V_{CN}^t as the value of consumption at final demand prices, V_{CT}^t, less indirect taxes less subsidies on products, V_{IT}^t:

(3) $V_{CN}^t \equiv V_{CT}^t - V_{IT}^t$.

Now equate the two expressions for the value of GDP given by (1) and (2) and use the resulting equation to express business sector value added V_B^t in terms of final demand components and the value of non-business sector value added V_N^t. Making use of (3), the resulting equation is the following one:[14]

(4) $V_B^t = V_{CN}^t + V_I^t + V_X^t - V_M^t + (V_G^t - V_N^t)$.

Conceptually, the aggregate $V_G^t - V_N^t$ should be equal to the sales of the business sector of goods and services to the non-business sector less the purchases of intermediate inputs of the business sector from the non-business sector. Put another way, the business sector's net sales of goods and services should equal its net deliveries to final demand sectors ($V_C^t + V_I^t + V_X^t - V_M^t$) plus its net deliveries to the non-business sector ($V_G^t - V_N^t$).

Recall that we did not use the Industry Division's concept of business sector value added; we subtracted the value of imputed and paid residential rent from our business sector aggregate. Let V_R^t be equal to the sum of imputed residential rent V_{OOH}^t and paid residential rent V_{PR}^t (see Table 1 for these series). Conceptually, if we subtract rents V_R^t from V_{CN}^t, we should obtain V_C^t, the consumption aggregate whose price and quantity is listed in Tables 2 and 3. Thus subtracting V_R^t from both sides of (4) leads to the following identity:

(5) $V_B^t - V_R^t = V_C^t + V_I^t + V_X^t - V_M^t + (V_G^t - V_N^t)$.

Thus our business sector value added aggregate can be formed using either the left or right hand sides of the identity (5). We will use the right hand side of (5) to form our value measure of business sector net output since we want to focus on the effects of changing international prices on the performance of the business sector.

How should the corresponding real quantities that correspond to the value aggregates on either side of (5) be calculated? Obviously, each cell in the supply and use tables that correspond to the value aggregate on the left hand side of (5) could be aggregated up using a chained superlative

[14] The identity (4) is not quite consistent with our treatment of indirect taxes less subsidies since we also made some indirect tax adjustments to the prices of exports and imports as explained above; i.e., since we used a slight modification of (3) to adjust final demand consumption prices for indirect tax wedges, we used a corresponding slight modification of the identity (4).

index number formula provided that an appropriate price deflator were available for each cell.[15] On the other hand, the value cells that are components on the right hand side of (5) that correspond to final demand components (at basic prices) could be aggregated up using a chained superlative index number formula. We can then ask: under what conditions would the corresponding quantity aggregates be equal? This question is addressed by Moyer, Reinsdorf and Yuskavage (2006) and in more detail by Diewert (2005c and 2006). The answer to this question is that if the detailed data are constructed in an appropriate manner and the Fisher formula is used, then the direct industry aggregation and the aggregation of final demand component approaches are perfectly consistent.[16] In addition, if two stage aggregation procedures are used and a superlative index number formula is used at each stage of aggregation, then the theoretical and empirical results in Diewert (1978) show that the commonly used single stage superlative indexes will approximate their two or more stage counterparts to a high degree of approximation if the chain principle is used.[17]

Using the above results, we will construct our measure of business sector real value added by aggregating up the value components on the right hand side of (5). Rather than work with both V_G^t and V_N^t as final demand components, we will aggregate over these two components to form the value aggregate V_{GN}^t equal to $(V_G^t - V_N^t)$, and conceptually, this value aggregate should be equal to the net deliveries of goods and services of our business sector to the non-business sector less the purchases of intermediate inputs by our business sector from the non-business sector. The year t price and quantity aggregates, P_{GN}^t and Q_{GN}^t, that correspond to these value aggregates V_{GN}^t are calculated using chained Fisher indexes with Q_N^t getting a negative weight in the index number formula. P_{GN}^t and Q_{GN}^t are listed in Table 4.

We now turn our attention to the export and import components of final demand. Current dollar exports of goods are available as CANSIM Series V498104 for the years 1961-2011. The corresponding chained 2002 dollar series is CANSIM Series V1992061 and these two series could be used to form price and quantity series for the exports of goods. However, in this study, we will form series for more detailed components of the exports and imports of goods. Current dollar exports of services are available as CANSIM Series V498105 for the years 1961-2011. The corresponding chained 2002 dollar series is CANSIM Series V1992062 and we use these two series to form price and quantity series for the exports of services, P_{15}^t and Q_{15}^t, which are listed in Tables 5 and 6.

Our starting point for obtaining disaggregated data on the exports and imports of goods is CANSIM Table 3800012, Exports and Imports of Goods and Services, Canada, Current Prices. It is possible to obtain disaggregated information on the value of exports for the following 7 classes for the years 1971-2011:

- Q_8: Exports of agricultural and fish products;

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[15] Quantities in the Make matrix would have a positive sign while quantities in the Use matrix would have a negative sign.
[16] See Diewert (2005c and 2006) and the numerical examples in Chapters 19 and 20 in IMF, ILO, OECD, Eurostat, UNECE and the World Bank (2004 and 2009).
[17] The results of Hill (2006) show that these approximation results will not necessarily hold for mean of order r superlative indexes if r is large in magnitude.

- Q_9: Exports of energy products;
- Q_{10}: Exports of forest products;
- Q_{11}: Exports of industrial goods and materials (excluding energy and forest product exports);
- Q_{12}: Exports of machinery and equipment (excluding automotive products);
- Q_{13}: Exports of automotive products;
- Q_{14}: Exports of other consumer goods (excluding automotive products);

The CANSIM Series numbers for the first 7 classes of exports are V498730-V498736. It is also possible to find corresponding constant dollar series in 1992 constant dollars over the period 1971-1997 in CANSIM Table 3800012 and the CANSIM Series numbers are V498767-V498773. Finally, constant dollar chained estimates for these export categories (in 2002 chained dollars) can be found for the years 1981-2011 in CANSIM Table 3800012 and the Series numbers are V1992162- V1992168. We used these series to form chained price and quantity series for these 7 export categories for the years 1981-2011. The constant dollar price series were linked to each chained price series at the year 1981 in order to extend the chained series back to 1971.[18]

There remains the problem of obtaining price series for the above 7 classes of exports to cover the years 1961-1971. From Leacy (1983), Series G415-428 Foreign trade, domestic exports, excluding coin and bullion, by main commodity sections, current values, we can obtain value series covering exports for the years 1946-1975 for the following 5 commodity classes:

- Live animals (G415);
- Food, feed, beverages and tobacco (G417);
- Crude materials (inedible) (G419);
- Fabricated materials (inedible) (G421);
- End products (inedible) (G423).

From the same source, price indexes for each of the above 5 classes of exports are available as Series K57-K61 in the Table with the title: Export price indexes, trade of Canada commodity classification, 1926-1975. Thus we can find price and quantity series for these 5 classes of exports that cover the years 1961-1971. Unfortunately, these price indexes are of the fixed base variety with a base year of 1948 so they are likely to differ substantially from the corresponding chain indexes (which are not publicly available). However, Leacy (1983) also lists as part of export price Series K57-K61 (Panel A) for the above 5 classes of exports some indexes that have a 1971 base year but these price indexes cover only the years 1968-1975. We use these latter price indexes to construct export price indexes for the years 1968-1971 and then we use the 1948 based indexes to further extend these 5 series back to 1961.

The above operations give us 5 disaggregated export price and quantity series for the period 1961-1971 but we have 7 classes of exports of goods for the years 1971-2011. We generated Fisher chained price and quantity indexes for exports of Live animals and for exports of Food,

[18] There were two other categories in the export and import classifications: Special transactions and Other balance of payments adjustments. These categories were small and were omitted in our analysis.

feed, beverages and tobacco for the years 1961-1971 and linked these series to our earlier series, P_8 and Q_8, exports of agricultural and fish products. But we need some additional series so that we can match the export and import series for the 1960s to the series that cover the post 1971 period. We will create separate export series for energy, forest products, automotive products and other consumer goods. Our sources for these extra series are the input output tables for the Canadian economy that cover the years 1961-1981 (Statistics Canada, 1987a and 1987b).

In order to create a price and quantity series for aggregate Energy exports for the years 1961-1971, we aggregated data for 6 classes of energy exports using the M level of aggregation: Coal, Crude mineral oils, Natural gas, Gasoline and fuel oil, Other petroleum and coal products and Electric power. These components were aggregated using Fisher (1922) chained indexes. The resulting price and quantity series were linked to our earlier price and quantity series, P_9 and Q_9, for energy at the year 1971.

In order to create aggregate Forestry exports for the years 1961-1971, we aggregated data for 7 classes of forest product exports using the M level of aggregation: Lumber and timber, Veneer and plywood, Other wood fabricated materials, Furniture and fixtures, Pulp, Newsprint and other paper stock, and Paper products. These components were aggregated using Fisher (1922) chained indexes. The resulting price and quantity series were linked to our earlier price and quantity series, P_{10} and Q_{10}, for forest product exports at the year 1971.

We aggregated the input output data for 2 classes of automotive product exports using the M level of aggregation: Motor vehicles and Motor vehicle parts. These components were aggregated using Fisher (1922) chained indexes. The resulting price and quantity series were linked to our earlier price and quantity series, P_{13} and Q_{13}, for automotive product exports at the year 1971.

In order to create an aggregate for Exports of other consumer goods (excluding automotive products) for the years 1961-1971, we aggregated data for 8 classes of consumer goods type exports using the M level of aggregation: Leather and leather products, Other textile products, Hosiery and knitted wear, clothing and accessories, appliances and receivers (households), Pharmaceuticals, Other chemical products and Other manufactured products. These components were aggregated using Fisher (1922) chained indexes. The resulting price and quantity series were linked to our earlier price and quantity series, P_{14} and Q_{14}, for exports of other consumer goods at the year 1971.

We generate price and quantity series over the years 1961-1971 for Exports of industrial goods and materials (excluding energy and forest product exports), P_{11} and Q_{11}, as a chained Fisher aggregate of our price and quantity series for Crude materials (inedible) (G419) and Fabricated materials (inedible) (G421) less our series for Exports of energy products P_9 and Q_9) and Exports of forest products (P_{10} and Q_{10}).[19] The resulting export price and quantity series for the years 1961-1971 are linked to our earlier series for P_{11} and Q_{11} at the year 1971.

[19] All four prices are entered as positive numbers in the index number formula while the first two quantities are entered positively and the last two quantities are entered negatively.

Finally, we generate price and quantity series over the years 1961-1971 for Exports of machinery and equipment (excluding automotive products), P_{12} and Q_{12}, as a chained Fisher aggregate of our price and quantity series for Exports of end products (inedible) (G423) less our series for Exports of automotive products P_{13} and Q_{13}) and less Exports of other consumer goods (P_{14} and Q_{14}).[20] The resulting export price and quantity series for the years 1961-1971 are linked to our earlier series for P_{12} and Q_{12} at the year 1971.

There is one additional adjustment which affects the price of energy exports. During the years 1974-1985, Canada imposed an export tax on its energy exports, which is included in the price of exports. However, producers do not receive this export tax revenue and so it must be subtracted from the export price. This adjustment of the export price index for exports of goods can be accomplished using the Oil Export Tax series, CANSIM Series V499746 from the National Income and Expenditure Accounts. After making this adjustment, the resulting price and quantity series are P_9^t and Q_9^t, which are listed in Tables 5 and 6 along with the other price and quantity series for the 8 classes of exports. Aggregate price and quantity indexes for exports, P_X^t and Q_X^t, were formed as chained Fisher aggregates of the 8 classes of exports listed in Tables 5 and 6 and the resulting P_X^t and Q_X^t are listed in Tables 2 and 3.

We now turn our attention to imports.

Current dollar information on imports of services can be found as CANSIM Series V498108 for the years 1961-2011 and the corresponding constant 2002 chained dollar series is CANSIM Series V1992065. We use these two series to form price and quantity series for the imports of services, P_{22}^t and Q_{22}^t, which are listed in Tables 7 and 8. Note that since imported goods and services are inputs into the business sector, when we form a value added aggregate, we need to append a minus sign to any quantity series pertaining to imports.

As was the case for our treatment of exports, the starting point for obtaining disaggregated data on imports of goods is CANSIM Table 3800012, Exports and Imports of Goods and Services, Canada, Current Prices. Using this Table, it is possible to obtain disaggregated information on the value of imports for the same 7 classes of imported good that was used for exports for the years 1971-2011. However, imports of forest products was small throughout the sample period and so this import component was aggregated with imports of industrial goods and materials (excluding forest and energy imports).[21] Thus we used CANSIM Table 38000012 in order to generate prices and quantities for the following 7 classes of imports for the years 1971-2011:[22]

- Q_{16}: Imports of agricultural and fish products;
- Q_{17}: Imports of energy products;
- Q_{18}: Imports of industrial goods and materials (including imports of forest products but excluding imports of energy products);
- Q_{19}: Imports of machinery and equipment (excluding automotive products);
- Q_{20}: Imports of automotive products;

[20] All three prices are entered as positive numbers in the index number formula while the first quantity is indexed with a positive sign and the last two quantities are indexed with negative signs.
[21] Chained Fisher indexes were used in order to do the aggregation.
[22] As in the case of export indexes, we used chained indexes whenever they were available.

- Q_{21}: Imports of other consumer goods and
- Q_{22}: Imports of services.

There remains the problem of obtaining price series for the above 6 classes of imports to cover the years 1961-1971. From Leacy (1983), Series G429-442: Foreign trade, imports, excluding coin and bullion, by main commodity sections, current values, 1946-1975, millions of dollars (all countries), we can obtain value series covering imports for the years 1946-1975 for the following 5 commodity classes:

- Live animals (G429);
- Food, feed, beverages and tobacco (G431);
- Crude materials (inedible) (G433);
- Fabricated materials (inedible) (G435);
- End products (inedible) (G437).

From the same source, price indexes for each of the above 5 classes of imports are available as Series K62-K67 in the Table with the title: Import price indexes, trade of Canada commodity classification, 1926-1975. Thus we can find price and quantity series for these 5 classes of exports that cover the years 1961-1971. Unfortunately, these price indexes are of the fixed base variety with a base year of 1948 so they are likely to differ substantially from the corresponding chain indexes. However, as was the case for export price indexes, Leacy (1983) also lists as part of import price Series K62-K67 (Panel A) for the above 5 classes of imports counterpart indexes that have a 1971 base year but these price indexes cover only the years 1968-1975. We used these latter price indexes to construct import price indexes for the years 1968-1971 and then we used the 1948 based indexes to further extend these 5 series back to 1961.

The above operations give us 5 disaggregated export price and quantity series for the period 1961-1971 but we have 6 classes of imports of goods for the years 1971-2011. We generated Fisher chained price and quantity indexes for imports of Live animals and for exports of Food, feed, beverages and tobacco for the years 1961-1971 and linked these series to our earlier series, P_{16} and Q_{16}, imports of agricultural and fish products. As was the case for extending our export series back to the 1960s, we need some additional series so that we can match the import series for the 1960s to the series that cover the post 1971 period. We created separate import series for energy, automotive products and other consumer goods using the input output tables for the Canadian economy that cover the years 1961-1981 (Statistics Canada, 1987a and 1987b). The rest of our import series computations paralleled our export series computations, except that we did not generate a separate series for forest product imports due to their small size throughout the sample period.

The price of imports does not include import duties that are added to the international cost of these imported goods. Hence we must add these import duties to the price of imports. We assumed that energy, automotive and service imports were exempt from import duties and we assumed a uniform rate for the remaining import categories.[23] The series on customs import duties is CANSIM Series V499741 and after adjusting the price of imports using this series, the resulting price and quantity series for the imports of goods and services are listed in Tables 7 and

[23] This is only a very rough approximation to the "truth".

8 below. Aggregate price and quantity indexes for imports, P_M^t and Q_M^t, were formed as chained Fisher aggregates of the 7 classes of imports listed in Tables 7 and 8 and the resulting P_M^t and Q_M^t are listed in Tables 2 and 3 above.

We turn our attention to forming estimates of business sector labour input.

Business Sector Labour Input Estimates

Statistics Canada has constructed detailed labour input data for the Canadian business sector for 36 types of labour for the years 1961-2010 in CANSIM Table 3830024 which we will make use of in this study. Labour input is classified according to a four way classification:

- By *education level* E. There are 3 categories in this classification: E=1 corresponds to Primary or Secondary Education; E=2 corresponds to Some or Completed Non-University Post-Secondary Education and E=3 corresponds to University Degrees or Above.

- By *age of worker* A. There are 3 categories in this classification: A=1 corresponds to 15-34 years old; A=2 corresponds to 35-54 years old and A=3 corresponds to 55 years old and over.

- By *sex* S. There are 2 categories in this classification: S=1 corresponds to a male worker and S=2 corresponds to a female worker.

- By *type of employment* T. There are 2 categories in this classification: T=1 corresponds to a paid worker and T=2 corresponds to a self employed worker.

Thus Table 3830024 provides annual hours and total compensation data for 3x3x2x2 or 36 types of worker in the Canadian business sector for the years 1961-2010. We aggregated over the age groups using Fisher chained indexes in order to form 12 price and quantity series for labour, P_{L1}-P_{L12} and Q_{L1}-Q_{L12}. These series are listed below in Tables 9 and 10. The characteristics of the 12 types of labour are as follows:

- Q_{L1} : E=1; S=1; T=1;
- Q_{L2} : E=1; S=2; T=1;
- Q_{L3} : E=1; S=1; T=2;
- Q_{L4} : E=1; S=2; T=2;
- Q_{L5} : E=2; S=1; T=1;
- Q_{L6} : E=2; S=2; T=1;
- Q_{L7} : E=2; S=1; T=2;
- Q_{L8} : E=2; S=2; T=2;
- Q_{L9} : E=3; S=1; T=1;
- Q_{L10} : E=3; S=2; T=1;
- Q_{L11} : E=3; S=1; T=2;
- Q_{L12} : E=3; S=2; T=2.

We have not explained how our estimates for the 12 types of labour input were constructed for 2011. From CANSIM Table 2820022, it is possible to estimate the total employment for the business sector for the years 2010 and 2011 by 4 types of labour: by employees and the self employed and by sex. From Table 3830010 and Series V15901071, the annual number of hours worked in the business sector over all jobs dropped from 1702 in 2010 to 1700 in 2011 so it appears that hours of work did not change much over the two years. Thus we estimated Q_{L1}^{2011}, Q_{L5}^{2011} and Q_{L9}^{2011} by the growth in employment of male business sector employees from 2010 to 2011, Q_{L2}^{2011}, Q_{L6}^{2011} and Q_{L10}^{2011} by the growth in employment of female business sector employees from 2010 to 2011, Q_{L3}^{2011}, Q_{L7}^{2011} and Q_{L11}^{2011} by the growth in male self employment from 2010 to 2011 and we estimated Q_{L4}^{2011}, Q_{L8}^{2011} and Q_{L12}^{2011} by the growth in female self employment from 2010 to 2011.

Our estimates for the prices of the 12 types of labour for 2011 were constructed in a very approximate manner. Define V_{Ln}^{2010} as $P_{Ln}^{2010}\times Q_{Ln}^{2010}$ for n = 1,...,12. Estimates for aggregate employee wages and salaries and supplementary labour income from business are available in CANSIM Table 3800004, Series V498167. We used the ratio of the 2011 entry for this series to the 2011 series *times* V_{Ln}^{2010} to form estimates for V_{Ln}^{2011} for n = 1,2,5,6,9,10. From CANSIM Table 3800004, Series V498170, we obtained estimates for unincorporated business net income for 2010 and 2011. We used the ratio of the 2011 entry for this series to the 2010 series *times* V_{Ln}^{2010} to form estimates for V_{Ln}^{2011} for n = 2,3,7,8,11,12. Finally, we defined $P_{Ln}^{2011} \equiv V_{Ln}^{2011}/Q_{Ln}^{2011}$ for n = 1,...,12.

The 12 labour price and quantity series listed in Tables 9 and 10 can be regarded as quality adjusted labour input series for the Canadian business sector. It should be noted that the KLEMS program has provided data for 3 types of quality adjusted labour; see CANSIM Table 3830021, Series V41713187, V41713204 and V41713221 for values for the years 1961-2008 and Series V41713000, V41713017 and V41713034 for the corresponding quantity indexes for the years 1961-2011.[24] The quantity series have the following titles: Canada: Labour Input of Workers with Primary or Secondary Education; Business Sector, Labour Input of workers with Some or Completed Post-Secondary Certificate or Diploma; Business Sector and Labour Input of Workers with University Degree or Above, Business Sector. When we aggregated our 12 types of labour input into the 3 categories used by the KLEMS program, we found that our value aggregates were very close to the corresponding KLEMS value aggregates for the 3 types of labour. However, our aggregated (Fisher chained) indexes of the 3 types of labour grew more slowly than the corresponding KLEMS 3 labour quantity indexes.[25]

[24] It is not apparent to us why the KLEMS program posts quantity data for the years 1961-2011 but only posts the corresponding value data for the years 1961-2008.

[25] The differences between the 3 KLEMS labour quantity indexes and our counterpart indexes are substantial. The KLEMS program probably uses the same data base but on a more disaggregated basis that takes into account work experience; i.e., the KLEMS program distinguishes 56 types of labour whereas our data base distinguishes on 36 types of labour. The KLEMS method for aggregating over sectors may also be different. We prefer to use our labour estimates rather than the KLEMS estimates for two reasons: (i) the data base that we use is published (by Statistics Canada) and is readily available for researchers to check and (ii) the experience variable is a difficult one to quantify in a reproducible way.

The Statistics Canada productivity program aggregate labour input measure is described as follows:

"The labour input is an aggregate of the hours worked of all persons classified by their education, work experience and class of employment (paid versus self-employed workers). This aggregate labour input measure is constructed by aggregating hours at work data for each of 56 types of workers classified by their educational attainment (4), work experience (7) and class of workers (2) using an annual chained-Fisher index. The effect of Fisher aggregation is to produce a measure of labour input that reflects both changes in total hours of work and changes in the composition of workers." John R. Baldwin, Wulong Gu and Beiling Yan (2007: 37).

Baldwin, Gu and Yan (2007: 26) describe their more disaggregated measures of labour input as follows:

"Labour input for MFP measures reflects the compositional shifts of workers by education, experience and class of workers (paid versus self-employed). The growth of labour input (labour services) is an aggregate of the growth of hours worked by different classes of workers, weighted by the hourly wages of each class."

Thus each of the three types of labour classified by educational attainment Q_{L1}^t, Q_{L2}^t and Q_{L3}^t is a Fisher quantity aggregate over the other characteristics, holding constant the relevant educational levels. Baldwin, Gu and Yan (2007: 26) also comment on the difficulties associated with breaking up the net operating surplus generated by the self employed into labour and capital compensation components:

"We have modified the assumptions about the share of labour going to the self-employed workers to reflect changes that occurred during the 1990s. In the past, it had been assumed that the self-employed essentially earned incomes similar to the employed. The Census of Population up to 1990 showed that this was a reasonable assumption; however, during the 1990s, self-employed income fell behind that of production workers. The new measure of self-employed for calculating labour input assumes that the hourly earnings of self-employed workers is proportional to that of paid workers with the same level of education and experience. The proportional or scaling factor for each level of education and experience is based on the relative hourly earnings of paid versus self-employed workers derived from the Census of Population."

We now turn our attention to the problems associated with the estimation of beginning of the year capital stocks for the business sector.

Business Sector Capital Stock Estimates

Our main source of information on beginning of the period capital stocks used by the Canadian business sector is CANSIM Table 310003, which has the title: Flows and stocks of fixed non-residential capital, by sector of North American Industry Classification System (NAICS) and asset, Canada, annually. This Table has a wealth of information on the reproducible capital stocks used by the business sector along with the corresponding annual investment and depreciation information by type of asset and by sector. This source of information on reproducible assets will be supplemented by the use of estimates from the Statistics Canada National Balance Sheets to obtain estimates of inventory and land stocks used by the business sector; see Statistics Canada (1997).

Table 310003 has estimates of current V_{In}^t and chained dollar Q_{In}^t business sector investment in the following 14 types of reproducible asset:

- Q_{I1}: Office furniture;
- Q_{I2} : Agricultural machinery;
- Q_{I3} : Industrial machinery;
- Q_{I4} : Automobiles;
- Q_{I5} : Trucks;
- Q_{I6} : Other transport equipment;
- Q_{I7} : Other machinery and equipment;
- Q_{I8} : Computers;
- Q_{I9} : Telecommunications equipment;
- Q_{I10} : Software;
- Q_{I11} : Industrial buildings;
- Q_{I12} : Commercial buildings;
- Q_{I13} : Institutional buildings;
- Q_{I14} : Engineering construction.

The annual current dollar investment that was used by the business sector for the years 1961-2011 for the above 14 assets, V_{In}^{t} for n = 1,...,14 can be found in CANSIM Table 310003. The Series numbers are: V43985602, V43985603, V43985604, V43985607, V43985608, V43985609, V43985611, V43985606, V43985610, V43985612,[26] V43985613, V43985614, V43985615 and V43985616. The corresponding chained 2002 dollar series, Q_{In}^{t}, can also be found in Table 310003. The Series numbers are: V43993266, V43993267, V43993268, V43993271, V43993272, V43993273, V43993275, V43993270, V43993274, V43993276, V43993277, V43993278, V43993279 and V43993280. Implicit price indexes P_{In}^{t} for the 14 types of investment can be obtained by dividing the current dollar series by the corresponding chained dollar series; i.e., define P_{In}^{t} as follows:[27]

$$(6)\quad P_{In}^{t} \equiv V_{In}^{t}/Q_{In}^{t}\ ; \qquad\qquad n = 1,...,14;\ t = 1961,....,2011.$$

CANSIM Table 31003 also has chained 2002 dollar information on year end capital stocks for the Canadian business sector constructed using geometric depreciation rates for each of the above asset classes. We use these year-end stocks as beginning of the next year capital stocks by asset class and denote these year t starting stocks as Q_{Kn}^{t} for n = 1,...,14 and t = 1962-2012. The Series numbers for these 14 stocks are as follows: V43993448, V43993449, V43993450, V43993453, V43993454, V43993455, V43993457, V43993452, V43993456, V43993458, V43993459, V43993460, V43993461 and V43993462.

Define the amount of depreciation for asset n in year t by Q_{Dn}^{t}. Using the geometric model of depreciation, the beginning of year t+1 capital stock for asset n, Q_{Kn}^{t+1}, should be related to the

[26] The software investment series (V_{I10}^{t} and Q_{I10}^{t}) start in 1981 and the corresponding beginning of the year capital stock series (Q_{K10}^{t}) starts in 1982.

[27] For n = 10 (software), t starts at 1981. After we estimate depreciation rates for the 14 classes of asset, the prices defined by (6) were normalized to equal 1 in 1961 (except the software price was normalized to equal 1 in 1981) and the units for the Q_{In}^{t} were adjusted accordingly. The price of software investment was artificially set equal to 1 for the years 1961-1980.

corresponding beginning of year t capital stock, $Q_{Kn}{}^{t}$, plus year t investment, $Q_{In}{}^{t}$, less year t depreciation, $Q_{Dn}{}^{t}$; i.e., the following equations should hold:

$$(7)\ Q_{Kn}{}^{t+1} = Q_{Kn}{}^{t} + Q_{In}{}^{t} - Q_{Dn}{}^{t}\ ; \qquad n = 1,...,14;\ t = 1962,....,2011.$$ [28]

Equations (7) can be solved for the depreciation amounts $Q_{Dn}{}^{t}$ and then these depreciation estimates can be divided by the corresponding year t starting stocks $Q_{Kn}{}^{t}$ to give us estimates for the year t geometric depreciation rates $\delta_n{}^{t}$:

$$(8)\ \delta_n{}^{t} \equiv Q_{Dn}{}^{t}/Q_{Kn}{}^{t}\ ; \qquad n = 1,...,14;\ t = 1962,....,2011.$$

The resulting depreciation rates were somewhat volatile and many asset depreciation rates had substantial trends.[29] We do not expect geometric depreciation rates to change much from year to year so we decided to smooth the rates which were generated by (8). The trends in the depreciation rates were not linear or even piecewise linear so we used a nonparametric smoothing method in order to reduce the volatility in the rates. We used the Lowess locally weighted nonparametric method due to Cleveland (1979) as implemented by White (2004) in the econometrics program Shazam.

We used the cross validation criterion to pick the best smoothing parameter.[30] We set the depreciation rates $\delta_n{}^{1961}$ for 1961 equal to the corresponding smoothed rates for 1962.[31] The resulting smoothed depreciation rates $\delta_n{}^{t}$ are listed in Table 11.

We can use our estimated depreciation rates for 1961, the Statistics Canada estimated starting capital stocks for 1962 and the investment information for 1961 in chained 2002 dollars in order to generate estimated starting capital stocks for our 14 types of asset for 1961; i.e., consider the following equation:

$$(9)\ Q_{Kn}{}^{t+1} = (1-\delta_n{}^{t})Q_{Kn}{}^{t} + Q_{In}{}^{t}\ .$$

Rearrange the above equation for t = 1961 to solve for $Q_{Kn}{}^{1961}$ for n = 1,2,...,9,11,...,14. A similar equation can be used to generate the starting stock for asset 10 for 1981, $Q_{K10}{}^{1981}$.

Now use equations (9), the smoothed depreciation rates listed in Table 11 and the investment information $Q_{In}{}^{t}$ along with the starting capital stocks $Q_{Kn}{}^{1961}$ in order to generate capital stock

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[28] For n = 10, t = 1982,...,2011. The same years t also apply to equations (8) for n = 10.

[29] The sample average depreciation rates were as follows: δ_1 = 0.19583; δ_2 = 0.32578; δ_3 = 0.19064; δ_4 = 0.39929; δ_5 = 0.31457; δ_6 = 0.18500; δ_7 = 0.12853; δ_8 = 0.45736; δ_9 = 0.20666; δ_{10} = 0.37454; δ_{11} = 0.08088 ; δ_{12} = 0.06641 ; δ_{13} = 0.04787; δ_{14} = 0.08308.

[30] In case of a tie in the criterion between two smoothing parameters, we chose the higher parameter, which led to slightly smoother depreciation rates. The smoothing parameter choices varied between 0.09 and 0.23 except that the best smoothing parameter for institutional buildings turned out to be 0.55. The sample averages for the smoothed depreciation rates turned out to be as follows: 0.19584; 0.32574; 0.19063; 0.39927; 0.31429; 0.18502; 0.12854; 0.45733; 0.20668; 0.37445; 0.08088; 0.06640; 0.04802; 0.008307. These smoothed average rates are very close to the raw average depreciation rates listed earlier.

[31] The depreciation rates for software for the years 1961-1981 were set equal to the smoothed rate for 1982.

series Q_{Kn}^{t} for the 14 reproducible assets.[32] We will value the starting capital stocks for year t at the average investment prices for year t, P_{In}^{t}, that were described earlier. We renormalized these prices to equal 1 in 1961 (instead of in 2002) and we changed the capital stock units to match these normalized investment prices.[33] These normalized prices for investment and the corresponding starting capital stocks, $P_{Kn}^{t,}$ are listed in Table 12. The corresponding normalized capital stocks, Q_{Kn}^{t}, are listed in Table 13.[34]

We turn our attention to the problems associated with the construction of business inventory change and inventory stock. From CANSIM Table 3800002, we can obtain current dollar estimates for business sector investment in inventories from Series V498100 and in chained 2002 dollars from Series V1992057. However, division of the current value series by the constant dollar series produces nonsensical implicit price estimates for many years.[35] Thus a different method for constructing estimates of real inventory change must be used.

End of the year current market value[36] starting stocks of inventories for persons and unincorporated business and for corporations the entire economy and for the government sector are available from the National Balance Sheet Accounts; see CANSIM Table 3780051, Series V52229234 and Table 3780052, Series V52229291) for the years 1961-2011. Adding these two series will give us estimates for the value of the business sector beginning of the year inventory stocks for the years 1962-2012, V_{K15}^{t}. We can subtract the value of inventory change for 1961 (CANSIM Series V498100) from the starting stock of inventories in 1962 in order to extend the value of inventory stock series back to 1961. Statistics Canada provided us with a price index for business sector inventory stocks for the years 1961-2006, P_{K15}^{t}.[37] We extended this price series to the years 2007-2011 by using the January indexes for the Industrial Product Price Index for Canada and for All Commodities, CANSIM Series V53384722, Table 3290056. The inventory value series V_{K15}^{t} can be divided by the inventory stock price series P_{K15}^{t}, in order to obtain a real beginning of the year business sector stock of inventories, Q_{K15}^{t}. The resulting price and quantity series (after normalization so that the price is unity in 1961) are listed in Table 12 for P_{K15}^{t} and Table 13 for Q_{K15}^{t}.

[32] The capital stock series for software start at 1981 rather than 1961.

[33] Define the constants $C_n = P_{In}^{1961}$ and define new investment and capital stock prices for period t as P_{In}^{t}/C_n and the corresponding beginning of year t capital stocks are rescaled to equal $Q_{Kn}^{t}\times C_n$ for n = 1,...,9,11,...14. The rescaling is of course a bit different for asset 10 which only starts in 1981. We denote the rescaled capital stock (and investment) prices as P_{In}^{t} and quantities Q_{Kn}^{t} in an abuse of notation.

[34] Note that our investment series for the 14 assets, Q_{In}^{t}, can be recovered from Tables 12 and 13 using equations (9). Thus we did not table the Q_{In}^{t}.

[35] Diewert (2005b) showed that traditional index number theory breaks down when the value aggregate can take both positive and negative signs and he suggested that indexes of inventory stocks be constructed (in place of indexes of inventory change) and then the stock estimates should be differenced in order to obtain estimates of inventory change. It is interesting to note that *SNA 2008* suggested this solution to the problem: “Index number formulae are generally not applicable to time series that can take positive, negative and zero values. Nevertheless, there are ways of deriving pseudo chain volume series expressed in terms of monetary values in such cases. The most commonly used approach is to identify two associated time series that take only positive values and are such that when differenced yield the target series.” Eurostat, IMF, OECD, UN and the World Bank (2008: 302).

[36] These series are labelled as book value series but we believe that they are market value series.

[37] Our thanks to Wulong Gu on this point.

It is possible to generate an alternative value of inventory stock series by cumulating information on the value of inventory change from the System of National Accounts. Thus the CANSIM series V498100 estimates the current value of business investment in inventories, which conceptually, should equal the value of inventory change over the year. Using the balance sheet estimates of the starting stock of inventories for 1962 (which was $13,698 million) and the above series, we can cumulate inventory changes and obtain an alternative SNA based estimated value of inventory change, which ended up at $108,049 million at the start of 2012. However, using the balance sheet estimates for the beginning of 2012 value of business inventories, we obtain the estimate $242,049 million, which is 2.42 times as big as the implied SNA estimate. Thus the SNA based estimates basically give us an inventory to output ratio that is implausibly low at the end of the sample period. It is true that inventory to output ratios have been falling due to just in time delivery and other inventory management techniques but the number of goods that are being produced has also been growing, which implies an increasing need for inventories. In any case, we will take the balance sheet estimates of inventory stocks as the “truth”.[38]

A preliminary price series for inventory change P_{II}^{t} in year t is set equal to P_{K15}^{t+1} listed in Table 12.[39] A preliminary series for the quantity of inventory change in year t listed in Table 13, Q_{II}^{t}, is set equal to the stock at the beginning of year t+1, Q_{K15}^{t+1}, less the stock at the beginning of year t, Q_{K15}^{t}. These preliminary series, P_{II}^{t} and Q_{II}^{t} are then renormalized so that P_{II}^{t} equals unity in 1961 and Q_{II}^{t} is adjusted accordingly to offset this change in units and these renormalized series are the series which appear in Tables 2 and 3.

We need estimates for the price and quantity of agricultural land and other land that is used by the Canadian business sector. We will also construct estimates for the stock of residential housing and the stock of residential land. The National Balance Sheets have annual values for 5 classes of nonfinancial assets:[40]

- Residential structures;
- Nonresidential structures;
- Machinery and Equipment;
- Inventories and
- Land.

There are estimates for the above 5 components for 3 sectors:

- Persons and unincorporated businesses;
- Corporate and government businesses and

[38] This choice will lead to an increase in measured multifactor productivity compared to estimates that rely on the SNA estimates of inventory change. See Diewert and Smith (1994) for a detailed accounting framework for inventories that is consistent with the Hicks (1961) and Edwards and Bell (1961) model of production and Diewert (2005b) for a critical review of SNA conventions for measuring inventory change.
[39] Diewert (2005b) showed that in order to obtain a user cost of inventories that is consistent with other user costs and the measurement of output, inventory changes should be valued at end of year prices.
[40] The CANSIM National Balance Sheet value estimates that we will use are labelled as book values but we note that these book value series which start in 1961 coincide with market value series that start in 1971. Thus we will interpret these “book value” series as market value series.

- The non-business government sector.

It can be seen that the Balance Sheet Sectors do not correspond exactly to our business sector. We have already formed estimates for business sector structures, machinery and equipment and inventories, which leaves agricultural land, other business land, residential land and residential structures to be estimated.

We first form estimates for the quantity and *value of agricultural land*. For the years 1981-2011, we can obtain end of year estimates for the value of agricultural land from CANSIM Table 20020 (Balance Sheet of the Agricultural Sector), Series V157699. This series will give us beginning of the year values for agricultural land $V_{K16}{}^{t}$ for the years t = 1982-2012. For census years, we can obtain direct estimates for the quantity of agricultural land from CANSIM Table 1530038, Series V32166910, which provides estimates for the agricultural land area for Canada.[41] To obtain estimates for non-census years, we interpolated between census years using an annualized geometric rate of growth.[42] The resulting preliminary quantity series is $Q_{K16}{}^{t}$. For the years 1982-2011, we can obtain a preliminary price series for agricultural land, $P_{K16}{}^{t}$, by dividing $V_{K16}{}^{t}$ by $Q_{K16}{}^{t}$. We linked $P_{K16}{}^{t}$ to a value of farmland per acre series at 1982. This series was Series V381831 in CANSIM Table 2003. The resulting price series $P_{K16}{}^{t}$ was normalized to equal 1 in 1961 (and $Q_{K16}{}^{t}$ was renormalized as well); see Table 12 for a listing of $P_{K16}{}^{t}$ and Table 13 for a listing of $Q_{K16}{}^{t}$.

From the National Balance Sheets, we can obtain estimates for the *market value of land held by corporations and government business enterprises* at the end of the year for the years 1961-2011; see CANSIM Table 3780052, Series V52229292.[43] We will convert these estimates into beginning of the year stocks of business land for the years 1962-2012 and label the resulting series $V_{K17}{}^{t}$ for t = 1962,...,2012. We assume that the stock of nonagricultural business land is fixed over the sample period. This is a very rough approximation to the actual situation but it is likely that land used for manufacturing has declined while land used for office space and warehousing has increased over time and so the assumption that the aggregate amount of nonagricultural land is fixed may be satisfactory.[44] Thus a preliminary price series for business nonagricultural land $P_{K17}{}^{t}$ can be obtained for t = 1962,...,2012 by dividing the year t value $V_{K17}{}^{t}$ by $V_{K17}{}^{1962}$, which equals $Q_{K17}{}^{t}$. We use the rate of change of an average land cost series over the

[41] These estimates for the census years 1971-2006 (at 5 year intervals) were as follows: 622,426.1; 619,900.4; 597,154.8; 611,111.6; 613,317.0; 616,541.4; 610,788.8; and 674,007.5. The 10 per cent jump in land area going from 2001 to 2006 does not seem possible. Hence we will use earlier data from this source (downloaded in 2008) augmented by information from Leacy (1983), Series M-23, Area of Land in Farm Holdings, Census Data, Canada (thousands of acres). The estimates for 1961 and 1966 were converted into hectares at 1 hectare = 2.471 acres.

[42] We used the annualized 2001-2006 geometric growth rate to extrapolate our agricultural land estimates from 2006 to 2011.

[43] Unfortunately, the household sector owns a considerable amount of land that is used for business purposes; i.e., unincorporated persons own land used for business purposes and the land used in these enterprises should appear as inputs into the business sector. The corporate business sector also owns some land associated with residential rental properties but we are trying to exclude these inputs from our measure of business sector input. Thus our estimates for the value of business sector land are only approximate ones.

[44] We know of no accurate published source of information on the *quantity* of business land. The National Balance Sheets may have this information but it is not publically available.

years 1961-1962 to extrapolate our price series $P_{K17}{}^t$ back to 1961.[45] The resulting $P_{K17}{}^t$ series is normalized to equal 1 in 1961 (and the units of $Q_{K17}{}^t$ are adjusted to offset the change in the units of measurement for $P_{K17}{}^t$). $P_{K17}{}^t$ is listed in Table 12 and $Q_{K17}{}^t$ is listed in Table 13.

From the National Balance Sheets, we can obtain estimates for the market value of land held by persons and unincorporated business at the end of the year for the years 1961-2011; see CANSIM Table 3780051, Series V52229235. We will convert these estimates into beginning of the year stocks of personal and unincorporated business land for the years 1962-2012 and label the resulting series $V_{LP}{}^t$ for t = 1962,...,2012. We will form an estimate of the *value of residential land held by households*, $V_{K18}{}^t$ by subtracting the value of agricultural land $V_{K16}{}^t$ from $V_{LP}{}^t$; i.e., define $V_{K18}{}^t$ as follows:

$$(10)\ V_{K18}{}^t \equiv V_{LP}{}^t - V_{K16}{}^t\ ; \qquad t = 1962,...,2012.$$

We estimate the value of *household residential land* for 1961 by multiplying $V_{K18}{}^{1962}$ by the same rate of change of an average land cost series over the years 1961-1962 that we used to extrapolate our price series $P_{K17}{}^t$ back to 1961. We make the assumption that the quantity of household residential land $Q_{K18}{}^t$ has remained fixed throughout the sample period so that $Q_{K18}{}^t \equiv V_{K18}{}^{1961}$ and $P_{K18}{}^t \equiv V_{K18}{}^t/Q_{K18}{}^t$ for t = 1961-2012. Finally, we normalize the price and quantity series so that $P_{K18}{}^{1961} = 1$. The resulting price and quantity series are listed in Tables 12 and 13. Note that we do not include this asset (and the following one) as inputs into our definition of the Canadian business sector; we include information on the price and quantity of housing assets in this data Appendix mainly for comparison purposes.[46]

From the National Balance Sheets, we can obtain estimates for the market value of *residential structures* held by all sectors at the end of the year for the years 1961-2011; see CANSIM Table 3780049, Series V52229098. We will convert these estimates into beginning of the year stocks of residential structures for the years 1962-2012 and label the resulting (preliminary) series $V_{K19}{}^t$ for t = 1962,...,2012. From Table 2 above, we have a price series for residential investment, $P_{IR}{}^t$, for the years 1961-2011. We set the stock price equal to this flow price; i.e., define $P_{K19}{}^t \equiv P_{IR}{}^t$ for t = 1961,...,2011. We can obtain a preliminary quantity series for residential housing stocks by setting $Q_{K19}{}^t \equiv V_{K19}{}^t/P_{K19}{}^t$ for t = 1962-2011. Recall that estimates of annual investment in residential structures, $Q_{IR}{}^t$, are available in Table 3. Thus we can solve the following equations to produce annual estimates for the residential housing depreciation rates, $\delta_{19}{}^t$:

$$(11)\ Q_{K19}{}^{t+1} = (1-\delta_{19}{}^t)Q_{K19}{}^t + Q_{IR}{}^t\ ; \qquad t = 1962,....,2010.$$

We found that

$$(12)\ \delta_{19}{}^t = 0.04$$

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[45] The series is the series S317 in Leacy (1983): NHA average land cost per dwelling unit, single detached dwelling units. This series matches up well with $P_{K17}{}^t$ for the early 1960s.

[46] However, this residential housing information will prove to be useful in allocating property taxes to households and businesses.

fit the data very well; i.e., the geometric model of depreciation and a residential housing annual depreciation rate of 4 per cent fits the Balance Sheet and SNA information on residential structure stocks and flows very well. Thus we used equations (11) with $\delta_{19}{}^{t}$ defined by (12) to generate new estimates for $Q_{K19}{}^{t}$ for t = 1963-2012, starting with our initial estimate for $Q_{K19}{}^{1962}$.[47] The price and quantity series $P_{K19}{}^{t}$ and $Q_{K19}{}^{t}$ are listed in Tables 12 and 13.

The units for the quantities in Table 13 are in millions of 1961 constant (mostly chained) dollars.

Primary Input Tax Rates, Balancing Real Rates of Return and User Costs

Nonresidential structures (office buildings, factories, etc.) and business land have to pay property taxes on these inputs whereas machinery and equipment and inventory stocks are generally exempt from paying these taxes. Thus it is necessary to take into account property taxes when constructing user costs of capital for business nonresidential structures and business land. Information on property taxes for the years 1961-2011 is available from Statistics Canada; see CANSIM Series V499942, Table 3800035 (Real Property Taxes of Local Governments) and CANSIM Series V499841, Table 3800033 (Real Property Taxes of Provincial Governments). We approximate the asset base on which these taxes fall as the total beginning of the year national value of land, residential structures and nonresidential structures. Data on these values are available for the years 1962-2012 from the National Balance Sheets: Series V52229098 for residential structures, Series V52229099 for nonresidential structures and Series V52229103 for land. These series were summed and the sum was used as the tax base for the sum of the two property tax series, V499942 plus V499841. The resulting *property tax rates* are reported as the series $\tau_{P}{}^{t}$ in Table 14[48] and it will be used in the construction of the user costs of business sector land and nonresidential structures.[49] Our estimated property tax rate starts at 1.5 per cent and trends down to 1 per cent[50] We will apply this property tax rate to assets 11-14 and 16 and 17. Thus define the *asset specific property tax rates* for year t and asset n, $\tau_{Pn}{}^{t}$, as follows:

(13) $\tau_{Pn}{}^{t} \equiv 0$ for n = 1-10 and 15 and $\tau_{Pn}{}^{t} \equiv \tau_{P}{}^{t}$ for n = 11-14 and 16-17.

It is of some interest to calculate the average business tax rate for taxes that apply to the use of financial capital in the business sector so we provide estimates for this tax rate by year. These business taxes that fall on the return to capital are defined to be the sum of the following taxes:

- Taxes less subsidies on factors of production (CANSIM Series V1992216, Table 3800001) less local government and Provincial government property taxes;

[47] We also used equation (11) for t = 1961 to generate $Q_{K19}{}^{1961}$.
[48] The tax rate for 1961 was set equal to the corresponding rate for 1962.
[49] This is a very rough approximation to the actual property tax rates on business sector land and nonresidential structures since actual property tax rates are different across different sectors and assets. For example, business sector property assets are generally taxed more heavily than household property assets.
[50] This property tax rate is probably too high for residential property and too low for business property, which is generally taxed at higher rates than corresponding residential properties.

- Total government taxes on income from corporations and government business enterprises (CANSIM Series V499131, Table 3800007); and

- Total government taxes on income from nonresidents (CANSIM Series V499132, Table 3800007).

The sum of the above three sources of general business taxes that fall on capital stock components for year t was divided by the corresponding sum of the beginning of the year t value of assets for our 17 types of business sector asset, $V_{Kn}^t \equiv P_{Kn}^t Q_{Kn}^t$ for n = 1,...,17. We denote the resulting business tax rate for year t as τ_B^t and it is listed in Table 14.

Using the asset specific property tax rates τ_{Pn}^t, the general business tax rates τ_B^t, the depreciation rates δ_n^t for n = 1-14 that are listed in Table 11[51] and the asset prices P_{Kn}^t that are listed in Table 12, we can define *user costs* U_n^t for our 17 asset classes as follows:[52]

$$(14)\quad U_n^t \equiv [r^t + \tau_B^t + \tau_{Pn}^t + \delta_n^t]P_{Kn}^t ; \qquad n = 1,...,17 ; t = 1961,...,2011$$

where r^t is suitable after tax cost of capital that applies to the business sector in year t. In the present study, we will follow national income accounting conventions and will take r^t to be the *balancing real rate of return*;[53] i.e., it is the rate of return that is consistent with the year t value of business sector net output being equal to the value of primary inputs used by the business sector in year t, where the user costs defined by (14) are used as prices for the beginning of the year capital inputs. Thus r^t can be determined as the solution to the following linear in r^t equation for t = 1961,...,2011:

$$(15)\quad P_C^tQ_C^t + P_{GN}^tQ_{GN}^t + P_{IG}^tQ_{IG}^t + P_{IR}^tQ_{IR}^t + P_{IN}^tQ_{IN}^t + P_{IM}^tQ_{IM}^t + P_{II}^tQ_{II}^t + \sum_{n=8}^{15} P_n^tQ_n^t + \sum_{n=16}^{22} P_n^tQ_n^t = \sum_{n=1}^{12} P_{Ln}^tQ_{Ln}^t + \sum_{n=1}^{12} [r^t + \tau_B^t + \tau_{Pn}^t + \delta_n^t]P_{Kn}^tQ_{Kn}^t$$

where the various price and quantity series are defined in the tables.[54] The resulting series of balancing real rates of return are listed in Table 14. It should be noted that r^t can be interpreted as a real interest rate; i.e. it is the income earned by the business sector in year t relative to the starting capital stock, valued at the average investment prices for the period. This explains why we have not included a capital gains term in the user cost formulae defined by (14).[55]

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[51] The depreciation rates δ_n^t for assets n = 15-17 are defined to be zero; i.e., we assume that inventories, agricultural land and non-agricultural business land does not depreciate.

[52] For additional material on user costs and many historical references, see Hall and Jorgenson (1967), Christensen and Jorgenson (1969), Harper, Berndt and Wood (1980), Jorgenson (1989, 1996a, and 1996b), Diewert (1980 and 2005a) and Schreyer (2009).

[53] For most purposes, it is probably preferable to use an exogenous real rate of return in the user costs (14) since the resulting prices will probably approximate market rental prices better. However, when we used the sample average real rate of return in the user costs defined by (14), our results were basically unchanged.

[54] P_{XG}^t and Q_{XG}^t are chained Fisher aggregates of our 7 classes of exports of goods, P_{XS}^t and Q_{XS}^t are the price and quantity of exports of services, P_{MG}^t and Q_{MG}^t are chained Fisher aggregates of our 6 classes of imports of goods and P_{MS}^t and Q_{MS}^t are the price and quantity of imports of services.

[55] We have essentially absorbed the capital gains (or losses) term into r^t.

The sample average property tax rate was $\tau_P \equiv 0.01368$, the sample average business income tax rate was $\tau_B \equiv 0.03780$ and the sample average real after tax rate of return was $r \equiv 0.06133$. Once r^t has been determined, then the 17 series of user costs defined by (14) can also be calculated; these series are listed in Table 15. Note that r^t is a *real after tax rate of return* because we do not include a capital gains term in our user costs and all user costs are evaluated at the average prices for the corresponding investment good for year t.

Tables 13 and 15 provide estimates for the prices and quantities of business sector capital services for the 17 assets in our data base for the years 1961-2011.

As noted earlier, the sample average of the balancing after tax real rates of return r^t was a rather large 6.133 per cent per year. The average property tax rate τ_P^t was 1.368 per cent while the average business tax rate on assets was 3.780 per cent. The before business tax real rate of return averaged 9.913 per cent. Thus it appears that governments are taking about 38.1 per cent of the before tax return to capital assets on average.[56] However, it must be kept in mind that these balancing rates of return may not be very reliable; they contain the net effect of all the measurement errors that were made in constructing this data set.

The high average after-tax rates of return for the business sector are a source of concern. The corresponding balancing real rate of returns for Australia averaged around 3 per cent (Diewert and Lawrence, 2006). Normally, after-tax real rates of return are in the 1 to 3 per cent rate whereas our estimated average rate is over 6 per cent. This suggests that our estimates of the value of output may be too high[57] or that the value of labour input is too low or that our estimated asset values for business sector capital inputs are too small. We think that the last possibility is the most probable one. Using the data tabled in this Appendix, we calculated a business sector nominal and real value of business sector output, V_Y^t and Q_Y^t,[58] and we also calculated the corresponding business sector nominal and real capital stock inputs, V_{KW}^t and Q_{KW}^t. Nominal and real business sector capital-output ratios were computed, V_{KW}^t/V_Y^t and Q_{KW}^t/Q_Y^t respectively. These capital-output ratios are listed in Table 14. We found that the nominal business sector capital-output ratio fell from 2.22 in 1961 to 1.85 in 2011 while the real capital-output ratio fell from 2.22 in 1961 to 1.33 in 2011. These falls in the capital-output ratio seem unlikely. It is very likely that the Statistics Canada depreciation rates for reproducible assets are too high. However, for the purposes of this study, we will accept these high depreciation rates.

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[56] This relatively high rate of business taxation has two negative effects: (i) it raises the user cost of capital and hence lessens the beneficial effects of capital deepening and (ii) the high rates lead to a relatively large loss of productive efficiency; i.e. the deadweight losses of such large tax rates are likely to be large.

[57] See Diewert and Fox (2001) for a discussion of output mismeasurement problems.

[58] P_Y^t was computed as a chained Törnqvist price index of the 9 net output aggregates listed in Tables 2 and 3 (the sign of import quantities Q_M^t was changed from a positive sign to a negative sign) and Q_Y^t is the corresponding implicit quantity index of business sector value added at producer prices. P_{KW}^t and Q_{KW}^t are the chained Fisher index price and quantity of wealth stocks that are used as inputs into the business sector; see Tables 12 and 13 for a listing of the 17 components that were used in constructing these indexes. These price and quantity indexes are listed in Table 14.

Sources of Error

There are many problems with the data constructed in this Appendix. Some of the more important possible sources of error are listed as follows:

- Our adjustments for converting final demand prices (those facing the final demanders of the goods and services produced by the business sector) into basic prices (prices facing the producers of the goods and services) were rather crude and some aggregation error will be associated with our procedures. In particular, only crude adjustments for the effects of indirect taxes on the components of consumption were made. Also our method for estimating the net supplies of the business sector to the non-business sector are rather indirect and subject to some error.[59]

- Our tax adjustments for the price of imports and exports were also not completely satisfactory due to various aggregation errors; i.e. we were not able to assign taxes accurately to the various components of imports and exports.

- Our measure of labour input relies on CANSIM Table 3830024, which provides price and quantity information for 36 separate types of labour. However, the KLEMS program makes use of even more disaggregated data and obtains significantly different rates of growth of quality adjusted labour input for the Canadian business sector and so our estimates may be subject to some aggregation error.

- Our estimates for 14 capital stock components relied on CANSIM Table 310003 and the estimates of business sector capital stocks and investment flows implied very high depreciation rates for these assets. These high depreciation rates are not really plausible since they essentially lead to a declining real capital-output ratio for the Canadian business sector, which seems unlikely.

- We also relied heavily on the Statistics Canada Balance Sheet estimates for the value of business land but the Balance Sheet estimates are highly aggregated in particular, there is not enough detail on the allocation of land. Moreover, there is a lack of accurate information on the quantity of land used by the business sector.

- Our treatment of property taxes and business income taxes is very approximate.

- Our user costs of capital were constructed using a particular set of assumptions (no capital gains and endogenous real rates of return) and these assumptions are not universally accepted.

- The roles of infrastructure capital and R&D investments were not taken into account.

- The role of resource depletion was also not taken into account.

[59] In particular, we did not have access to *chained* price indexes for the non-business sector for the years prior to 1997 and this will lead to some aggregation errors.

- We did not take into account the business sector's holdings of working capital including bank deposits and currency.

The latest international version of the System of National Accounts, *SNA 2008*, recognized the role of capital services in the production accounts. This is a big step forward since it allows inputs in the SNA production accounts to be decomposed into price and quantity components and hence the revised SNA will facilitate the development of productivity accounts for each country that implements the revised SNA. However, just introducing capital services into the SNA will not be sufficient in order to develop accurate sectoral productivity accounts. Some of the problems associated with the introduction of capital services into the SNA are as follows:

- More attention needs to be given to the development of basic prices by industry and by commodity; i.e. we need accurate information on the exact location of indirect taxes (and commodity subsidies) by commodity and industry on both outputs and intermediate inputs.

- In order to deal adequately with the complications introduced by international trade, the existing Input Output production accounts need to be reworked so that the role of traded goods and services can be tracked by industry.[60]

- The treatment of inventory change in the present SNA seems inadequate for the needs of productivity accounts. Inventory change should be integrated with the balance sheet accounts and the user cost accounts.[61]

- The investment accounts need to be integrated with the corresponding balance sheet accounts, both in nominal and real terms.

- The treatment of land in the balance sheets requires additional work; i.e., there are problems in obtaining information on the quantity of land used by each industry and sector and valuing the land appropriately.[62]

- Difficult decisions must be made on the exact form of the user cost formula to be used when measuring capital services; i.e., the revised SNA should make specific recommendations on how user costs should be constructed so that some measure of international comparability can be achieved in the accounts.

- The problems involved in making imputations for the labour input of the self-employed (and unpaid family workers) should also be addressed.

The introduction of capital services into the SNA framework will provide challenges for statistical agencies. However, as national statistical agencies make productivity accounts a part

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[60] In principle, this problem is recognized in *SNA 2008*. However, implementation by national statistical agencies will be difficult.

[61] Again, in principle, these problems are recognized in *SNA 2008*.

[62] There are some difficult conceptual and practical problems involved in separating structure value from land value; see Diewert (2007) for a discussion of some of these problems.

of their regular production of the national accounts, there will be benefits to the statistical system as a whole since a natural output of the new system of accounts will be balancing real rates of return by sector or industry. These balancing real rates of return will provide a check on the accuracy of the sectoral data: if the rates are erratic or very large or very small, this can indicate measurement error in the sectoral data and hence will give the statistical agency an early indication of problems with the data.

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Appendix Table 1

Housing Value, Quantity and Price Series for Imputed and Paid Rents, 1961-2011

	V_{OOH}	V_{PR}	Q_{OOH}	Q_{PR}	P_{OOH}	P_{PR}
	Value Series		Quantity Series		Price Series	
	Imputed Rents for Owner Occupied Dwellings	Paid Rents	Imputed Rents for Owner Occupied Dwellings	Paid Rents	Imputed Rents for Owner Occupied Dwellings	Paid Rents
Year	(millions, dollars)		(millions, 1961 dollars)		(index, 1961=1.000)	
1961	2,292	1,107	2,292	1,107	1.000	1.000
1962	2,436	1,176	2,380	1,149	1.024	1.024
1963	2,660	1,290	2,412	1,170	1.103	1.103
1964	2,832	1,396	2,477	1,221	1.143	1.143
1965	2,976	1,503	2,531	1,278	1.176	1.176
1966	3,249	1,658	2,620	1,337	1.240	1.240
1967	3,585	1,860	2,678	1,390	1.339	1.339
1968	3,985	2,091	2,707	1,420	1.472	1.472
1969	4,416	2,342	2,784	1,476	1.586	1.586
1970	4,897	2,645	2,833	1,530	1.729	1.729
1971	5,388	2,918	2,864	1,551	1.881	1.881
1972	5,757	3,183	2,866	1,584	2.009	2.009
1973	6,307	3,451	2,862	1,566	2.204	2.204
1974	7,107	3,787	2,923	1,558	2.431	2.431
1975	8,313	4,290	2,992	1,544	2.779	2.779
1976	10,038	4,842	3,072	1,482	3.267	3.267
1977	12,126	5,443	3,084	1,384	3.932	3.932
1978	14,090	6,106	3,051	1,322	4.618	4.618
1979	15,797	6,829	2,996	1,295	5.273	5.273
1980	17,869	7,686	3,053	1,313	5.853	5.853
1981	20,512	8,822	3,159	1,359	6.493	6.493
1982	23,489	10,082	3,213	1,410	7.310	7.152
1983	26,285	11,295	3,256	1,444	8.073	7.822
1984	28,446	12,181	3,294	1,471	8.636	8.281
1985	30,694	12,967	3,360	1,500	9.135	8.645
1986	33,386	13,955	3,463	1,539	9.641	9.069
1987	36,117	15,090	3,573	1,599	10.108	9.437
1988	39,587	16,419	3,801	1,662	10.415	9.877
1989	44,078	18,201	4,011	1,726	10.989	10.545
1990	48,016	19,786	4,221	1,798	11.376	11.004
1991	51,779	21,133	4,469	1,853	11.586	11.406
1992	54,872	22,269	4,627	1,899	11.859	11.729
1993	57,263	23,108	4,770	1,943	12.005	11.892
1994	60,557	24,056	4,887	1,982	12.391	12.135
1995	63,613	24,869	5,001	2,016	12.720	12.338
1996	65,418	25,632	5,116	2,049	12.787	12.511
1997	67,405	26,425	5,245	2,097	12.851	12.598
1998	69,835	27,223	5,389	2,139	12.959	12.728
1999	72,144	28,173	5,557	2,187	12.983	12.879
2000	74,582	29,059	5,704	2,231	13.075	13.025
2001	77,093	30,092	5,843	2,279	13.194	13.205
2002	80,895	31,491	6,074	2,341	13.318	13.449
2003	83,916	32,829	6,250	2,413	13.427	13.604
2004	87,609	34,133	6,482	2,487	13.516	13.723
2005	91,542	35,435	6,730	2,560	13.602	13.840
2006	96,748	37,137	6,985	2,638	13.851	14.078
2007	103,305	39,263	7,249	2,715	14.251	14.459
2008	109,860	41,381	7,528	2,797	14.594	14.797
2009	115,263	43,243	7,786	2,881	14.804	15.011
2010	120,256	44,955	8,049	2,966	14.940	15.155
2011	125,685	46,819	8,322	3,054	15.103	15.330
Compound Annual Growth Rates, per cent						
1961-2011	8.34	7.78	2.61	2.05	5.58	5.61
2000-2011	4.86	4.43	3.49	2.90	1.32	1.49
1961-1973	8.80	9.94	1.87	2.93	6.81	6.81
1973-1981	15.88	12.45	1.24	-1.76	14.46	14.46
1981-1989	10.03	9.48	3.03	3.03	6.80	6.25
1989-2000	4.90	4.34	3.25	2.36	1.59	1.94
2000-2008	4.96	4.52	3.53	2.87	1.38	1.61
2008-2011	4.59	4.20	3.40	2.97	1.15	1.19

Appendix Table 2
Price Indexes for Business Sector Net Outputs: Consumption, Investment and Trade, 1961-2011

	P_C	P_{GN}	P_{IG}	P_{IR}	P_{IN}	P_{IM}	P_{II}	P_X	P_M
	Consumption	Net Sales of the Nonbusiness Sector to the Business Sector	Government Investment	Residential Investment	Non-residential Investment	Machinery and Equipment Investment	Inventory Change	Exports	Imports
Year	(index, 1961=1.000)								
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.006	0.994	1.009	1.005	1.006	1.020	1.002	1.030	1.058
1963	1.020	0.976	1.039	1.028	1.033	1.034	1.013	1.041	1.096
1964	1.023	0.927	1.062	1.073	1.062	1.068	1.032	1.057	1.105
1965	1.036	0.912	1.139	1.134	1.123	1.093	1.055	1.080	1.102
1966	1.074	0.883	1.210	1.208	1.193	1.119	1.072	1.125	1.119
1967	1.107	0.891	1.232	1.285	1.242	1.132	1.084	1.154	1.144
1968	1.148	0.961	1.238	1.314	1.252	1.150	1.110	1.201	1.167
1969	1.185	0.968	1.285	1.381	1.325	1.195	1.135	1.231	1.196
1970	1.215	1.006	1.339	1.426	1.391	1.244	1.150	1.267	1.220
1971	1.242	1.103	1.409	1.532	1.468	1.281	1.203	1.286	1.248
1972	1.293	1.144	1.485	1.673	1.551	1.323	1.316	1.333	1.275
1973	1.384	1.221	1.648	1.971	1.719	1.372	1.427	1.515	1.360
1974	1.582	1.358	2.011	2.361	2.034	1.521	1.547	1.913	1.646
1975	1.820	1.484	2.234	2.561	2.273	1.703	1.651	2.167	1.890
1976	1.904	1.643	2.345	2.769	2.401	1.822	1.770	2.297	1.929
1977	2.028	1.787	2.490	2.878	2.530	1.954	1.927	2.502	2.172
1978	2.190	1.929	2.662	3.041	2.711	2.133	2.136	2.738	2.417
1979	2.403	2.185	2.885	3.280	2.963	2.315	2.341	3.208	2.730
1980	2.691	2.489	3.199	3.555	3.325	2.498	2.559	3.735	2.980
1981	2.898	2.794	3.683	3.993	3.687	2.797	2.758	3.998	3.266
1982	3.166	3.106	3.927	4.082	3.961	3.014	2.910	4.089	3.439
1983	3.407	3.374	4.015	4.254	3.931	3.088	3.044	4.151	3.423
1984	3.564	3.486	4.171	4.418	4.081	3.091	3.126	4.297	3.582
1985	3.676	3.672	4.208	4.556	4.214	3.129	3.158	4.381	3.677
1986	3.756	3.742	4.203	4.908	4.275	3.163	3.207	4.371	3.744
1987	3.852	3.797	4.224	5.408	4.473	3.110	3.263	4.458	3.692
1988	3.958	3.786	4.338	5.783	4.728	3.068	3.315	4.471	3.601
1989	4.071	3.826	4.437	6.132	4.925	3.078	3.363	4.560	3.594
1990	4.302	3.864	4.531	6.112	5.089	3.092	3.365	4.529	3.644
1991	4.540	3.926	4.318	6.323	5.003	2.938	3.519	4.371	3.580
1992	4.599	3.944	4.319	6.397	4.975	2.954	3.526	4.496	3.726
1993	4.689	3.970	4.343	6.584	5.038	3.016	3.700	4.694	3.925
1994	4.718	4.179	4.420	6.765	5.205	3.115	3.830	4.973	4.161
1995	4.735	4.299	4.516	6.767	5.273	3.127	3.919	5.291	4.277
1996	4.833	4.202	4.538	6.756	5.430	3.102	3.782	5.321	4.222
1997	4.913	4.103	4.579	6.875	5.567	3.103	3.807	5.327	4.237
1998	4.978	4.140	4.597	6.960	5.715	3.144	3.867	5.316	4.380
1999	5.069	4.290	4.572	7.132	5.830	3.048	3.956	5.379	4.360
2000	5.207	4.432	4.690	7.298	6.028	3.022	4.040	5.710	4.442
2001	5.365	4.459	4.680	7.488	6.079	3.060	4.109	5.803	4.584
2002	5.434	4.567	4.730	7.812	6.182	3.088	3.871	5.689	4.615
2003	5.571	4.569	4.727	8.213	6.305	2.888	3.910	5.648	4.315
2004	5.652	4.651	4.799	8.716	6.704	2.775	3.957	5.786	4.206
2005	5.777	4.749	4.914	9.125	7.125	2.677	4.022	5.952	4.156
2006	5.880	4.810	5.107	9.799	7.633	2.603	4.137	5.975	4.117
2007	5.989	4.954	5.282	10.510	8.100	2.526	4.149	6.031	4.014
2008	6.156	5.111	5.643	10.798	8.560	2.545	4.187	6.644	4.244
2009	6.183	5.273	5.686	10.811	8.713	2.683	4.191	5.991	4.283
2010	6.255	5.388	5.680	11.137	8.993	2.503	4.326	6.123	4.103
2011	6.392	5.558	5.840	11.440	9.286	2.425	4.430	6.559	4.175
Compound Annual Growth Rates, per cent									
1961-2011	3.78	3.49	3.59	4.99	4.56	1.79	3.02	3.83	2.90
2000-2011	1.88	2.08	2.01	4.17	4.01	-1.98	0.84	1.27	-0.56
1961-1973	2.75	1.68	4.25	5.82	4.62	2.67	3.01	3.52	2.60
1973-1981	9.68	10.90	10.57	9.23	10.01	9.31	8.59	12.90	11.57
1981-1989	4.34	4.01	2.36	5.51	3.69	1.20	2.51	1.66	1.20
1989-2000	2.26	1.35	0.51	1.60	1.85	-0.17	1.68	2.07	1.94
2000-2008	2.11	1.80	2.34	5.02	4.48	-2.12	0.45	1.91	-0.57
2008-2011	1.26	2.83	1.15	1.94	2.75	-1.60	1.90	-0.43	-0.54

Appendix Table 3
Quantity Aggregates for Business Sector Net Outputs: Consumption, Investment and Trade, 1961-2011

	Q_C	Q_{GN}	Q_{IG}	Q_{IR}	Q_{IN}	Q_{IM}	Q_{II}	Q_X	Q_M
	Consumption	Net Sales of the Nonbusiness Sector to the Business Sector	Government Investment	Residential Investment	Non-residential Investment	Machinery and Equipment Investment	Inventory Change	Exports	Imports
Year	(millions, 1961 dollars)								
1961	20,117	1,420	1,887	2,211	2,618	2,144	1	6,867	7,897
1962	21,175	1,447	2,094	2,271	2,545	2,322	560	7,195	8,033
1963	22,127	1,446	2,101	2,354	2,637	2,556	936	7,832	8,031
1964	23,357	1,596	2,141	2,715	3,050	3,027	532	9,105	8,989
1965	24,791	1,798	2,426	2,825	3,320	3,611	1,228	9,418	10,180
1966	26,048	2,320	2,668	2,699	3,802	4,337	1,313	10,696	11,579
1967	27,029	2,684	2,718	2,754	3,613	4,350	454	11,827	12,306
1968	28,317	2,950	2,758	3,132	3,593	3,984	619	12,910	13,527
1969	29,705	3,068	2,700	3,551	3,592	4,307	1,580	13,802	15,377
1970	30,227	3,858	2,645	3,254	3,946	4,419	180	15,211	15,293
1971	32,085	3,885	2,985	3,728	4,089	4,537	-232	15,929	16,480
1972	34,636	3,942	2,938	4,066	4,074	4,940	148	17,257	18,892
1973	37,401	4,247	2,781	4,371	4,396	5,993	2,542	19,008	21,754
1974	39,498	4,819	2,845	4,464	4,675	6,737	4,839	18,347	23,977
1975	41,166	5,397	2,962	4,386	5,286	7,121	-334	16,951	23,228
1976	43,591	5,254	2,855	5,172	5,168	7,363	250	18,390	24,774
1977	45,148	5,963	2,916	5,242	5,479	7,260	1,319	19,678	24,836
1978	46,909	5,833	2,875	5,291	5,626	7,492	1,300	21,544	26,197
1979	48,338	5,796	2,803	5,251	6,337	8,526	3,691	22,467	28,092
1980	49,160	6,062	2,869	4,977	7,055	9,054	167	22,548	28,715
1981	49,549	5,845	2,967	5,279	7,620	10,142	891	23,012	30,716
1982	47,858	6,019	3,095	4,340	6,929	8,597	-4,603	22,882	25,710
1983	49,205	5,998	2,991	5,079	6,361	8,207	-1,049	24,326	28,444
1984	51,575	5,838	3,124	5,131	6,288	8,696	1,744	28,444	33,270
1985	54,441	6,539	3,497	5,578	6,590	9,652	1,467	29,938	35,548
1986	56,557	6,635	3,485	6,267	6,210	10,605	1,029	31,456	37,965
1987	58,999	6,789	3,621	7,190	6,454	12,171	1,701	32,933	39,889
1988	61,384	7,814	3,789	7,340	7,110	14,394	2,078	35,371	45,163
1989	63,294	8,423	4,184	7,640	7,345	15,424	1,406	35,434	47,820
1990	63,534	9,043	4,463	6,835	7,346	14,706	-583	37,556	48,551
1991	61,649	9,508	4,692	5,824	7,075	14,271	-3,899	38,167	49,281
1992	62,362	9,458	4,621	6,238	5,960	14,120	-551	40,921	51,473
1993	63,317	9,223	4,560	6,024	5,993	13,731	-878	45,382	55,461
1994	65,342	8,537	4,894	6,271	6,533	15,058	709	51,076	60,606
1995	66,670	8,165	4,740	5,340	6,574	16,239	3,164	55,452	64,385
1996	68,463	8,263	4,536	5,852	6,696	17,230	2,417	58,646	67,340
1997	71,965	8,414	4,390	6,330	7,881	21,703	1,780	63,457	77,378
1998	73,991	9,511	4,361	6,106	7,906	23,575	2,329	69,086	81,755
1999	76,954	9,380	5,039	6,324	8,101	25,951	1,249	76,337	88,261
2000	80,310	10,022	5,229	6,656	8,266	27,580	2,915	83,350	95,661
2001	82,116	11,040	5,830	7,363	8,712	26,758	-1,856	80,654	90,649
2002	85,095	11,443	6,044	8,403	8,195	25,995	3,367	81,599	92,347
2003	87,666	12,088	6,370	8,854	8,651	27,991	-1,722	79,268	96,341
2004	90,491	12,331	6,773	9,519	9,257	30,529	1,058	83,281	104,558
2005	93,826	12,483	7,543	9,820	10,211	34,837	2,299	84,847	112,552
2006	97,845	13,197	8,058	10,023	11,167	38,396	1,693	85,213	118,273
2007	102,531	13,469	8,580	10,303	11,423	40,009	1,554	86,367	125,533
2008	105,442	14,353	9,237	9,977	12,322	39,824	2,911	82,650	126,364
2009	105,202	15,394	10,049	9,181	9,593	32,063	-3,031	71,414	108,643
2010	108,742	15,922	11,852	10,119	9,863	35,861	-1,410	76,559	123,691
2011	111,173	15,718	11,482	10,355	11,210	40,330	1,671	80,232	132,890
Compound Annual Growth Rates, per cent									
1961-2011	3.48	4.93	3.68	3.14	2.95	6.04	16.00	5.04	5.81
2000-2011	3.00	4.18	7.41	4.10	2.81	3.51	-4.93	-0.35	3.03
1961-1973	5.30	9.56	3.28	5.84	4.41	8.94	92.20	8.85	8.81
1973-1981	3.58	4.07	0.81	2.39	7.12	6.80	-12.28	2.42	4.41
1981-1989	3.11	4.67	4.39	4.73	-0.46	5.38	5.87	5.54	5.69
1989-2000	2.19	1.59	2.05	-1.25	1.08	5.43	6.85	8.09	6.51
2000-2008	3.46	4.59	7.37	5.19	5.12	4.70	-0.02	-0.11	3.54
2008-2011	1.78	3.07	7.52	1.25	-3.10	0.42	-16.89	-0.98	1.69

Appendix Table 4

Business Sector, Nonbusiness Sector, Government Final Demand and Net Sales of the Business Sector to the Nonbusiness Sector Price and Quantity Aggregates, 1961-2011

	Q_B	Q_N	Q_G	Q_{GN}	P_B	P_N	P_G	P_{GN}
	Quantity Series				Price Series			
	Business sector	Nonbusiness Sector	Government Final Demand	Net Sales of Business Sector to the Nonbusiness Sector	Business Sector	Nonbusiness Sector	Government Final Demand	Net Sales of Business Sector to the Nonbusiness Sector
Year	(millions, 1961 dollars)				index, 1961=1.000)			
1961	33,097	5,204	6,624	1,420	1.000	1.000	1.000	1.000
1962	35,338	5,480	6,928	1,447	1.009	1.039	1.029	0.994
1963	37,217	5,713	7,164	1,447	1.030	1.082	1.060	0.976
1964	39,810	5,952	7,542	1,596	1.049	1.142	1.098	0.927
1965	42,658	6,120	7,883	1,798	1.076	1.215	1.152	0.912
1966	45,529	6,409	8,581	2,320	1.122	1.345	1.243	0.883
1967	46,616	6,870	9,334	2,684	1.161	1.457	1.328	0.891
1968	49,335	7,263	9,944	2,950	1.193	1.548	1.416	0.961
1969	51,965	7,585	10,376	3,068	1.235	1.713	1.538	0.968
1970	52,968	7,962	11,287	3,858	1.294	1.841	1.643	1.006
1971	55,844	8,255	11,631	3,885	1.336	1.960	1.759	1.103
1972	59,086	8,549	11,995	3,942	1.403	2.128	1.893	1.144
1973	63,467	8,887	12,559	4,247	1.549	2.312	2.049	1.221
1974	65,346	9,295	13,357	4,819	1.796	2.658	2.339	1.358
1975	65,545	9,790	14,251	5,397	2.038	3.053	2.660	1.484
1976	70,082	10,097	14,525	5,254	2.176	3.453	2.995	1.643
1977	72,425	10,348	15,205	5,964	2.327	3.739	3.246	1.787
1978	74,875	10,644	15,473	5,833	2.515	3.969	3.457	1.929
1979	77,878	10,805	15,635	5,796	2.801	4.292	3.776	2.185
1980	79,169	11,138	16,169	6,062	3.130	4.668	4.149	2.489
1981	81,847	11,496	16,441	5,845	3.402	5.229	4.650	2.794
1982	78,970	11,693	16,767	6,019	3.660	5.836	5.185	3.106
1983	81,077	11,952	17,045	5,998	3.895	6.123	5.481	3.374
1984	86,041	12,198	17,222	5,838	4.039	6.373	5.695	3.486
1985	90,944	12,471	17,959	6,539	4.139	6.580	5.906	3.672
1986	93,580	12,708	18,283	6,635	4.199	6.813	6.094	3.742
1987	97,824	12,840	18,525	6,789	4.384	7.172	6.363	3.797
1988	102,723	13,057	19,370	7,814	4.581	7.531	6.604	3.786
1989	105,427	13,224	19,903	8,423	4.756	8.034	6.957	3.826
1990	106,128	13,541	20,605	9,043	4.852	8.602	7.349	3.864
1991	104,194	13,849	21,208	9,508	4.906	9.019	7.650	3.926
1992	105,171	14,045	21,414	9,458	4.922	9.362	7.882	3.944
1993	108,151	14,150	21,422	9,223	4.977	9.509	7.990	3.970
1994	113,766	14,218	21,156	8,537	5.083	9.559	8.111	4.179
1995	117,124	14,279	21,034	8,165	5.236	9.620	8.199	4.299
1996	119,744	14,025	20,786	8,263	5.340	9.728	8.234	4.202
1997	125,797	13,787	20,579	8,414	5.402	9.954	8.346	4.103
1998	131,475	13,890	21,240	9,511	5.374	10.075	8.442	4.140
1999	139,515	14,320	21,687	9,380	5.475	10.182	8.579	4.290
2000	147,808	14,614	22,356	10,022	5.712	10.652	8.950	4.432
2001	149,733	14,926	23,229	11,040	5.808	10.886	9.114	4.459
2002	153,895	15,241	23,802	11,443	5.826	11.297	9.429	4.567
2003	156,933	15,608	24,551	12,088	6.026	11.737	9.711	4.569
2004	162,130	15,921	25,044	12,331	6.237	11.937	9.878	4.651
2005	167,081	16,154	25,398	12,484	6.464	12.416	10.232	4.749
2006	171,718	16,519	26,169	13,197	6.640	12.963	10.608	4.810
2007	175,499	17,001	26,882	13,469	6.860	13.345	10.922	4.954
2008	176,113	17,640	28,064	14,353	7.192	13.754	11.259	5.111
2009	169,030	18,080	29,074	15,394	6.978	14.190	11.617	5.273
2010	175,238	18,467	29,786	15,922	7.180	14.500	11.870	5.388
2011	180,295	18,735	30,020	15,718	7.417	14.957	12.244	5.558
Compound Annual Growth Rates, per cent								
1961-2011	3.45	2.60	3.07	4.93	4.09	5.56	5.14	3.49
2000-2011	1.82	2.28	2.72	4.18	2.40	3.13	2.89	2.08
1961-1973	5.58	4.56	5.48	9.56	3.71	7.23	6.16	1.68
1973-1981	3.23	3.27	3.42	4.07	10.33	10.74	10.79	10.90
1981-1989	3.22	1.77	2.42	4.67	4.28	5.51	5.16	4.01
1989-2000	3.12	0.91	1.06	1.59	1.68	2.60	2.32	1.35
2000-2008	2.21	2.38	2.88	4.59	2.92	3.25	2.91	1.80
2008-2011	0.79	2.03	2.27	3.07	1.03	2.83	2.84	2.83

Appendix Table 5
Price Indexes for Eight Commodity Classes of Exports, 1961-2011

	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
	Agricultural and Fish Products	Energy Products	Forest Products	Industrial Goods and Materials (excluding energy and forest products)	Machinery and Equipment (excluding automotive products)	Automotive Products	Other Consumer Goods (excluding automotive products)	Services
Year	(index, 1961=1.000)							
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.057	0.985	1.037	1.020	1.035	1.012	0.999	1.019
1963	1.053	1.011	1.050	1.027	1.046	1.028	1.009	1.044
1964	1.061	0.999	1.069	1.043	1.065	1.038	1.029	1.077
1965	1.076	1.019	1.087	1.068	1.090	1.036	1.037	1.122
1966	1.139	1.024	1.108	1.124	1.129	1.050	1.059	1.184
1967	1.154	0.965	1.129	1.153	1.176	1.066	1.076	1.268
1968	1.149	1.005	1.158	1.227	1.252	1.088	1.104	1.346
1969	1.110	1.053	1.211	1.265	1.281	1.099	1.147	1.413
1970	1.075	1.067	1.204	1.340	1.365	1.122	1.140	1.501
1971	1.103	1.123	1.247	1.289	1.372	1.152	1.156	1.579
1972	1.166	1.156	1.346	1.302	1.417	1.174	1.185	1.665
1973	1.656	1.391	1.617	1.495	1.468	1.187	1.260	1.790
1974	2.476	3.445	1.980	1.941	1.650	1.279	1.422	2.023
1975	2.442	4.392	2.317	2.105	1.862	1.403	1.566	2.295
1976	2.275	5.079	2.394	2.227	1.906	1.488	1.667	2.519
1977	2.136	5.890	2.625	2.509	2.028	1.616	1.768	2.729
1978	2.377	6.283	2.902	2.771	2.116	1.782	1.883	2.903
1979	2.890	8.053	3.477	3.537	2.274	1.966	2.001	3.146
1980	3.284	11.287	3.738	4.451	2.414	2.177	2.249	3.497
1981	3.569	12.197	3.965	4.550	2.555	2.414	2.497	3.947
1982	3.467	12.362	3.853	4.319	2.723	2.633	2.670	4.341
1983	3.393	11.855	3.836	4.352	2.753	2.738	2.804	4.664
1984	3.530	11.842	4.263	4.455	2.693	2.905	2.887	4.873
1985	3.515	11.152	4.325	4.412	2.683	3.130	3.003	5.133
1986	3.436	7.754	4.780	4.597	2.978	3.015	3.287	5.404
1987	3.324	7.556	5.203	4.732	3.020	3.023	3.407	5.594
1988	3.494	6.356	5.363	5.057	3.043	2.911	3.520	5.727
1989	3.731	6.872	5.596	5.033	3.068	2.870	3.718	5.932
1990	3.477	7.847	5.244	4.749	3.116	2.880	3.740	6.082
1991	3.147	6.822	4.698	4.454	3.072	2.968	3.826	6.292
1992	3.488	7.073	4.845	4.474	3.063	3.152	3.830	6.332
1993	3.719	7.475	5.372	4.530	3.098	3.354	3.892	6.517
1994	3.964	7.254	6.186	5.119	3.173	3.524	3.999	6.667
1995	4.410	7.110	7.365	5.721	3.220	3.658	4.098	6.884
1996	4.716	8.770	6.806	5.328	3.183	3.747	4.169	7.037
1997	4.461	9.008	6.779	5.289	3.123	3.838	4.198	7.220
1998	4.384	7.352	7.029	5.133	3.132	4.057	4.260	7.346
1999	4.319	9.260	7.128	5.034	3.088	4.037	4.317	7.462
2000	4.375	15.289	7.165	5.392	3.069	4.028	4.363	7.725
2001	4.626	15.720	7.302	5.320	3.092	4.172	4.439	7.748
2002	4.634	13.379	6.823	5.269	3.106	4.211	4.465	7.872
2003	4.532	16.642	6.336	5.248	2.980	3.845	4.474	7.936
2004	4.469	18.363	6.823	5.799	2.920	3.670	4.487	8.100
2005	4.148	23.473	6.447	6.118	2.875	3.462	4.512	8.295
2006	4.094	22.976	6.086	6.857	2.827	3.312	4.540	8.448
2007	4.377	23.072	5.718	7.408	2.792	3.166	4.549	8.589
2008	5.176	31.124	5.839	7.884	2.815	3.245	4.563	9.000
2009	4.746	20.280	5.491	7.079	2.943	3.460	4.653	9.047
2010	4.518	22.396	5.677	7.764	2.842	3.231	4.651	9.114
2011	5.116	25.917	5.666	8.776	2.839	3.190	4.680	9.397
Compound Annual Growth Rates, per cent								
1961-2011	3.32	6.73	3.53	4.44	2.11	2.35	3.13	4.58
2000-2011	1.43	4.91	-2.11	4.53	-0.71	-2.10	0.64	1.80
1961-1973	4.29	2.79	4.09	3.41	3.25	1.44	1.94	4.97
1973-1981	10.07	31.18	11.86	14.93	7.17	9.28	8.93	10.39
1981-1989	0.56	-6.92	4.40	1.27	2.31	2.19	5.10	5.22
1989-2000	1.46	7.54	2.27	0.63	0.00	3.13	1.46	2.43
2000-2008	2.12	9.29	-2.53	4.86	-1.07	-2.67	0.56	1.93
2008-2011	-0.39	-5.92	-1.00	3.64	0.28	-0.57	0.85	1.45

Appendix Table 6
Quantity Aggregates for Eight Commodity Classes of Exports, 1961-2011

	Q_8	Q_9	Q_{10}	Q_{11}	Q_{12}	Q_{13}	Q_{14}	Q_{15}
	Agricultural and Fish Products	Energy Products	Forest Products	Industrial Goods and Materials (excluding energy and forest products)	Machinery and Equipment (excluding automotive products)	Automotive Products	Other Consumer Goods (excluding automotive products)	Services
Year				(millions, 1961 dollars)				
1961	1,432	252	1,574	2,057	402	50	64	1,036
1962	1,329	364	1,593	2,130	512	63	78	1,132
1963	1,572	364	1,685	2,243	582	94	91	1,204
1964	1,964	409	1,835	2,532	793	188	102	1,286
1965	1,799	426	1,870	2,721	791	348	112	1,360
1966	1,954	484	1,965	2,809	911	986	136	1,492
1967	1,613	579	1,928	2,998	1,147	1,620	147	1,865
1968	1,590	657	2,127	3,283	1,240	2,534	183	1,499
1969	1,493	757	2,291	3,091	1,378	3,182	215	1,657
1970	1,968	951	2,339	3,676	1,437	3,138	236	1,767
1971	2,168	1,154	2,374	3,611	1,437	3,614	243	1,747
1972	2,269	1,480	2,662	3,708	1,663	4,002	271	1,721
1973	2,217	1,790	2,826	4,086	1,951	4,539	320	1,893
1974	1,778	1,508	2,810	3,986	2,089	4,431	324	2,095
1975	1,880	1,216	2,186	3,513	2,165	4,555	290	1,998
1976	2,048	978	2,718	3,824	2,326	5,499	311	2,049
1977	2,445	920	3,001	3,955	2,345	6,388	338	2,052
1978	2,525	938	3,313	4,281	2,915	6,954	405	2,273
1979	2,538	1,102	3,370	4,293	3,881	6,004	507	2,556
1980	2,786	952	3,287	4,634	4,469	5,002	571	2,658
1981	2,924	950	3,127	4,529	4,810	5,586	548	2,738
1982	3,143	1,010	2,962	4,134	4,587	6,388	525	2,508
1983	3,256	1,079	3,284	4,170	4,413	7,748	547	2,535
1984	3,300	1,210	3,501	4,965	5,762	10,115	652	2,685
1985	2,979	1,461	3,545	5,179	6,361	10,539	666	2,839
1986	3,178	1,417	3,709	5,607	6,826	10,494	767	3,254
1987	3,566	1,701	4,031	5,791	6,884	10,541	776	3,295
1988	3,527	2,009	4,025	6,316	7,121	11,928	799	3,546
1989	3,102	1,997	3,836	6,413	7,810	11,839	709	3,704
1990	3,831	1,779	3,878	6,765	9,260	12,042	895	3,857
1991	4,169	2,068	3,958	7,016	9,537	10,950	908	3,893
1992	4,397	2,185	4,132	7,238	10,413	12,087	1,167	4,157
1993	4,343	2,375	4,352	7,774	11,895	14,491	1,441	4,519
1994	4,746	2,647	4,709	8,302	14,403	16,350	1,776	5,093
1995	4,754	2,868	4,989	8,896	17,402	17,200	2,030	5,396
1996	4,913	2,971	5,073	9,822	19,457	16,913	2,279	5,851
1997	5,554	3,017	5,178	10,709	22,070	18,100	2,555	6,264
1998	5,712	3,239	5,042	11,526	25,770	19,342	2,950	7,085
1999	5,930	3,226	5,623	11,889	28,713	24,098	3,240	7,400
2000	6,309	3,477	5,970	12,609	35,854	24,300	3,484	7,937
2001	6,718	3,548	5,517	12,744	33,170	22,176	3,674	7,967
2002	6,662	3,687	5,459	13,318	31,257	22,958	3,960	8,276
2003	6,450	3,637	5,448	12,730	29,761	22,728	3,842	7,983
2004	6,864	3,709	5,777	13,443	31,201	24,629	3,848	8,269
2005	7,256	3,703	5,653	13,762	32,346	25,419	3,801	8,345
2006	7,697	3,778	5,495	13,739	32,989	24,756	3,923	8,300
2007	7,937	3,957	5,119	14,144	33,463	24,325	4,119	8,335
2008	7,894	4,040	4,343	14,121	32,756	18,847	3,982	8,257
2009	7,847	3,937	3,556	11,180	27,240	12,664	3,854	7,758
2010	8,176	4,058	3,849	12,429	26,771	17,572	3,532	8,042
2011	8,022	4,327	3,951	13,322	28,392	18,592	3,494	8,243
Compound Annual Growth Rates, per cent								
1961-2011	3.51	5.85	1.86	3.81	8.89	12.56	8.34	4.24
2000-2011	2.21	2.01	-3.68	0.50	-2.10	-2.40	0.03	0.34
1961-1973	3.71	17.73	5.00	5.88	14.06	45.58	14.39	5.15
1973-1981	3.52	-7.61	1.27	1.30	11.94	2.63	6.97	4.72
1981-1989	0.74	9.73	2.59	4.44	6.25	9.84	3.27	3.85
1989-2000	6.67	5.17	4.10	6.34	14.86	6.76	15.57	7.17
2000-2008	2.84	1.89	-3.90	1.43	-1.12	-3.13	1.68	0.50
2008-2011	0.54	2.32	-3.10	-1.92	-4.65	-0.45	-4.26	-0.06

Appendix Table 7

Price Indexes for Seven Commodity Classes of Imports, 1961-2011

	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}
	Agricultural and Fish Products	Energy Products	Industrial goods and Materials (including imports of forest products but excluding imports of energy products)	Machinery and Equipment (excluding automotive products)	Automotive Products	Other Consumer Goods	Services
Year	(index, 1961=1.000)						
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.037	1.029	1.044	1.086	1.052	1.001	1.052
1963	1.300	1.010	1.082	1.093	1.070	1.010	1.079
1964	1.284	1.005	1.109	1.099	1.094	1.025	1.098
1965	1.080	1.025	1.137	1.131	1.076	1.030	1.136
1966	1.060	1.054	1.141	1.161	1.093	1.045	1.170
1967	1.031	0.990	1.170	1.195	1.123	1.062	1.226
1968	1.067	1.048	1.161	1.213	1.160	1.080	1.288
1969	1.079	1.006	1.194	1.237	1.189	1.104	1.369
1970	1.142	1.016	1.206	1.237	1.201	1.109	1.429
1971	1.172	1.117	1.173	1.267	1.240	1.115	1.499
1972	1.259	1.203	1.169	1.280	1.270	1.158	1.540
1973	1.558	1.435	1.308	1.330	1.296	1.216	1.633
1974	1.932	4.222	1.712	1.466	1.407	1.338	1.751
1975	2.032	5.434	1.889	1.721	1.635	1.492	1.981
1976	1.898	5.634	1.904	1.719	1.715	1.558	2.044
1977	2.299	6.421	2.140	1.854	1.932	1.754	2.341
1978	2.578	7.148	2.499	1.893	2.210	2.013	2.698
1979	2.916	9.229	3.055	2.022	2.444	2.239	3.042
1980	3.205	14.045	3.569	1.798	2.718	2.566	3.393
1981	3.370	16.895	3.723	1.685	3.264	2.813	3.816
1982	3.249	16.654	3.761	1.808	3.525	2.913	4.104
1983	3.195	15.354	3.788	1.750	3.624	2.958	4.308
1984	3.446	15.577	3.975	1.818	3.824	3.224	4.638
1985	3.368	16.060	3.933	1.852	4.026	3.348	4.989
1986	3.615	10.456	4.047	1.880	4.202	3.599	5.293
1987	3.540	10.916	4.061	1.795	4.157	3.631	5.289
1988	3.630	9.091	4.209	1.736	4.035	3.638	5.093
1989	3.597	9.696	4.232	1.702	4.089	3.671	5.094
1990	3.597	11.945	4.174	1.683	4.164	3.725	5.249
1991	3.587	10.193	4.036	1.653	4.127	3.752	5.317
1992	3.592	10.162	4.125	1.712	4.395	3.969	5.634
1993	3.666	9.840	4.312	1.818	4.681	4.280	6.198
1994	3.978	9.836	4.638	1.912	4.991	4.580	6.682
1995	4.253	10.177	5.092	1.892	5.157	4.756	6.902
1996	4.212	11.943	4.913	1.805	5.198	4.735	7.013
1997	4.366	11.847	4.944	1.780	5.261	4.789	7.261
1998	4.356	9.765	5.093	1.831	5.517	5.119	7.802
1999	4.242	11.435	5.014	1.793	5.521	5.137	7.975
2000	4.247	16.953	5.212	1.763	5.524	5.179	8.185
2001	4.395	16.323	5.394	1.796	5.670	5.409	8.646
2002	4.453	16.808	5.333	1.794	5.734	5.422	8.846
2003	4.290	18.583	5.019	1.600	5.396	4.924	8.396
2004	4.190	21.359	5.209	1.480	5.214	4.590	8.241
2005	4.094	27.042	5.296	1.390	5.003	4.409	8.158
2006	3.986	30.135	5.508	1.322	4.849	4.227	8.132
2007	4.095	30.847	5.398	1.260	4.631	4.036	8.098
2008	4.484	40.536	5.902	1.276	4.591	4.143	8.408
2009	4.654	27.569	5.704	1.389	4.842	4.528	8.660
2010	4.390	32.838	5.634	1.257	4.645	4.200	8.200
2011	4.501	40.354	5.974	1.209	4.560	4.180	8.211
Compound Annual Growth Rates, per cent							
1961-2011	3.05	7.68	3.64	0.38	3.08	2.90	4.30
2000-2011	0.53	8.20	1.25	-3.37	-1.73	-1.93	0.03
1961-1973	3.76	3.06	2.26	2.40	2.18	1.64	4.17
1973-1981	10.12	36.10	13.97	3.00	12.24	11.05	11.19
1981-1989	0.82	-6.71	1.61	0.13	2.86	3.38	3.68
1989-2000	1.52	5.21	1.91	0.32	2.77	3.18	4.41
2000-2008	0.68	11.51	1.57	-3.96	-2.29	-2.75	0.34
2008-2011	0.13	-0.15	0.40	-1.78	-0.23	0.30	-0.79

Appendix Table 8
Quantity Aggregates for Seven Commodity Classes of Imports, 1961-2011

	Q_{16}	Q_{17}	Q_{18}	Q_{19t}	Q_{20}	Q_{21}	Q_{22}
	Agricultural and Fish Products	Energy Products	Industrial goods and Materials (including imports of forest products but excluding imports of energy products)	Machinery and Equipment (excluding automotive products)	Automotive Products	Other Consumer Goods	Services
Year	(millions, 1961 dollars)						
1961	720	478	1,617	1,609	615	659	1,535
1962	735	481	1,684	1,572	699	710	1,480
1963	687	542	1,707	1,563	707	699	1,467
1964	709	548	1,955	1,829	857	736	1,619
1965	817	583	2,170	2,099	1,157	829	1,693
1966	898	593	2,331	2,471	1,573	933	1,850
1967	950	639	2,210	2,690	1,964	970	1,935
1968	986	686	2,384	2,741	2,650	1,084	2,014
1969	1,129	738	2,668	3,079	3,031	1,277	2,337
1970	1,119	766	2,659	3,102	2,759	1,276	2,472
1971	1,131	817	2,937	3,246	3,249	1,443	2,476
1972	1,245	896	3,371	3,891	3,819	1,758	2,586
1973	1,421	928	3,656	4,694	4,619	2,033	2,888
1974	1,464	789	4,146	5,558	4,931	2,310	3,278
1975	1,465	766	3,559	5,272	4,955	2,258	3,550
1976	1,696	720	3,652	5,411	5,417	2,621	3,971
1977	1,614	654	3,637	5,518	5,865	2,573	3,883
1978	1,637	626	3,933	6,688	5,919	2,612	3,824
1979	1,622	625	4,443	8,152	6,097	2,752	3,637
1980	1,680	599	4,299	10,726	4,900	2,637	3,760
1981	1,744	574	4,514	13,412	4,800	2,722	3,860
1982	1,674	405	3,624	10,470	4,129	2,527	3,595
1983	1,736	336	4,178	11,847	5,142	2,822	3,690
1984	1,896	394	4,781	14,574	6,668	3,159	3,775
1985	1,915	395	5,291	15,289	7,684	3,110	3,905
1986	2,000	486	5,568	16,643	7,845	3,327	4,268
1987	2,088	542	5,616	18,560	7,844	3,490	4,536
1988	2,082	569	6,380	23,461	8,226	3,730	5,185
1989	2,295	642	6,684	25,439	7,813	4,092	5,793
1990	2,430	686	6,624	25,497	7,319	4,256	6,406
1991	2,510	650	6,419	25,942	7,502	4,428	6,664
1992	2,710	637	6,950	27,260	7,664	4,773	6,739
1993	3,005	708	7,822	29,208	8,533	4,993	6,865
1994	3,162	708	8,839	34,377	9,583	5,118	6,755
1995	3,145	711	9,349	40,020	9,713	5,371	6,763
1996	3,356	804	9,851	42,310	9,832	5,457	7,111
1997	3,585	897	11,520	51,315	11,562	6,215	7,375
1998	3,961	884	12,330	55,221	12,105	6,754	7,367
1999	4,162	936	12,947	60,379	13,754	7,203	7,684
2000	4,369	1,053	13,875	69,709	14,017	7,747	8,114
2001	4,635	1,087	13,221	62,337	12,799	7,931	7,954
2002	4,890	986	13,506	59,066	14,208	8,572	8,091
2003	5,014	1,066	13,605	61,665	14,176	9,404	8,831
2004	5,107	1,160	14,720	70,313	14,840	10,397	9,363
2005	5,384	1,245	15,423	79,792	15,667	11,225	9,858
2006	5,888	1,153	15,840	86,790	16,465	12,303	10,247
2007	6,236	1,209	16,365	92,508	17,264	13,574	11,036
2008	6,359	1,312	16,086	96,094	15,674	13,905	11,284
2009	6,306	1,231	13,579	77,689	11,426	12,704	10,537
2010	6,738	1,235	15,900	90,579	14,794	13,755	11,564
2011	7,250	1,289	16,827	103,132	15,631	14,263	12,283
Compound Annual Growth Rates, per cent							
1961-2011	4.73	2.00	4.80	8.68	6.68	6.34	4.25
2000-2011	4.71	1.86	1.77	3.62	1.00	5.71	3.84
1961-1973	5.82	5.69	7.03	9.33	18.30	9.84	5.41
1973-1981	2.59	-5.84	2.67	14.02	0.48	3.71	3.69
1981-1989	3.50	1.41	5.03	8.33	6.28	5.23	5.20
1989-2000	6.03	4.61	6.87	9.60	5.46	5.97	3.11
2000-2008	4.80	2.78	1.86	4.09	1.41	7.59	4.21
2008-2011	4.46	-0.58	1.51	2.38	-0.09	0.85	2.87

Appendix Table 9
Price Indexes for 12 Types of Business Sector Labour

	P_{L1}	P_{L2}	P_{L3}	P_{L4}	P_{L5}	P_{L6}	P_{L7}	P_{L8}	P_{L9}	P_{L10}	P_{L11}	P_{L12}
	Primary or Secondary Education				Some or Completed Non-University Post-Secondary Education				Completed University Degrees or Above			
	Paid Worker		Self Employed		Paid Worker		Self Employed		Paid Worker		Self Employed	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Year	(index, 1961=1.000)											
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.009	1.015	1.220	1.161	1.192	1.262	1.307	1.397	1.024	1.067	1.005	1.224
1963	1.043	1.040	1.254	1.186	1.251	1.299	1.370	1.410	1.067	1.104	1.028	1.269
1964	1.089	1.073	1.303	1.220	1.280	1.310	1.403	1.372	1.117	1.166	1.062	1.238
1965	1.163	1.136	1.454	1.313	1.323	1.351	1.517	1.403	1.192	1.217	1.134	1.239
1966	1.250	1.210	1.532	1.366	1.371	1.400	1.529	1.389	1.292	1.269	1.207	1.237
1967	1.352	1.269	1.605	1.420	1.418	1.427	1.564	1.405	1.372	1.330	1.280	1.257
1968	1.450	1.340	1.748	1.503	1.461	1.466	1.623	1.433	1.474	1.471	1.365	1.279
1969	1.580	1.445	1.864	1.595	1.529	1.543	1.674	1.494	1.596	1.550	1.521	1.384
1970	1.699	1.524	1.985	1.667	1.581	1.592	1.698	1.531	1.697	1.583	1.643	1.479
1971	1.815	1.658	2.047	2.208	1.760	1.776	1.888	1.910	1.630	1.675	1.659	1.617
1972	1.975	1.838	2.232	2.884	1.915	1.953	2.082	2.344	1.618	1.720	1.724	1.807
1973	2.183	2.022	2.531	3.762	2.072	2.100	2.325	2.873	1.632	1.697	1.821	2.051
1974	2.560	2.349	2.968	4.935	2.356	2.376	2.610	3.519	1.786	1.824	2.028	2.362
1975	3.024	2.694	3.390	6.162	2.677	2.666	2.833	4.177	1.974	1.968	2.375	2.811
1976	3.549	3.110	4.103	7.942	3.002	2.970	3.174	5.060	2.144	2.083	2.578	3.234
1977	3.931	3.493	4.573	9.745	3.228	3.240	3.412	5.926	2.162	2.125	2.835	3.729
1978	4.082	3.731	4.807	11.025	3.348	3.472	3.485	6.542	2.360	2.380	2.953	4.161
1979	4.352	4.069	4.980	12.540	3.570	3.809	3.516	7.230	2.609	2.694	3.055	4.600
1980	4.771	4.468	5.519	15.104	3.943	4.357	3.862	9.051	2.800	3.039	3.391	5.648
1981	5.378	4.968	5.725	15.287	4.396	4.865	3.970	9.416	3.500	3.813	3.872	6.759
1982	6.132	5.431	5.539	14.450	4.943	5.267	3.942	9.761	3.711	3.770	4.361	7.164
1983	6.109	5.785	5.251	14.691	5.227	5.924	3.979	10.766	4.036	4.325	4.416	8.137
1984	6.496	6.279	5.706	16.817	5.324	6.144	4.003	11.987	4.267	4.593	4.708	8.749
1985	6.842	6.431	5.969	17.752	5.712	6.378	4.118	12.404	4.585	4.630	5.028	9.134
1986	6.878	6.754	6.995	22.097	5.759	6.776	4.643	14.567	4.842	5.254	5.105	10.417
1987	7.283	7.124	6.260	20.249	5.918	7.068	4.324	13.700	4.873	5.376	5.328	10.414
1988	7.810	7.520	7.819	25.535	6.328	7.467	5.074	16.155	5.088	5.550	5.584	10.910
1989	8.011	7.892	7.004	23.632	6.544	7.896	4.772	15.506	6.094	6.820	5.958	12.040
1990	8.010	7.842	7.246	24.708	7.292	8.273	5.305	17.186	6.395	7.383	5.930	13.332
1991	8.163	8.301	6.893	26.891	7.547	8.890	5.108	18.397	7.285	8.505	5.956	14.575
1992	8.257	8.751	6.803	31.148	7.632	9.545	5.035	20.702	7.233	9.002	5.597	16.128
1993	8.445	8.815	7.023	31.951	7.551	9.488	4.827	20.498	7.141	8.519	5.309	14.649
1994	8.398	8.853	6.577	32.818	7.563	9.516	4.637	20.035	6.886	8.250	5.032	14.520
1995	8.584	8.667	8.097	36.590	7.743	9.717	5.297	22.461	7.086	7.783	5.002	14.271
1996	8.668	8.796	8.801	36.731	7.683	9.762	5.361	21.294	7.197	9.357	4.796	15.722
1997	8.925	9.042	8.237	33.228	7.930	10.019	5.487	20.198	8.168	9.701	4.356	13.636
1998	9.196	9.221	8.650	32.616	8.181	10.285	5.606	19.544	8.563	10.132	4.492	13.415
1999	9.344	9.399	9.545	35.034	8.382	10.410	5.989	20.542	8.945	10.484	4.668	13.889
2000	9.832	9.858	10.141	36.745	8.753	10.987	6.564	22.646	9.324	10.997	5.118	15.164
2001	10.021	10.040	9.554	36.529	9.027	11.346	6.422	23.059	9.714	11.511	5.577	17.260
2002	10.138	10.186	9.533	36.988	9.147	11.477	6.496	23.964	9.975	11.770	6.064	17.780
2003	10.390	10.457	9.469	37.826	9.367	11.777	6.531	24.565	9.998	11.990	6.038	18.525
2004	10.725	10.822	9.897	38.532	9.567	12.286	6.689	24.623	10.295	12.364	6.162	18.088
2005	11.335	11.487	10.350	43.423	9.983	12.708	7.027	27.600	10.568	12.682	6.351	19.490
2006	11.927	11.871	11.189	40.929	10.466	13.339	7.309	25.304	11.211	13.405	6.141	18.436
2007	12.235	12.248	12.142	42.611	10.870	13.902	7.938	26.417	11.457	13.741	6.386	18.342
2008	12.610	12.590	12.475	43.633	11.204	14.114	8.263	26.351	11.781	13.824	6.501	18.423
2009	12.686	13.015	12.785	44.922	11.316	14.626	8.327	27.479	11.881	14.406	6.737	19.011
2010	12.991	13.565	13.343	46.131	11.437	14.916	8.435	27.282	11.876	14.508	6.529	19.098
2011	13.269	14.160	14.355	48.387	11.681	15.570	9.075	28.616	12.130	15.144	7.024	20.031
Compound Annual Growth Rates, per cent												
1961-2011	5.31	5.44	5.47	8.07	5.04	5.64	4.51	6.94	5.12	5.59	3.98	6.18
2000-2011	2.76	3.35	3.21	2.53	2.66	3.22	2.99	2.15	2.42	2.95	2.92	2.56
1961-1973	6.72	6.04	8.05	11.67	6.26	6.38	7.28	9.19	4.17	4.51	5.12	6.17
1973-1981	11.93	11.89	10.74	19.16	9.86	11.07	6.92	16.00	10.01	10.65	9.89	16.08
1981-1989	5.11	5.96	2.55	5.60	5.10	6.24	2.33	6.43	7.18	7.54	5.53	7.48
1989-2000	1.88	2.04	3.42	4.09	2.68	3.05	2.94	3.50	3.94	4.44	-1.37	2.12
2000-2008	3.16	3.10	2.62	2.17	3.13	3.18	2.92	1.91	2.97	2.90	3.04	2.46
2008-2011	1.71	4.00	4.79	3.51	1.40	3.33	3.17	2.79	0.98	3.09	2.61	2.83

Appendix Table 10
Quantity Aggregates for 12 Types of Business Sector Labour, 1961-2011

	Q_{L1}	Q_{L2}	Q_{L3}	Q_{L4}	Q_{L5}	Q_{L6}	Q_{L7}	Q_{L8}	Q_{L9}	Q_{L10}	Q_{L11}	Q_{L12}
	Primary or Secondary Education				Some or Completed Non-University Post-Secondary Education				Completed University Degrees or Above			
	Paid Worker		Self Employed		Paid Worker		Self Employed		Paid Worker		Self Employed	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Year	(millions, 1961 dollars)											
1961	12,608	2,758	1,738	46	554	66	91	2	768	55	550	3
1962	12,796	2,835	1,678	48	934	144	114	5	809	65	567	4
1963	12,687	2,885	1,617	49	1,296	220	136	7	833	75	568	5
1964	12,847	2,985	1,578	50	1,683	299	161	9	877	83	594	6
1965	13,189	3,095	1,443	48	2,103	381	177	10	930	93	611	7
1966	13,433	3,203	1,469	49	2,544	463	212	13	991	104	673	8
1967	13,218	3,308	1,413	52	2,902	546	232	15	1,030	113	674	9
1968	12,944	3,359	1,287	52	3,228	621	239	17	1,053	118	641	9
1969	12,860	3,440	1,260	52	3,591	703	265	18	1,095	125	658	10
1970	12,573	3,458	1,159	51	3,889	771	280	20	1,119	133	679	11
1971	12,353	3,494	1,124	53	4,283	868	306	22	1,227	162	705	13
1972	12,268	3,595	1,047	50	4,729	982	326	23	1,362	194	689	15
1973	12,606	3,795	1,002	47	5,349	1,124	345	23	1,538	233	640	16
1974	12,550	3,892	1,006	49	5,832	1,241	389	26	1,676	265	678	19
1975	11,964	3,936	967	49	6,073	1,338	418	28	1,761	293	684	21
1976	11,575	3,947	902	47	6,367	1,415	434	30	1,839	316	618	21
1977	11,384	3,920	831	47	6,742	1,489	441	31	1,947	334	647	24
1978	11,430	4,091	805	50	7,297	1,618	486	35	2,090	365	695	28
1979	11,653	4,340	793	51	8,031	1,792	539	38	2,322	409	729	31
1980	11,511	4,591	724	47	8,557	1,955	540	39	2,502	448	752	35
1981	11,494	4,662	757	48	8,773	2,132	566	39	2,689	524	729	37
1982	10,533	4,404	741	48	8,162	2,144	547	41	2,544	535	780	43
1983	10,446	4,329	748	49	8,190	2,219	550	44	2,535	556	834	51
1984	10,597	4,385	756	50	8,473	2,389	568	48	2,701	627	945	68
1985	10,820	4,437	848	53	8,835	2,543	634	55	2,858	693	1,035	76
1986	11,039	4,634	794	48	9,253	2,761	620	51	3,111	811	1,042	74
1987	11,435	4,778	790	49	9,820	2,940	643	54	3,376	895	1,046	79
1988	11,663	4,942	792	49	10,315	3,132	664	57	3,650	995	1,112	90
1989	11,739	5,019	795	53	10,626	3,273	693	62	3,851	1,085	1,124	94
1990	11,383	4,984	798	57	10,578	3,402	695	64	4,045	1,110	1,080	85
1991	10,603	4,715	787	56	10,150	3,391	718	64	4,073	1,121	1,135	95
1992	10,216	4,498	779	59	10,019	3,399	703	68	4,184	1,244	1,199	91
1993	10,012	4,310	751	62	10,392	3,503	757	72	4,605	1,369	1,296	115
1994	10,133	4,194	767	61	11,237	3,719	775	88	4,870	1,504	1,335	125
1995	10,070	4,180	736	57	11,929	3,969	822	91	5,053	1,604	1,241	124
1996	10,207	4,145	730	62	12,259	4,153	915	103	5,218	1,716	1,403	138
1997	9,888	4,049	722	58	13,262	4,427	1,025	113	5,511	1,835	1,392	152
1998	9,748	4,183	758	60	13,563	4,665	1,029	119	5,864	1,984	1,540	174
1999	10,128	4,369	719	59	14,000	4,809	1,047	121	6,008	2,189	1,522	161
2000	10,229	4,536	690	55	14,539	4,996	982	115	6,405	2,393	1,479	179
2001	10,138	4,452	628	48	14,730	5,183	945	115	6,722	2,514	1,525	169
2002	10,221	4,519	589	49	15,090	5,259	940	116	6,931	2,538	1,470	170
2003	9,930	4,471	580	47	15,637	5,476	980	116	7,072	2,721	1,563	170
2004	10,119	4,547	588	47	16,144	5,656	991	117	7,538	2,882	1,581	180
2005	10,194	4,455	589	47	16,145	5,582	927	118	7,984	3,194	1,489	187
2006	10,286	4,573	565	45	16,265	5,615	901	115	8,399	3,294	1,603	198
2007	10,256	4,455	567	46	16,713	5,836	967	123	8,773	3,500	1,606	212
2008	10,222	4,448	554	44	16,933	5,906	933	120	8,881	3,641	1,597	202
2009	9,392	4,109	535	44	16,059	5,779	888	123	8,817	3,640	1,539	217
2010	9,507	4,086	509	41	16,812	5,763	890	122	9,143	3,855	1,573	227
2011	9,776	4,111	503	41	17,288	5,799	879	123	9,402	3,879	1,554	230
Compound Annual Growth Rates, per cent												
1961-2011	-0.51	0.80	-2.45	-0.25	7.12	9.38	4.64	8.29	5.14	8.87	2.10	9.06
2000-2011	-0.41	-0.89	-2.83	-2.70	1.59	1.36	-1.00	0.63	3.55	4.49	0.45	2.30
1961-1973	0.00	2.69	-4.49	0.12	20.80	26.72	11.74	21.33	5.96	12.70	1.26	14.67
1973-1981	-1.15	2.61	-3.45	0.31	6.38	8.33	6.37	6.56	7.23	10.69	1.64	11.64
1981-1989	0.26	0.93	0.63	1.12	2.42	5.50	2.55	5.91	4.59	9.52	5.56	12.18
1989-2000	-1.24	-0.91	-1.28	0.44	2.89	3.92	3.23	5.86	4.73	7.45	2.53	6.05
2000-2008	-0.01	-0.24	-2.71	-2.78	1.92	2.11	-0.64	0.50	4.17	5.39	0.97	1.52
2008-2011	-1.47	-2.60	-3.16	-2.47	0.69	-0.61	-1.96	0.96	1.92	2.13	-0.91	4.41

Appendix Table 11
Smoothed Depreciation Rates for 14 Business Sector Reproducible Assets, 1961-2011

	δ_1	δ_2	δ_3	δ_4	δ_5	δ_6	δ_7	δ_8	δ_9	δ_{10}	δ_{11}	δ_{12}	δ_{13}	δ_{14}
	Office Furniture	Ag. Machinery	Industrial Machinery	Automo-biles	Trucks	Other Transport Equipment	Other Machinery and Equipment	Computers	Telecom Equipment	Software	Industrial Buildings	Comml. Buildings	Inst. Buildings	Engineer-ing Construc-tion
Year							(depreciation rates)							
1961	0.132	0.278	0.163	0.307	0.230	0.135	0.102	0.279	0.145	0.284	0.074	0.061	0.045	0.066
1962	0.132	0.278	0.163	0.307	0.230	0.135	0.102	0.279	0.145	0.284	0.074	0.061	0.045	0.066
1963	0.131	0.288	0.166	0.314	0.235	0.136	0.102	0.286	0.147	0.284	0.074	0.061	0.045	0.066
1964	0.130	0.297	0.170	0.321	0.241	0.138	0.102	0.292	0.149	0.284	0.075	0.062	0.045	0.067
1965	0.129	0.303	0.174	0.332	0.246	0.142	0.102	0.299	0.151	0.284	0.077	0.062	0.045	0.067
1966	0.130	0.305	0.176	0.345	0.251	0.146	0.101	0.300	0.153	0.284	0.077	0.062	0.045	0.068
1967	0.132	0.303	0.175	0.352	0.257	0.147	0.101	0.301	0.153	0.284	0.077	0.062	0.045	0.068
1968	0.135	0.298	0.173	0.358	0.261	0.148	0.102	0.305	0.153	0.284	0.076	0.062	0.045	0.069
1969	0.137	0.293	0.174	0.364	0.266	0.148	0.102	0.309	0.152	0.284	0.076	0.062	0.045	0.070
1970	0.139	0.294	0.175	0.367	0.271	0.150	0.103	0.316	0.153	0.284	0.077	0.062	0.045	0.071
1971	0.139	0.301	0.176	0.374	0.277	0.152	0.103	0.323	0.154	0.284	0.077	0.062	0.045	0.071
1972	0.137	0.315	0.176	0.394	0.283	0.156	0.102	0.331	0.155	0.284	0.076	0.063	0.045	0.072
1973	0.135	0.331	0.179	0.415	0.289	0.163	0.101	0.339	0.158	0.284	0.077	0.063	0.045	0.072
1974	0.136	0.342	0.180	0.431	0.294	0.169	0.101	0.348	0.161	0.284	0.077	0.064	0.045	0.073
1975	0.140	0.349	0.180	0.435	0.298	0.172	0.101	0.358	0.163	0.284	0.077	0.064	0.045	0.073
1976	0.145	0.349	0.179	0.434	0.301	0.171	0.102	0.372	0.162	0.284	0.077	0.064	0.045	0.074
1977	0.148	0.345	0.179	0.434	0.301	0.172	0.103	0.391	0.160	0.284	0.077	0.064	0.045	0.074
1978	0.152	0.343	0.178	0.442	0.301	0.176	0.105	0.415	0.159	0.284	0.077	0.064	0.045	0.075
1979	0.157	0.343	0.179	0.448	0.300	0.180	0.107	0.443	0.159	0.284	0.078	0.063	0.045	0.076
1980	0.163	0.343	0.181	0.456	0.299	0.183	0.110	0.459	0.160	0.284	0.079	0.063	0.046	0.077
1981	0.169	0.340	0.183	0.457	0.300	0.180	0.113	0.462	0.161	0.284	0.080	0.063	0.046	0.078
1982	0.176	0.338	0.182	0.465	0.301	0.175	0.115	0.463	0.161	0.284	0.079	0.063	0.046	0.079
1983	0.183	0.340	0.180	0.486	0.304	0.173	0.116	0.461	0.160	0.294	0.078	0.063	0.046	0.079
1984	0.192	0.348	0.179	0.508	0.308	0.176	0.119	0.469	0.161	0.303	0.078	0.064	0.046	0.080
1985	0.202	0.354	0.181	0.520	0.314	0.178	0.123	0.482	0.162	0.312	0.078	0.064	0.047	0.081
1986	0.212	0.358	0.184	0.530	0.320	0.179	0.128	0.490	0.164	0.319	0.078	0.064	0.047	0.081
1987	0.220	0.361	0.187	0.552	0.325	0.181	0.133	0.490	0.168	0.326	0.079	0.065	0.047	0.082
1988	0.223	0.364	0.190	0.569	0.328	0.187	0.137	0.486	0.172	0.333	0.079	0.065	0.047	0.082
1989	0.221	0.365	0.192	0.566	0.331	0.190	0.138	0.475	0.177	0.340	0.080	0.065	0.047	0.083
1990	0.217	0.362	0.191	0.531	0.333	0.189	0.138	0.473	0.182	0.345	0.080	0.065	0.048	0.083
1991	0.216	0.354	0.188	0.490	0.335	0.193	0.136	0.482	0.189	0.347	0.080	0.065	0.048	0.083
1992	0.219	0.355	0.186	0.463	0.337	0.193	0.133	0.497	0.196	0.351	0.080	0.064	0.048	0.083
1993	0.223	0.358	0.186	0.450	0.338	0.188	0.131	0.520	0.203	0.359	0.080	0.064	0.048	0.084
1994	0.225	0.355	0.189	0.433	0.340	0.185	0.131	0.541	0.210	0.367	0.081	0.064	0.048	0.085
1995	0.225	0.343	0.192	0.410	0.343	0.190	0.132	0.560	0.219	0.372	0.082	0.065	0.049	0.087
1996	0.229	0.337	0.195	0.384	0.346	0.195	0.134	0.579	0.233	0.377	0.084	0.065	0.049	0.088
1997	0.235	0.338	0.199	0.365	0.349	0.203	0.137	0.596	0.247	0.384	0.085	0.066	0.049	0.090
1998	0.238	0.335	0.202	0.356	0.350	0.210	0.140	0.604	0.263	0.390	0.086	0.066	0.050	0.091
1999	0.238	0.322	0.203	0.352	0.351	0.215	0.144	0.600	0.278	0.394	0.087	0.067	0.050	0.092
2000	0.241	0.308	0.204	0.340	0.353	0.219	0.150	0.581	0.291	0.399	0.088	0.068	0.051	0.094
2001	0.243	0.301	0.204	0.328	0.354	0.219	0.155	0.561	0.297	0.408	0.088	0.071	0.051	0.097
2002	0.247	0.298	0.205	0.322	0.355	0.215	0.159	0.552	0.298	0.417	0.088	0.073	0.052	0.098
2003	0.252	0.297	0.208	0.321	0.357	0.211	0.162	0.557	0.300	0.421	0.088	0.075	0.052	0.099
2004	0.258	0.300	0.213	0.317	0.359	0.214	0.165	0.566	0.303	0.425	0.088	0.077	0.053	0.101
2005	0.263	0.303	0.219	0.314	0.360	0.221	0.169	0.571	0.307	0.427	0.088	0.078	0.054	0.102
2006	0.265	0.307	0.224	0.314	0.359	0.230	0.173	0.568	0.309	0.430	0.088	0.078	0.054	0.104
2007	0.265	0.311	0.227	0.311	0.357	0.237	0.174	0.556	0.311	0.431	0.088	0.078	0.055	0.104
2008	0.262	0.309	0.227	0.302	0.355	0.236	0.173	0.541	0.312	0.427	0.088	0.078	0.055	0.105
2009	0.261	0.304	0.226	0.295	0.353	0.229	0.172	0.535	0.314	0.420	0.089	0.077	0.056	0.105
2010	0.262	0.301	0.227	0.295	0.351	0.228	0.173	0.539	0.318	0.417	0.089	0.077	0.057	0.104
2011	0.262	0.303	0.229	0.296	0.348	0.232	0.175	0.545	0.322	0.417	0.089	0.077	0.057	0.104
Average Depreciation Rates														
1961-2011	0.19	0.32	0.19	0.40	0.31	0.18	0.13	0.45	0.21	0.34	0.08	0.07	0.05	0.08
2001-2011	0.26	0.30	0.22	0.31	0.36	0.22	0.17	0.55	0.31	0.42	0.09	0.08	0.05	0.10
1961-1973	0.13	0.30	0.17	0.35	0.26	0.15	0.10	0.30	0.15	0.28	0.08	0.06	0.04	0.07
1974-1981	0.15	0.34	0.18	0.44	0.30	0.18	0.11	0.41	0.16	0.28	0.08	0.06	0.05	0.07
1982-1989	0.20	0.35	0.18	0.52	0.32	0.18	0.13	0.48	0.17	0.31	0.08	0.06	0.05	0.08
1990-2000	0.23	0.34	0.19	0.42	0.34	0.20	0.14	0.55	0.23	0.37	0.08	0.07	0.05	0.09
2001-2008	0.26	0.30	0.22	0.32	0.36	0.22	0.17	0.56	0.30	0.42	0.09	0.08	0.05	0.10
2009-2011	0.26	0.30	0.23	0.30	0.35	0.23	0.17	0.54	0.32	0.42	0.09	0.08	0.06	0.10

Appendix Table 12

Price Indexes for 19 Capital Stock Components, 1961-2011 (beginning of the year estimates)

Year	P_{K1} Office Furniture	P_{K2} Ag. Machinery	P_{K3} Industrial Machinery	P_{K4} Automo-biles	P_{K5} Trucks	P_{K6} Other Transport Equip-ment	P_{K7} Other Machin-ery and Equip-ment	P_{K8} Comput-ers	P_{K9} Telecom Equip-ment	P_{K10} Software	P_{K11} Industrial Buildings	P_{K12} Comml. Buildings	P_{K13} Inst. Buildings	P_{K14} Engineer-ing Construc-tion	P_{K15} Inventory Change	P_{K16} Ag. Land	P_{K17} Business Non-ag. Land	P_{K18} Household Res. Land	P_{K19} Res. Structures
	(index, 1961=1.000)																		
1961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.011	1.057	1.001	0.973	1.020	1.006	1.029	0.964	0.998	1.000	0.996	0.995	0.994	1.016	1.008	1.040	1.070	1.070	1.005
1963	1.068	1.080	1.040	0.970	1.021	1.006	1.087	1.017	0.983	1.000	1.013	1.012	1.010	1.049	1.010	1.100	1.142	1.131	1.028
1964	1.024	1.083	1.097	0.973	1.041	1.076	1.059	0.997	0.989	1.000	1.027	1.028	1.028	1.088	1.021	1.220	1.230	1.175	1.073
1965	1.051	1.100	1.153	0.967	1.047	1.094	1.108	1.054	1.004	1.000	1.077	1.073	1.072	1.158	1.040	1.360	1.339	1.281	1.134
1966	1.050	1.131	1.178	0.964	1.058	1.116	1.129	1.025	1.025	1.000	1.146	1.146	1.143	1.220	1.063	1.520	1.509	1.402	1.208
1967	1.093	1.180	1.163	0.976	1.073	1.134	1.124	1.052	1.083	1.000	1.194	1.189	1.186	1.274	1.080	1.720	1.721	1.532	1.285
1968	1.099	1.222	1.163	1.002	1.111	1.170	1.107	1.059	1.139	1.000	1.195	1.187	1.180	1.296	1.093	1.900	1.904	1.659	1.314
1969	1.118	1.281	1.203	1.005	1.137	1.229	1.113	1.060	1.194	1.000	1.249	1.243	1.247	1.369	1.118	1.940	2.064	1.857	1.381
1970	1.154	1.307	1.292	1.024	1.163	1.274	1.173	1.082	1.269	1.000	1.311	1.307	1.306	1.440	1.144	1.960	2.308	2.072	1.426
1971	1.229	1.318	1.322	1.042	1.194	1.343	1.245	1.100	1.304	1.000	1.376	1.376	1.386	1.533	1.159	2.000	2.575	2.294	1.532
1972	1.224	1.366	1.370	1.061	1.229	1.403	1.244	1.101	1.374	1.000	1.439	1.485	1.427	1.626	1.212	2.160	2.920	2.627	1.673
1973	1.212	1.415	1.460	1.055	1.266	1.406	1.264	1.112	1.432	1.000	1.671	1.632	1.706	1.763	1.326	2.620	3.378	3.074	1.971
1974	1.281	1.591	1.691	1.123	1.410	1.544	1.438	1.088	1.548	1.000	2.016	1.978	2.001	2.080	1.438	3.420	4.097	3.748	2.361
1975	1.383	1.848	2.017	1.195	1.507	1.743	1.681	1.128	1.698	1.000	2.151	2.231	2.143	2.399	1.559	4.340	5.140	4.453	2.561
1976	1.398	1.956	2.167	1.242	1.609	1.885	1.726	1.006	1.811	1.000	2.252	2.282	2.215	2.627	1.664	5.140	6.113	5.001	2.769
1977	1.393	2.079	2.404	1.349	1.786	2.130	1.833	0.877	1.945	1.000	2.337	2.336	2.337	2.830	1.783	5.920	6.867	5.541	2.878
1978	1.324	2.361	2.723	1.468	1.996	2.375	1.964	0.626	2.330	1.000	2.483	2.442	2.454	3.075	1.941	7.020	7.740	6.221	3.041
1979	1.403	2.681	3.068	1.627	2.245	2.646	2.137	0.548	2.480	1.000	2.727	2.627	2.704	3.373	2.152	8.680	8.753	6.894	3.280
1980	1.408	3.034	3.460	1.786	2.490	2.924	2.287	0.391	2.506	1.000	3.050	2.921	2.981	3.729	2.359	10.940	10.132	7.828	3.555
1981	1.484	3.275	3.882	2.000	2.758	3.284	2.531	0.324	2.511	1.000	3.350	3.373	3.264	4.174	2.578	12.300	11.805	9.462	3.993
1982	1.554	3.429	4.204	2.069	2.919	3.554	2.722	0.314	2.774	1.047	3.606	3.649	3.533	4.574	2.779	12.280	13.596	11.125	4.082
1983	1.490	3.578	4.291	2.129	3.039	3.794	2.716	0.219	2.954	1.042	3.701	3.632	3.558	4.740	2.932	12.007	14.679	10.977	4.254
1984	1.474	3.686	4.528	2.201	3.219	4.069	2.790	0.187	3.071	1.035	3.725	3.584	3.549	4.925	3.067	11.475	15.069	11.894	4.418
1985	1.501	3.720	4.780	2.301	3.440	4.374	2.900	0.154	3.151	1.041	3.866	3.671	3.615	5.078	3.150	10.771	15.919	13.045	4.556
1986	1.514	3.817	4.984	2.473	3.640	4.502	2.959	0.127	3.246	0.998	4.074	3.823	3.753	5.169	3.182	9.983	16.602	13.369	4.908
1987	1.516	3.797	4.977	2.493	3.688	4.510	2.939	0.104	3.280	0.986	4.310	4.047	3.922	5.246	3.231	9.386	17.788	15.515	5.408
1988	1.523	3.818	4.919	2.523	3.780	4.437	2.911	0.094	3.255	0.956	4.549	4.280	4.140	5.463	3.287	9.223	19.231	18.330	5.783
1989	1.543	3.881	5.065	2.648	3.950	4.488	2.969	0.077	3.161	0.905	4.837	4.585	4.463	5.609	3.340	9.826	21.059	20.910	6.132
1990	1.581	3.933	5.157	2.680	4.084	4.613	3.039	0.069	3.175	0.869	4.981	4.731	4.644	5.815	3.388	10.624	22.806	24.587	6.112
1991	1.414	3.999	5.110	2.408	4.068	4.583	2.920	0.051	3.002	0.849	4.855	4.574	4.521	5.809	3.390	10.910	24.329	24.221	6.323
1992	1.435	4.162	5.357	2.434	4.267	4.889	2.989	0.045	3.026	0.786	4.900	4.576	4.532	5.700	3.546	10.698	24.950	26.881	6.397
1993	1.464	4.396	5.642	2.483	4.457	5.199	3.076	0.043	3.044	0.776	4.993	4.591	4.549	5.740	3.552	10.753	25.420	28.750	6.584
1994	1.499	4.704	5.958	2.589	4.728	5.506	3.208	0.039	2.983	0.763	5.157	4.677	4.661	5.953	3.728	11.171	26.612	30.942	6.765
1995	1.556	4.938	6.213	2.742	5.074	5.863	3.356	0.034	2.864	0.749	5.292	4.894	4.811	6.009	3.859	12.030	28.079	33.027	6.767
1996	1.565	5.117	6.384	2.905	5.203	5.969	3.419	0.027	2.984	0.739	5.425	4.985	4.900	6.235	3.948	13.018	29.028	32.174	6.756
1997	1.564	5.329	6.598	2.953	5.323	6.117	3.558	0.023	3.074	0.724	5.560	5.086	5.007	6.439	3.811	14.077	30.407	33.048	6.875
1998	1.583	5.668	7.055	2.943	5.533	6.423	3.718	0.020	3.192	0.708	5.627	5.186	5.114	6.612	3.836	15.658	31.728	34.687	6.960
1999	1.577	5.811	7.177	2.885	5.647	6.529	3.736	0.016	3.163	0.702	5.790	5.302	5.215	6.657	3.896	16.571	33.120	36.347	7.132
2000	1.586	5.879	7.267	2.924	5.731	6.727	3.791	0.014	3.130	0.721	6.020	5.580	5.464	6.835	3.986	17.363	34.738	39.074	7.298
2001	1.607	6.135	7.542	2.926	5.754	6.974	3.917	0.012	3.227	0.730	6.176	5.735	5.617	6.935	4.071	18.103	36.731	41.539	7.488
2002	1.641	6.374	7.755	2.928	5.811	7.209	4.154	0.011	3.233	0.716	6.309	5.838	5.727	7.018	4.140	19.154	38.193	45.852	7.812
2003	1.565	5.888	7.178	2.865	5.666	6.844	3.787	0.010	2.879	0.674	6.555	6.047	5.898	7.079	3.901	20.513	39.904	52.026	8.213
2004	1.542	5.743	6.940	2.811	5.044	6.555	3.661	0.008	2.590	0.653	6.957	6.439	6.274	7.492	3.940	21.925	42.360	57.049	8.716
2005	1.529	5.667	6.794	2.781	4.768	6.462	3.564	0.007	2.421	0.634	7.394	6.831	6.612	8.031	3.987	23.443	45.976	65.835	9.125
2006	1.493	5.440	6.682	2.783	4.522	6.321	3.472	0.006	2.298	0.613	7.911	7.370	7.217	8.712	4.052	25.147	49.637	75.284	9.799
2007	1.475	5.418	6.590	2.727	4.407	6.218	3.411	0.006	2.170	0.609	8.566	8.087	7.838	9.208	4.168	26.986	54.787	85.690	10.510
2008	1.508	5.618	6.832	2.666	4.445	6.368	3.497	0.005	2.151	0.626	9.419	8.741	8.474	9.639	4.180	29.512	60.396	96.375	10.798
2009	1.574	6.089	7.381	2.717	4.803	6.794	3.744	0.005	2.260	0.648	8.872	8.378	8.268	9.914	4.219	31.569	66.280	101.983	10.811
2010	1.495	5.700	6.838	2.606	4.491	6.361	3.494	0.005	2.078	0.640	8.900	8.448	8.356	10.367	4.223	33.028	68.259	106.266	11.137
2011	1.466	5.630	6.654	2.504	4.338	6.172	3.411	0.004	1.981	0.637	9.250	8.731	8.645	10.791	4.359	34.747	71.882	111.737	11.440
Compound Annual Growth Rates, per cent																			
1961-2011	0.77	3.52	3.86	1.85	2.98	3.71	2.48	-10.50	1.38	-0.90	4.55	4.43	4.41	4.87	2.99	7.35	8.93	9.89	5.00
2000-2011	-0.71	-0.39	-0.80	-1.40	-2.50	-0.78	-0.96	-10.83	-4.07	-1.12	3.98	4.15	4.26	4.24	0.81	6.51	6.83	10.02	4.17
1961-1973	1.62	2.94	3.20	0.45	1.99	2.88	1.97	0.89	3.04	0.00	4.37	4.17	4.55	4.84	2.38	8.36	10.68	9.81	5.82
1973-1981	2.56	11.06	13.00	8.32	10.22	11.19	9.06	-14.28	7.27	0.00	9.08	9.50	8.45	11.37	8.67	21.33	16.93	15.09	9.22
1981-1989	0.50	2.14	3.38	3.57	4.59	3.98	2.02	-16.42	2.92	-1.24	4.70	3.91	3.99	3.76	3.29	-2.77	7.50	10.42	5.51
1989-2000	0.25	3.85	3.34	0.91	3.44	3.75	2.25	-14.51	-0.09	-2.05	2.01	1.80	1.86	1.81	1.62	5.31	4.66	5.85	1.59
2000-2008	-0.63	-0.57	-0.77	-1.15	-3.13	-0.68	-1.00	-11.47	-4.58	-1.75	5.75	5.77	5.64	4.39	0.59	6.86	7.16	11.95	5.02
2008-2011	-0.92	0.07	-0.88	-2.07	-0.80	-1.03	-0.83	-9.09	-2.70	0.60	-0.60	-0.04	0.67	3.84	1.40	5.59	5.98	5.05	1.94

Appendix Table 13
Quantity Aggregates for 19 Capital Stock Components, 1961-2011(beginning of the year estimates)

Year	Q_{K1} Office Furniture	Q_{K2} Ag. Machinery	Q_{K3} Industrial Machinery	Q_{K4} Automo-biles	Q_{K5} Trucks	Q_{K6} Other Transport Equip-ment	Q_{K7} Other Machin-ery and Equip-ment	Q_{K8} Comput-ers	Q_{K9} Telecom Equip-ment	Q_{K10} Software	Q_{K11} Industrial Buildings	Q_{K12} Comml. Buildings	Q_{K13} Inst. Buildings	Q_{K14} Engineer-ing Construc-tion	Q_{K15} Inventory Change	Q_{K16} Ag. Land	Q_{K17} Business Non-ag. Land	Q_{K18} Household Res. Land	Q_{K19} Res. Structures
	(millions, 1961 dollars)																		
1961	975	1,147	4,326	535	934	1,909	2,656	313	1,360	0	4,365	5,136	536	14,959	13,594	5,954	6,376	10,680	28,710
1962	977	1,126	4,392	560	899	1,873	2,719	371	1,406	0	4,481	5,460	566	15,430	13,595	5,965	6,376	10,680	29,773
1963	981	1,153	4,478	598	898	1,866	2,780	409	1,465	0	4,599	5,770	589	15,934	14,151	5,976	6,376	10,680	30,853
1964	1,013	1,213	4,819	643	917	1,861	2,908	461	1,530	0	4,802	6,159	605	16,616	15,079	5,986	6,376	10,680	31,972
1965	1,063	1,293	5,294	698	954	1,950	3,071	522	1,629	0	5,073	6,637	624	17,350	15,607	5,997	6,376	10,680	33,409
1966	1,132	1,389	5,959	769	1,005	2,070	3,383	618	1,772	0	5,463	7,245	641	18,214	16,826	6,008	6,376	10,680	34,898
1967	1,208	1,451	6,355	823	1,047	2,228	3,728	703	1,899	0	5,675	7,686	651	19,086	18,130	5,977	6,376	10,680	36,201
1968	1,260	1,433	6,515	833	1,083	2,332	4,016	742	1,985	0	5,792	8,041	655	19,988	18,580	5,946	6,376	10,680	37,507
1969	1,326	1,379	6,786	928	1,135	2,402	4,359	829	2,075	0	5,979	8,367	648	20,773	19,195	5,916	6,376	10,680	39,139
1970	1,387	1,278	7,136	955	1,149	2,443	4,694	892	2,147	0	6,210	8,710	639	21,741	20,763	5,885	6,376	10,680	41,124
1971	1,427	1,239	7,398	1,004	1,210	2,447	4,987	938	2,263	0	6,353	9,119	624	22,735	20,942	5,854	6,376	10,680	42,733
1972	1,533	1,250	7,582	1,103	1,370	2,489	5,312	998	2,388	0	6,423	9,590	610	23,595	20,711	5,806	6,376	10,680	44,752
1973	1,690	1,339	7,981	1,242	1,618	2,719	5,739	1,094	2,530	0	6,521	10,280	596	24,467	20,858	5,759	6,376	10,680	47,028
1974	1,878	1,497	8,516	1,351	1,783	2,975	6,222	1,274	2,787	0	6,702	11,026	584	25,328	23,381	5,711	6,376	10,680	49,518
1975	2,050	1,653	8,910	1,508	1,954	3,091	6,705	1,451	3,069	0	6,856	11,910	583	26,460	28,184	5,664	6,376	10,680	52,001
1976	2,182	1,851	9,238	1,544	2,060	3,041	7,366	1,634	3,296	0	6,940	12,662	585	27,476	27,852	5,618	6,376	10,680	54,307
1977	2,316	1,918	9,475	1,547	2,143	2,971	7,921	1,890	3,442	0	7,113	13,332	584	28,632	28,101	5,634	6,376	10,680	57,307
1978	2,526	1,964	9,546	1,647	2,205	2,984	8,475	2,579	3,476	0	7,190	14,072	585	29,807	29,409	5,651	6,376	10,680	60,257
1979	2,814	2,076	9,761	1,806	2,360	3,166	9,008	3,471	3,522	0	7,368	15,104	593	31,129	30,700	5,667	6,376	10,680	63,138
1980	3,120	2,109	10,108	1,900	2,308	3,299	9,556	5,563	3,639	0	7,735	16,155	608	32,776	34,364	5,683	6,376	10,680	65,863
1981	3,471	2,180	10,918	2,282	2,233	3,467	10,028	9,732	3,830	797	8,177	17,103	624	34,514	34,529	5,700	6,376	10,680	68,205
1982	3,503	2,042	11,167	2,149	2,054	3,355	10,583	11,480	3,929	1,527	8,409	17,457	633	36,004	35,413	5,716	6,376	10,680	70,756
1983	3,726	1,854	10,986	2,233	1,962	3,323	10,845	16,736	3,882	2,217	8,404	17,908	647	36,762	30,845	5,733	6,376	10,680	72,266
1984	4,100	1,740	10,702	2,441	1,931	3,279	10,894	22,210	3,872	2,968	8,443	18,486	660	37,317	29,803	5,750	6,376	10,680	74,455
1985	4,628	1,617	10,660	2,292	1,850	3,416	11,069	28,441	3,858	3,710	8,601	19,290	677	37,836	31,534	5,766	6,376	10,680	76,607
1986	5,233	1,502	11,021	2,437	1,757	3,437	11,092	35,833	3,886	4,659	8,644	20,363	696	37,654	32,990	5,783	6,376	10,680	79,121
1987	6,125	1,385	11,478	2,504	1,721	3,299	11,380	54,457	4,060	5,660	8,707	21,647	709	37,451	34,011	5,782	6,376	10,680	82,223
1988	6,863	1,289	12,236	3,024	1,722	3,567	11,821	61,764	4,342	7,023	8,835	23,079	733	37,610	35,699	5,781	6,376	10,680	86,124
1989	7,451	1,201	13,161	3,477	1,675	3,689	12,133	77,686	4,688	8,501	9,029	24,561	746	37,762	37,761	5,779	6,376	10,680	90,019
1990	7,422	1,134	13,652	3,791	1,625	3,632	12,451	86,680	5,033	10,131	9,126	25,814	753	38,084	39,157	5,778	6,376	10,680	94,058
1991	7,465	1,051	13,755	3,750	1,539	3,705	12,901	102,617	5,283	11,474	9,080	26,545	748	38,622	38,578	5,777	6,376	10,680	97,130
1992	7,572	984	13,421	3,806	1,495	3,730	13,082	132,748	5,569	12,823	8,894	26,768	742	38,622	34,708	5,782	6,376	10,680	99,069
1993	8,078	1,090	12,986	4,102	1,438	3,427	12,835	144,592	5,658	14,902	8,717	26,962	725	38,708	34,162	5,787	6,376	10,680	101,344
1994	8,336	1,131	12,801	4,883	1,429	3,261	12,594	176,603	5,639	17,362	8,686	26,878	757	39,266	33,291	5,792	6,376	10,680	103,314
1995	8,354	1,152	12,817	5,421	1,481	3,125	12,430	222,674	5,614	18,979	8,684	26,728	753	39,692	33,994	5,797	6,376	10,680	105,453
1996	8,321	1,206	12,782	6,062	1,391	3,077	12,192	284,098	5,565	21,101	8,843	26,613	763	39,874	37,134	5,803	6,376	10,680	106,575
1997	9,082	1,336	13,294	6,480	1,411	3,265	12,160	365,549	5,847	23,824	8,999	27,058	774	40,542	39,533	5,793	6,376	10,680	108,164
1998	9,196	1,639	13,442	7,291	1,529	3,552	11,958	548,271	5,882	27,182	9,060	27,430	756	41,268	41,299	5,784	6,376	10,680	110,167
1999	9,020	1,741	13,453	8,796	1,683	3,839	11,833	755,557	6,155	29,843	9,157	27,900	723	41,872	43,611	5,774	6,376	10,680	111,867
2000	8,826	1,708	13,546	10,059	1,785	4,054	11,781	978,557	6,787	31,779	9,326	27,785	708	42,820	44,851	5,765	6,376	10,680	113,715
2001	9,016	1,713	13,152	10,146	1,577	4,455	12,229	1,055,585	7,230	33,827	9,290	27,761	710	43,880	47,744	5,755	6,376	10,680	115,823
2002	8,756	1,562	12,719	10,703	1,906	4,259	12,729	1,187,980	7,303	34,474	9,127	27,704	714	44,407	45,902	5,757	6,376	10,680	118,553
2003	9,128	1,519	12,764	11,202	1,858	4,055	13,409	1,375,561	7,326	35,644	8,909	27,606	702	45,330	49,244	5,758	6,376	10,680	122,214
2004	9,944	1,492	12,919	11,437	1,985	3,994	14,112	1,732,471	7,470	38,259	8,680	27,685	709	46,540	47,534	5,760	6,376	10,680	126,179
2005	10,488	1,468	13,824	11,113	2,318	4,157	14,801	2,156,580	7,617	42,475	8,406	27,646	708	48,566	48,584	5,761	6,376	10,680	130,651
2006	11,655	1,538	14,699	11,364	2,761	4,293	15,534	2,737,726	7,881	45,813	8,282	27,959	706	50,681	50,866	5,763	6,376	10,680	135,244
2007	12,326	1,605	15,401	11,480	2,839	4,670	16,071	3,144,545	7,916	51,425	8,168	28,087	701	52,815	52,546	5,764	6,376	10,680	139,857
2008	12,761	1,755	16,122	10,600	2,949	5,060	15,937	3,570,520	8,275	54,804	8,029	28,422	701	55,349	54,089	5,766	6,376	10,680	144,566
2009	12,920	1,692	15,629	8,983	2,871	4,767	15,462	3,448,026	8,279	55,870	7,840	28,625	697	55,605	56,978	5,767	6,376	10,680	148,760
2010	13,259	1,675	15,592	7,933	3,017	4,622	15,425	3,782,510	8,714	57,608	7,653	28,615	691	56,263	53,970	5,768	6,376	10,680	151,991
2011	13,572	1,682	15,695	7,146	3,179	4,518	15,687	4,497,614	9,331	59,617	7,510	28,642	682	57,383	52,570	5,770	6,376	10,680	156,030

Compound Annual Growth Rates, per cent

	Q_{K1}	Q_{K2}	Q_{K3}	Q_{K4}	Q_{K5}	Q_{K6}	Q_{K7}	Q_{K8}	Q_{K9}	Q_{K10}	Q_{K11}	Q_{K12}	Q_{K13}	Q_{K14}	Q_{K15}	Q_{K16}	Q_{K17}	Q_{K18}	Q_{K19}
1961-2011	5.41	0.77	2.61	5.32	2.48	1.74	3.62	21.10	3.93	n.a.	1.09	3.50	0.48	2.73	2.74	-0.06	0.00	0.00	3.44
2000-2011	3.99	-0.14	1.35	-3.06	5.39	0.99	2.64	14.87	2.94	5.89	-1.95	0.28	-0.34	2.70	1.45	0.01	0.00	0.00	2.92
1961-1973	4.69	1.29	5.24	7.27	4.68	2.99	6.63	10.98	5.31	n.a.	3.40	5.95	0.89	4.18	3.63	-0.28	0.00	0.00	4.20
1973-1981	9.41	6.29	3.99	7.90	4.11	3.09	7.23	31.42	5.32	n.a.	2.87	6.57	0.57	4.39	6.50	-0.13	0.00	0.00	4.76
1981-1989	10.02	-7.18	2.36	5.41	-3.53	0.78	2.41	29.65	2.56	34.44	1.25	4.63	2.26	1.13	1.12	0.17	0.00	0.00	3.53
1989-2000	1.55	3.26	0.26	10.14	0.58	0.86	-0.27	25.90	3.42	12.74	0.29	1.13	-0.47	1.15	1.58	-0.02	0.00	0.00	2.15
2000-2008	4.72	0.34	2.20	0.66	6.48	2.81	3.85	17.56	2.51	7.05	-1.85	0.28	-0.14	3.26	2.37	0.00	0.00	0.00	3.05
2008-2011	2.08	-1.41	-0.89	-12.32	2.53	-3.71	-0.53	8.00	4.08	2.85	-2.20	0.26	-0.88	1.21	-0.94	0.03	0.00	0.00	2.58

Appendix Table 14

Business Sector Property Tax Rates, Business Income Tax Rates, Balancing Real After Tax Rates of Return, Output Price and Quantity Indexes, Wealth Stock Price and Quantity Indexes and Nominal and Real Capital-Ouput Ratios, 1961-2011

	τ_P	τ_B	r	P_Y	P_{KW}	Q_Y	Q_{KW}	V_{KW}/V_Y	Q_{KW}/Q_Y
	Business Sector Property Tax Rates	Business Sector Income Tax Rates	Balancing Real After Tax Rates of Return	Output Price Index	Wealth Stock Price Index	Output Quantity Index	Wealth Stock Quantity Index	Nominal Capital-Output Ratio	Real Capital-Output Ratio
Year	(per cent)			(index, 1961=1.000)		(millions, 1961 dollars)		(ratios)	
1961	0.015	0.033	0.052	1.000	1.000	29,368	65,074	2.216	2.216
1962	0.016	0.034	0.055	0.999	1.017	31,585	66,186	2.135	2.095
1963	0.016	0.035	0.067	1.007	1.047	34,008	67,985	2.079	1.999
1964	0.016	0.036	0.068	1.019	1.083	36,591	70,874	2.060	1.937
1965	0.016	0.034	0.066	1.049	1.140	39,269	73,925	2.046	1.883
1966	0.016	0.033	0.069	1.097	1.203	42,286	78,410	2.034	1.854
1967	0.016	0.032	0.054	1.131	1.261	43,046	82,234	2.130	1.910
1968	0.017	0.034	0.056	1.173	1.299	44,645	84,583	2.098	1.895
1969	0.017	0.036	0.051	1.214	1.354	46,806	87,164	2.076	1.862
1970	0.017	0.033	0.050	1.256	1.421	48,260	90,627	2.125	1.878
1971	0.016	0.034	0.047	1.298	1.491	50,453	92,937	2.115	1.842
1972	0.016	0.036	0.045	1.366	1.582	53,041	94,972	2.075	1.791
1973	0.015	0.039	0.074	1.509	1.742	58,833	98,134	1.926	1.668
1974	0.014	0.043	0.075	1.752	2.040	61,729	103,385	1.950	1.675
1975	0.013	0.038	0.041	1.970	2.354	59,494	110,211	2.214	1.852
1976	0.013	0.034	0.045	2.111	2.569	63,195	112,964	2.176	1.788
1977	0.014	0.032	0.055	2.216	2.782	67,878	115,949	2.144	1.708
1978	0.014	0.032	0.059	2.374	3.059	70,536	119,537	2.184	1.695
1979	0.013	0.033	0.072	2.633	3.417	74,697	123,921	2.153	1.659
1980	0.013	0.034	0.058	3.003	3.842	73,053	130,218	2.281	1.783
1981	0.013	0.032	0.039	3.259	4.297	74,433	135,275	2.397	1.817
1982	0.013	0.029	0.022	3.494	4.648	70,178	138,323	2.622	1.971
1983	0.013	0.030	0.049	3.721	4.782	73,158	136,998	2.406	1.873
1984	0.013	0.034	0.060	3.851	4.887	78,124	137,639	2.236	1.762
1985	0.013	0.033	0.064	3.955	5.015	82,741	140,493	2.153	1.698
1986	0.013	0.032	0.056	4.015	5.105	85,022	142,988	2.138	1.682
1987	0.013	0.035	0.071	4.186	5.205	90,562	145,848	2.003	1.610
1988	0.013	0.035	0.065	4.347	5.367	94,673	150,432	1.962	1.589
1989	0.013	0.035	0.055	4.511	5.591	96,093	155,302	2.003	1.616
1990	0.013	0.035	0.047	4.647	5.800	95,614	158,744	2.072	1.660
1991	0.014	0.033	0.029	4.752	5.791	90,124	160,238	2.167	1.778
1992	0.014	0.033	0.043	4.773	5.851	93,353	158,327	2.079	1.696
1993	0.014	0.036	0.043	4.839	5.933	94,376	157,980	2.052	1.674
1994	0.014	0.038	0.060	4.915	6.155	100,399	158,425	1.976	1.578
1995	0.014	0.040	0.065	5.044	6.371	103,942	159,699	1.941	1.536
1996	0.014	0.044	0.065	5.152	6.563	107,236	162,378	1.929	1.514
1997	0.014	0.047	0.054	5.207	6.725	111,372	166,742	1.934	1.497
1998	0.014	0.043	0.049	5.170	6.949	117,549	170,681	1.951	1.452
1999	0.014	0.049	0.053	5.288	7.079	123,970	174,830	1.888	1.410
2000	0.013	0.054	0.068	5.553	7.297	131,759	178,130	1.777	1.352
2001	0.013	0.044	0.071	5.630	7.506	133,542	181,277	1.810	1.357
2002	0.013	0.043	0.084	5.625	7.683	140,612	180,822	1.757	1.286
2003	0.012	0.045	0.079	5.884	7.663	137,172	183,931	1.746	1.341
2004	0.012	0.049	0.093	6.139	7.911	142,915	185,502	1.673	1.298
2005	0.012	0.048	0.099	6.400	8.259	146,942	189,852	1.667	1.292
2006	0.011	0.051	0.087	6.590	8.680	150,611	195,631	1.711	1.299
2007	0.011	0.047	0.088	6.861	9.155	153,240	200,440	1.745	1.308
2008	0.010	0.043	0.096	7.218	9.675	154,370	205,062	1.781	1.328
2009	0.010	0.039	0.050	6.934	10.029	145,290	205,338	2.044	1.413
2010	0.010	0.040	0.072	7.202	10.158	149,905	204,637	1.925	1.365
2011	0.010	0.039	0.091	7.515	10.472	154,907	205,655	1.850	1.328
	Period Average			**Compound Annual Growth Rates, per cent**					
1961-2011	0.014	0.038	0.061	4.12	4.81	3.38	2.33	-0.36	-1.02
2000-2011	0.011	0.044	0.083	2.79	3.34	1.48	1.31	0.37	-0.17
1961-1973	0.016	0.035	0.058	3.49	4.74	5.96	3.48	-1.16	-2.34
1973-1981	0.013	0.035	0.056	10.10	11.94	2.98	4.09	2.77	1.08
1981-1989	0.013	0.033	0.055	4.15	3.35	3.24	1.74	-2.22	-1.46
1989-2000	0.014	0.041	0.052	1.91	2.45	2.91	1.25	-1.09	-1.61
2000-2008	0.012	0.046	0.087	3.33	3.59	2.00	1.78	0.03	-0.22
2008-2011	0.010	0.039	0.071	1.35	2.67	0.12	0.10	1.28	-0.02

Appendix Table 15
Business Sector User Costs for 17 Asset Classes, 1961-2011

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15	U16	U17
	Office Furniture	Ag. Machinery	Industrial Machinery	Automo-biles	Trucks	Other Transport Equipment	Other Machinery and Equipment	Computers	Telecom Equipment	Software	Industrial Buildings	Comml. Buildings	Inst. Buildings	Engineer-ing Construc-tion	Inventory Change	Ag. Land	Business Non-ag. Land
Year	(rental price (in dollars) of one dollar of capital services)																
1961	0.218	0.363	0.248	0.393	0.315	0.221	0.187	0.364	0.231	0.370	0.174	0.162	0.146	0.167	0.086	0.101	0.101
1962	0.224	0.388	0.252	0.386	0.325	0.225	0.196	0.354	0.234	0.373	0.178	0.165	0.149	0.173	0.090	0.109	0.112
1963	0.248	0.420	0.278	0.402	0.343	0.238	0.221	0.394	0.244	0.385	0.194	0.180	0.163	0.192	0.102	0.129	0.134
1964	0.239	0.433	0.300	0.413	0.358	0.260	0.218	0.395	0.250	0.387	0.200	0.186	0.169	0.202	0.106	0.146	0.147
1965	0.242	0.443	0.317	0.418	0.363	0.265	0.224	0.421	0.253	0.385	0.208	0.191	0.173	0.213	0.105	0.159	0.156
1966	0.244	0.461	0.328	0.431	0.374	0.277	0.230	0.413	0.262	0.386	0.225	0.207	0.186	0.227	0.109	0.180	0.179
1967	0.238	0.458	0.303	0.427	0.367	0.264	0.210	0.407	0.259	0.370	0.213	0.195	0.174	0.217	0.093	0.175	0.175
1968	0.248	0.476	0.307	0.450	0.391	0.279	0.214	0.419	0.278	0.375	0.219	0.201	0.179	0.229	0.099	0.204	0.205
1969	0.250	0.487	0.314	0.453	0.401	0.289	0.211	0.419	0.285	0.371	0.225	0.206	0.185	0.238	0.097	0.201	0.214
1970	0.256	0.493	0.335	0.462	0.412	0.297	0.218	0.432	0.300	0.368	0.232	0.212	0.189	0.246	0.096	0.197	0.232
1971	0.270	0.503	0.339	0.474	0.427	0.312	0.228	0.444	0.305	0.365	0.239	0.219	0.196	0.258	0.094	0.194	0.250
1972	0.266	0.541	0.352	0.503	0.447	0.332	0.228	0.453	0.324	0.365	0.249	0.237	0.201	0.274	0.098	0.208	0.282
1973	0.301	0.628	0.426	0.557	0.509	0.388	0.271	0.503	0.388	0.397	0.341	0.312	0.294	0.353	0.150	0.335	0.432
1974	0.325	0.732	0.504	0.616	0.580	0.443	0.315	0.506	0.431	0.402	0.420	0.385	0.352	0.424	0.169	0.449	0.538
1975	0.303	0.790	0.523	0.614	0.568	0.437	0.303	0.492	0.410	0.363	0.363	0.347	0.292	0.396	0.123	0.399	0.472
1976	0.313	0.837	0.560	0.637	0.611	0.472	0.312	0.454	0.436	0.363	0.382	0.357	0.304	0.436	0.132	0.476	0.566
1977	0.328	0.899	0.639	0.703	0.694	0.552	0.348	0.420	0.481	0.371	0.416	0.385	0.341	0.495	0.156	0.599	0.695
1978	0.322	1.025	0.734	0.783	0.783	0.634	0.386	0.317	0.582	0.375	0.453	0.412	0.369	0.552	0.177	0.738	0.813
1979	0.368	1.201	0.871	0.899	0.909	0.754	0.453	0.300	0.654	0.389	0.533	0.475	0.440	0.651	0.226	1.020	1.029
1980	0.359	1.319	0.945	0.978	0.974	0.802	0.461	0.215	0.632	0.376	0.560	0.490	0.447	0.676	0.216	1.142	1.057
1981	0.356	1.346	0.985	1.056	1.023	0.823	0.465	0.173	0.584	0.355	0.548	0.497	0.423	0.677	0.183	1.033	0.992
1982	0.352	1.333	0.978	1.068	1.028	0.803	0.450	0.161	0.587	0.351	0.513	0.463	0.387	0.651	0.142	0.782	0.865
1983	0.390	1.499	1.109	1.202	1.163	0.954	0.530	0.118	0.706	0.388	0.627	0.563	0.491	0.810	0.231	1.102	1.348
1984	0.420	1.624	1.234	1.324	1.292	1.092	0.592	0.105	0.779	0.410	0.685	0.607	0.540	0.915	0.285	1.215	1.596
1985	0.449	1.679	1.329	1.420	1.414	1.204	0.639	0.089	0.817	0.425	0.728	0.638	0.566	0.969	0.306	1.185	1.751
1986	0.455	1.704	1.357	1.529	1.487	1.203	0.640	0.074	0.821	0.407	0.734	0.635	0.558	0.947	0.282	1.017	1.691
1987	0.494	1.773	1.455	1.641	1.589	1.295	0.700	0.062	0.897	0.426	0.851	0.744	0.651	1.054	0.342	1.118	2.118
1988	0.493	1.773	1.427	1.689	1.620	1.275	0.689	0.055	0.886	0.414	0.876	0.763	0.664	1.070	0.330	1.046	2.181
1989	0.480	1.767	1.426	1.737	1.664	1.254	0.677	0.044	0.843	0.389	0.884	0.770	0.672	1.044	0.300	1.014	2.172
1990	0.472	1.741	1.401	1.639	1.693	1.245	0.665	0.038	0.836	0.370	0.869	0.754	0.660	1.034	0.275	1.005	2.157
1991	0.392	1.664	1.274	1.328	1.614	1.167	0.576	0.028	0.752	0.347	0.755	0.641	0.557	0.923	0.209	0.826	1.841
1992	0.423	1.794	1.401	1.312	1.762	1.315	0.624	0.026	0.823	0.335	0.834	0.709	0.627	0.989	0.270	0.968	2.258
1993	0.442	1.921	1.492	1.312	1.858	1.386	0.644	0.026	0.856	0.340	0.865	0.723	0.642	1.014	0.279	1.001	2.366
1994	0.484	2.129	1.707	1.374	2.071	1.559	0.734	0.025	0.918	0.355	0.996	0.826	0.747	1.174	0.365	1.253	2.985
1995	0.513	2.214	1.843	1.412	2.273	1.728	0.796	0.023	0.928	0.357	1.065	0.898	0.805	1.234	0.405	1.429	3.336
1996	0.530	2.285	1.946	1.434	2.370	1.819	0.833	0.018	1.020	0.359	1.123	0.938	0.843	1.318	0.432	1.605	3.578
1997	0.525	2.338	1.976	1.375	2.391	1.855	0.844	0.016	1.070	0.351	1.108	0.915	0.820	1.316	0.384	1.611	3.481
1998	0.522	2.417	2.068	1.316	2.442	1.938	0.861	0.014	1.131	0.341	1.077	0.890	0.795	1.300	0.352	1.654	3.353
1999	0.536	2.464	2.189	1.308	2.559	2.066	0.919	0.011	1.201	0.348	1.174	0.969	0.867	1.385	0.397	1.921	3.840
2000	0.576	2.535	2.376	1.353	2.726	2.300	1.032	0.010	1.296	0.376	1.345	1.141	1.020	1.573	0.489	2.361	4.723
2001	0.575	2.549	2.408	1.294	2.696	2.331	1.058	0.008	1.330	0.381	1.330	1.137	1.006	1.556	0.467	2.313	4.693
2002	0.613	2.707	2.578	1.315	2.800	2.465	1.189	0.008	1.374	0.389	1.433	1.239	1.097	1.666	0.526	2.675	5.334
2003	0.589	2.483	2.386	1.276	2.728	2.293	1.083	0.007	1.220	0.368	1.471	1.281	1.116	1.670	0.485	2.806	5.459
2004	0.616	2.537	2.461	1.288	2.527	2.332	1.122	0.006	1.152	0.370	1.681	1.486	1.298	1.908	0.558	3.374	6.518
2005	0.627	2.553	2.490	1.283	2.420	2.381	1.127	0.005	1.100	0.364	1.829	1.619	1.407	2.101	0.588	3.733	7.321
2006	0.601	2.418	2.416	1.257	2.245	2.321	1.076	0.004	1.026	0.348	1.877	1.669	1.465	2.199	0.557	3.743	7.388
2007	0.590	2.416	2.382	1.217	2.167	2.313	1.054	0.004	0.967	0.345	2.004	1.805	1.570	2.302	0.562	3.928	7.974
2008	0.606	2.518	2.502	1.177	2.199	2.391	1.094	0.004	0.971	0.354	2.245	1.989	1.740	2.456	0.583	4.426	9.057
2009	0.552	2.396	2.331	1.045	2.126	2.168	0.982	0.003	0.913	0.330	1.672	1.485	1.289	2.027	0.379	3.154	6.622
2010	0.558	2.351	2.318	1.061	2.078	2.159	0.997	0.003	0.893	0.338	1.878	1.685	1.494	2.346	0.472	4.037	8.344
2011	0.574	2.435	2.385	1.067	2.074	2.235	1.037	0.003	0.895	0.348	2.116	1.895	1.704	2.630	0.565	4.863	10.060
Compound Annual Growth Rates, per cent																	
1961-2011	0.42	1.53	1.30	1.02	1.42	1.20	0.61	0.18	0.72	0.37	0.85	0.74	0.66	1.00	0.28	1.40	2.65
2001-2011	0.59	2.49	2.42	1.21	2.37	2.31	1.07	0.01	1.08	0.36	1.78	1.57	1.38	2.08	0.52	3.55	7.16
1961-1973	0.25	0.47	0.32	0.44	0.39	0.28	0.22	0.42	0.28	0.38	0.22	0.21	0.18	0.23	0.10	0.18	0.20
1974-1981	0.33	1.02	0.72	0.79	0.77	0.61	0.38	0.36	0.53	0.37	0.46	0.42	0.37	0.54	0.17	0.73	0.77
1982-1989	0.44	1.64	1.29	1.45	1.41	1.14	0.61	0.09	0.79	0.40	0.74	0.65	0.57	0.93	0.28	1.06	1.72
1990-2000	0.49	2.14	1.79	1.38	2.16	1.67	0.78	0.02	0.98	0.35	1.02	0.85	0.76	1.21	0.35	1.42	3.08
2001-2008	0.60	2.52	2.45	1.26	2.47	2.35	1.10	0.01	1.14	0.36	1.73	1.53	1.34	1.98	0.54	3.37	6.72
2009-2011	0.56	2.39	2.34	1.06	2.09	2.19	1.01	0.00	0.90	0.34	1.89	1.69	1.50	2.33	0.47	4.02	8.34

Estimating Capital Input for Measuring Business Sector Multifactor Productivity Growth in Canada: Response to Diewert and Yu

Wulong Gu[1]
Statistics Canada

ABSTRACT

Diewert and Yu estimate that multifactor productivity grew at a 1.0 per cent average annual rate in the Canadian business sector from 1961 to 2011, compared to Statistics Canada's Canadian Productivity Program estimate of 0.3 per cent. The major reason for this difference is that Diewert and Yu find capital services grew at 3.0 per cent per year, compared to Statistics Canada's estimate of 4.8 per cent. This article identifies and discusses the three reasons for this discrepancy. First, while the Canadian Productivity Program aggregates capital services across industries to derive the capital input measure at the level of the business sector, Diewert and Yu use a top-down approach and directly compute capital and labour input series at the business sector level. Second, there are differences in the way the price of capital services is computed. Third, the Canadian Productivity Program bases its capital measures on a more detailed list of assets than Diewert and Yu. Statistics Canada estimates follow international guidelines and practices adopted by other statistical agencies in order to make estimates internationally comparable.

RÉSUMÉ

Diewert et Yu trouvent que la productivité multifactorielle a augmenté de 1.0% par an dans le secteur des entreprise canadien entre 1961 et 2011 par rapport à 0.3% dans le programme canadien de la productivité de Statistiques Canada. La raison majeure pour cette différence est que Diewert et Yu trouvent que les services du capital ont augmenté à un taux annuel de 3.0% par rapport à 4.8% de la Statistique Canada. Cet article identifie et discute les trois raisons pour cet écart. Premièrement, tandis que le programme de la productivité aggrége les services de capital à travers les industries pour obtenir une mesure d'intrants de capital à l'échelle du secteur des affaires, Diewert et Yu se serent d'une approache descendante dans laquelle seuls les éléments d'actif sont agrégés a l'échelle du secteur des entreprises. Deuxièmement, il y a des différences dans la manière de calculer les prix des services du capital. Troisièmement, le programme de la productivité se sert d'un ensemble plus détaille d'éléments d'actif que Diewert et Yu pour estimer les intrants de capital. Le programme de la productivité de Statistique Canada suit les lignes directrices et les pratiques internationales adoptées par d'autres bureaux de la statistique afin que les estimations soient comparables à l'échelle internationale.

1 Wulong Gu works in the Economic Analysis Division at Statistics Canada. He would like to thank Isabelle Amano, John Baldwin, Andrew Sharpe and Jianmin Tang for their comments and Weimin Wang for his assistance. E-mail: Wulong.Gu@statcan.gc.ca,

DIEWERT AND YU (2012) HAVE constructed a new estimate of multifactor productivity growth for the Canadian business sector for the period 1961-2011. Their estimate of multifactor productivity (MFP) increases at an average annual rate of 1.0 per cent per year over that period. This is higher than the estimate from the Canadian Productivity Program of Statistics Canada which has MFP increasing at 0.3 per cent per year.[2]

The growth in multifactor productivity is calculated as the difference between actual output growth and the output growth that would have been expected from the combined capital and labour input growth. Consequently, the difference in the two estimates of MFP growth can arise from differences in output growth, capital input growth and labour input growth. As Diewert and Yu point out, the difference in the two estimates of MFP growth can be almost entirely traced to the difference in capital input growth. Diewert and Yu found that capital input growth increased at 3.0 per cent per year, while the Canadian Productivity Program has capital input increasing at 4.8 per cent per year.

This article examines in more detail the sources of the difference in the estimates of the growth in capital inputs. It concludes that the discrepancy is mainly due to the difference in the approach used for estimating capital input. The approach adopted by the Canadian Productivity Program of Statistics Canada follows international guidelines and practices adopted by other statistical agencies in order to make the estimates internationally comparable. The approach used by Diewert and Yu is not commonly used by other statistical agencies. In particular, their estimate is not comparable with the MFP estimate for the United States produced by the U.S. Bureau of Labor Statistics.

Approaches for Estimating Capital Input

Baldwin and Gu (2007) discussed the various approaches for estimating capital input for measuring multifactor productivity growth. This section follows that discussion. Capital input measures the services that flow from the stock of capital. This differs from the stock of capital sometimes used in productivity measurement because not all forms of capital provide services at the same rate, just as not all hours worked of different workers provide labour services at the same rate. Short-lived assets, such as computers, provide all of their services in the few years before they completely depreciate. Office buildings provide their services over decades. So, in a year, a dollar's worth of computers provides relatively more services than a dollar's worth of a building. Because of differences in capital services between assets, capital input can increase not only because investment increases the amount of the capital stock, but also if investment shifts toward assets — such as equipment — that provide relatively more services per dollar of capital stock.

To address this measurement problem, Jorgenson (1963) and Jorgenson and Griliches (1967) developed the notion of an asset-specific "user cost of capital", sometimes referred to as the rental price of capital. This price of capital can be used to aggregate the heterogeneous assets that make up capital stock to derive a measure of capital input that is used annually in the production process.

The user cost of capital measures the price of using capital in the production process during a period. It can be thought of as the price that a well functioning market would pay for an asset that is being rented by an owner to a user of that asset. That price would comprise a term reflecting the opportunity cost of capital (r_t), a term

2 MFP growth estimates and related variables for the business sector can be obtained from CANSIM Table 383-0021.

reflecting the depreciation of the asset (δ), and a term reflecting capital gains or losses from holding the asset (reflecting changes in the market price of an asset, $p_t - p_{t-1}$). Jorgenson (1963) and Jorgenson and Griliches (1967) show that the formula for the user cost of a unit of capital asset i that costs p_{it} can be estimated as:

$$c_{it} = p_{it-1} r_{it} + p_{it}\delta_i - (p_{it} - p_{it-1})$$
$$= p_{it-1}(r_{it} + (p_{it} - p_{it-1})\delta_i - \pi_{it})$$

The opportunity cost of capital (r_{it}) is often called the nominal rate of return. The difference between the nominal rate of return and the nominal capital gains term ($\pi_{it} = (p_{it} - p_{it-1})/p_{it-1}$) is called the real rate of return.[3]

Total capital input is derived from weighting heterogeneous assets using weights based on the user cost of the asset. Weighting assets by their user cost, which approximates the marginal revenue product in a competitive equilibrium, effectively incorporates differences in the productive contribution of heterogeneous investments as the composition of investment and capital changes. Changes in weighted capital input have two distinct components — changes in the quantity of capital stock, and changes in the composition of the various types of assets with different user costs. This second effect — arising from the change in the importance of different capital types in the aggregate capital stock — is referred to here as the composition effect resulting from changes in the bundle of capital assets.

The increase in the weighted bundle will be higher than in the simple aggregate when assets with higher rental prices (representing higher marginal products) are increasing at faster rates. Weighting explicitly captures substitution between heterogeneous assets in response to changing relative prices, or biased technical change. When this weighting is done for labour, the increase in the weighted aggregate is considerably above the simple sum of hours worked because the labour inputs with higher wage rates (e.g. from more experienced and more educated workers) have been increasing faster than those with lower wage rates. The same phenomenon has been occurring for capital assets with higher user costs of capital.

While Jorgenson's pioneering efforts provided the framework needed to overcome the lack of directly observable and measurable prices of capital services, providing a link between the model's theoretical structure and its application has been more difficult. In particular, there is a considerable difference between the rental price as a theoretical paradigm and its real world empirical application. Schreyer (2009), Diewert, Harrison, and Schreyer (2005), and Baldwin and Gu (2007) discussed the issues that have to be resolved in order to bridge this gap. Those issues include the rate of return, depreciation rates, capital gains, and whether the estimates are derived from direct aggregation across industries with a fully developed industry production accounts (the bottom-up approach) or whether estimates are derived from the aggregate productivity function approach (the top-down approach).

The remainder of this section will discuss those various issues, and highlight the differences between Diewert and Yu and the Canadian Productivity Program. In making various assumptions, the Canadian Productivity Program used a number of criteria. First, the choice should be based on the best available empirical evidence. Second, the choices should reflect best practices by other national statistical agencies so that the Canadian estimates are internationally

3 Alternatively, the real rate of return can be defined as the nominal rate of return minus a general inflation rate such as the CPI as in Diewert, Harrison and Schreyer (2005). A variation of the user cost of capital formula can then be expressed as the difference between the real rate of return (nominal rate of return deflated by CPI) and real capital gains (nominal capital gains deflated by CPI) plus a term for depreciation. This is not used in Diewert and Yu (2012).

comparable. Third, since Canadian productivity performance is often compared to the productivity performance in the United States, the methodology behind the estimates for Canada should be comparable to the largest extent possible to that used by the U.S. Bureau of Labor Statistics (BLS).

Exogenous versus Endogenous Rates of Return

Two main options are available for estimating the rate of return on capital: rates calculated endogenously from the System of National Accounts and rates taken exogenously from observed market rates. The statistical agencies in Canada and Australia use an endogenous rate of return in their productivity accounts, and the BLS essentially uses the endogenous method,[4] while Statistics Netherlands uses an exogenous rate of return. The advantage of using the method that employs endogenous rates is that it provides a fully integrated set of accounts. The surplus is taken directly from the National Accounts that provides the underlying data for the productivity accounts. But the method assumes a fully competitive economy with a production process subject to constant returns to scale. Choosing an exogenous rate of return allows the assumptions of constant returns to scale and competitive markets to be relaxed (Balk, 2010). And it does not require that the assets used completely exhaust capital income, thereby recognizing that some assets may be excluded in existing estimates. But it requires an exogenous rate that reflects individual risk characteristics of the assets that are not easy to obtain.

Diewert and Yu and the Canadian Productivity Program both choose the endogenous rate of return method for estimating capital input. In earlier work, Diewert (2008) used an exogenous rate of return method. The endogenous rate of return method has been chosen by the Canadian Productivity Program so as to provide a set of Productivity Accounts that are integrated into the Industry Accounts of Statistics Canada (e.g. the Input/Output Accounts).

Expected Capital Gains and Real versus Nominal Rates of Return

The capital gains component of the rental price formula has been and continues to be controversial. There is little disagreement that, on theoretical grounds, capital gains should be included in the rental price of capital. A lessor of capital will charge a lower price if a capital gain is expected by the end of the holding period or a higher price if a capital loss is expected. Nevertheless, there is some disquiet among practitioners when it comes to including a term for capital gains and losses. First, there is a concern about whether capital gains should be included in empirical studies, as the volatility in capital gains is not likely to be matched in the short run by changes in the marginal product of capital because of long gestation periods for capital projects.

Second, there is some uncertainty as to whether capital gains should be asset-specific and differ across assets. The answer to the question depends on whether there are ways that holding-period gains arising from differential rates of asset price increases can be harvested, especially for investment goods. This concern revolves around the level of transaction costs that must be incurred in selling investment goods. Because many assets are firm specific, they lose a considerable portion of their value when transferred — especially if they are transferred to alternate uses. If there is no inexpensive way to realize capital gains, the change in asset prices may not provide a

4 It replaces the endogenous rate of return with an external rate in about 40 per cent of its industries when it deems the endogenous rate implausible. Source: BLS website.

very precise estimate of the amount of capital gains that should be included in the user cost of capital.

Diewert and Yu and the Canadian Productivity Program make different choices about the asset-specific capital gains. Diewert and Yu assume that there are no asset-specific capital gains in the user-cost of capital while the Canadian Productivity Program assumes that there are asset-specific capital gains. The choice made by Diewert and Yu comes from their assumption that the real rate of return (defined as nominal rate of return minus nominal capital gains) is equalized across assets for applying the endogenous rate of return method for estimating capital input. The choice made by the Canadian Productivity Program stems from the assumption that the nominal rate of return is equalized across assets when applying the endogenous rate of return method.

The Canadian Productivity Program of Statistics Canada includes asset-specific capital gains and assumes that the nominal rate of return is equalized across assets. This is a common practice adopted by other statistical agencies including the U.S. Bureau of Labor Statistics and the Australia Bureau of Statistics. The practice has been adopted by a major international initiative EU-KLEMS that attempts to harmonize capital input and multifactor productivity estimates across European Union countries, Canada, the United States and a number of other non-EU countries (Timmer *et al.*, 2007 and 2011). The choice has also been adopted by the pioneering work of Jorgenson and his coauthors in developing the growth accounts for the United States and other major developed countries including Canada (Jorgenson and Fraumeni, 1987; Jorgensen, Ho and Stiroh, 2005).

Bottom-up versus Top-down Approach

Aggregate capital input for the total business sector can be estimated using bottom-up or top-down approaches. The bottom-up approach or the direct aggregation across industries involves the aggregation of various asset types within each industry to estimate industry capital services, and the aggregation of capital services across industries to derive aggregate capital input in the total business sector. The top-down approach or the aggregation production approach involves the aggregation of various asset types at the total business sector to derive aggregate capital input.

Jorgenson *et al.* (2005) presented those two alternative methods for estimating capital input and multifactor productivity at the aggregate level and discussed various assumptions underlying those two approaches. They conclude that the most restrictive approach is the aggregate production function or the top-down approach, which imposes highly restrictive and implausible assumptions about the relative prices and mobility of the primary factors of production, capital and labour. Jorgenson, Gollop, and Fraumeni (1987) show the aggregation of heterogeneous types of capital and labour must be the same across industries, and each type of capital and labour must command the same price in each industry. Under these assumptions, the aggregate production function yields a valid representation of the underlying industry-level production structure.

The alternative approach is a direct aggregation across industries or bottom-up approach, which relaxes all of the restrictions on inputs across industries. Measures of industry output, input, and productivity growth are weighted by the relative size of the industry and summed across all industries.[5] This approach makes no

5 For capital inputs the weights are the share of nominal capital income. For labour, the weights are the share of labour income. For output, the weights are for share of nominal value-added. For discussion of this issue, see Jorgenson (2012).

assumption about common prices of outputs or inputs across industries and treats the aggregate economy as a weighted average of the component industries.

More specifically, the bottom-up approach allows for differences in the user cost of capital of an asset and the rate of return across industries. In contrast, the top-down approach assumes the user cost of capital of an asset and the rate of return is the same across industries.

Baldwin and Gu (2007) found that there is a large variation in the rate of return and the user cost of capital across industries. Those large variations are also found in EU-KLEMS. Baldwin and Gu (2007) found that differences in the rate of return across industries can be significant and that capital tends to move towards those industries that earn relatively higher rates of return. These differences in the rate of return to capital may reflect barriers to mobility of capital across industries and indicate that adjustments that bring rates of return together do not happen quickly. In this case, a bottom-up approach should be used for estimating aggregate capital input using different rates of return across industries.

The top-down approach for estimating aggregate capital input would be justified if markets operated quickly and capital earned approximately the same rate of return across industries. In this case, the observed difference in earned rates of return across industries would reflect random measurement errors in investment, capital stock and capital income. The use of a common rate of return and common user cost of capital would reduce measurement errors in capital services estimates that would otherwise be present in the underlying data.

The difference between the estimates from the bottom-up and top-down approaches reflects the effect of the reallocation of capital services across industries. This effect is often found to be positive as capital tends to shift towards those industries with relatively higher rates of return, higher user cost of capital, and implicitly higher marginal products of capital.

Diewert and Yu used the top-down approach for estimating aggregate capital input in the total business sector. The Canadian Productivity Program uses the bottom-up approach for estimating aggregate capital input and is consistent with the empirical evidence that there are considerable differences in the rate of returns across Canadian industries.

Asset Classification

Aggregate capital input is derived from weighting heterogeneous assets using the user cost of capital as weights to reflect differences in the productive contribution of different assets. Ideally, the assets with a similar user cost of capital (e.g. similar depreciation rates and similar capital gains) should be grouped together. In practice, the asset classification used for estimating capital input is mainly determined by data availability. Diewert and Yu (2012) estimate capital input from 14 types of reproducible assets (machinery and equipment, and structures) plus land and inventory. The Canadian Productivity Program estimates capital input using 28 types of reproducible assets (15 types of machinery and equipment, and 13 types of structures) plus land and inventories.

The choice of different asset classifications may yield different estimates of capital input if individual assets within a broad asset group have different growth rates and different user costs of capital arising from the difference in depreciation rates and capital gains. The capital input estimate from a more detailed asset classification will grow faster if assets in a broad asset grouping with higher user costs increase faster than those with lower user costs.

An Overview of Differences

To sum up, Diewert and Yu and the Canadian Productivity Program used different approaches for estimating aggregate capital input in the Canadian business sector. The approach chosen by the Canadian Productivity Program is to use as detailed an asset and industry classification as possible to reflect differences across industries and assets and methods that reflects international guideline and practices adopted by other statistical agencies.

There are thus three main differences when it comes to estimating aggregate capital input between Diewert and Yu and the Canadian Productivity Program.

- the Canadian Productivity Program uses the bottom-up approach for estimating aggregate capital input, while Diewert and Yu uses the top-down approach.
- the Canadian Productivity Program assumes that the nominal rate of return is equalized across assets and the user cost of capital includes asset-specific capital gains when using the endogenous rate of return method for estimating capital input. In contrast, Diewert and Yu assume that the real rate of return is equalized across assets and the user cost of capital does not include asset-specific capital gains.
- the Canadian Productivity Program estimates capital input from a more detailed list of assets than Diewert and Yu.

In addition to those three main differences, there are a number of other differences. As shown in the next section, those differences are found to have little effect on aggregate capital input estimates. First, the estimate of land in constant dollars differs. Diewert and Yu assume that the volume of land is constant. The Canadian Productivity Program set the real value of land equal to an estimate of total area of the dependable agriculture land for cultivation and total area of urban land.

Second, there are some differences in depreciation rates. Diewert and Yu and the Canadian Productivity Program both use depreciation rates that are estimated in recent studies employing used asset prices that provide new empirical evidence on the depreciation rate for various types of assets in Canada (Statistics Canada, 2008). Those new depreciation rates differ from those used in early capital stock estimates. But there are some differences between Diewert and Yu and the Canadian Productivity Program. The Canadian Productivity Program has applied those depreciation rates to estimate capital stock over time.[6] In contrast, Diewert and Yu allowed depreciation rates to vary over time and introduced the new depreciation rates that are from Statistics Canada (2008) gradually into their capital stock estimates.[7]

In addition, the Canadian Productivity Program provides a more comprehensive treatment of tax provisions in estimating the user cost of capital. It takes into account the effect of corporate income tax rates and capital consumption allowance on the estimated user cost of capital. The coverage of the business sector differs between the Canadian Productivity Program and Diewert and Yu. The Canadian Productivity Program defines the business sector to include the rental housing sector, while Diewert and Yu do not.

6 The U.S. Bureau of Labor Statistics adopts a similar approach and assumes the depreciation rates do not change over time for almost all assets.

7 The Productivity Accounts make use of depreciation rates that can be estimated from used asset prices that are available after 1987 and assumes these depreciation rates for earlier periods. There are no estimates of depreciation rates from used asset prices for earlier periods. There are arbitrary estimates derived from a set of tax related sources for previous periods. The Productivity Program considered them sufficiently unreliable as not to use them for the historical period. These are the estimates that Diewert and Yu employ for the earlier period.

Table 1
Reconciling Aggregate Capital Input Growth between Diewert and Yu and the Canadian Productivity Program
(average annual rate of change)

	1961-2011	1961-1980	1980-2011
Canadian Productivity Program (bottom-up, variable land, equal nominal rates, 28 reproducible assets)	4.8	6.6	3.7
Canadian Productivity Program modified to adopt			
top-down approach	4.0	5.4	3.2
plus constant land	4.0	5.5	3.1
plus equal real rates of return across assets	3.6	4.8	2.8
plus 14 reproducible assets	3.2	4.0	2.7
Diewert and Yu (2012)	3.0	4.2	2.3

Sources of Difference in Capital Input Estimates between Diewert and Yu and the Canadian Productivity Program

In this section, the variation between aggregate capital input estimates from the Canadian Productivity Program and Diewert and Yu is traced to various differences in the approaches used to estimate capital input. The features of the method used by the Canadian Productivity Program for estimating aggregate capital input include: bottom-up approach; variable land; equalized nominal rates of returns across assets; and aggregation over 28 reproducible assets plus land and inventory stock. The method used by Diewert and Yu includes: top-down approach; constant land; equalized real rates of returns across assets; and aggregation over 14 reproducible assets plus land and inventory stock.

To examine the effect of the differences across these areas on the estimate of capital input, the data on investment and capital stock for 28 reproducible assets plus land and inventory at a detail level of industry aggregation for estimating capital input in Statistics Canada's productivity program are used.[8] The section starts with the approach used in the Canadian Productivity Program and estimates aggregate capital input from the bottom-up approach, variable land, equalized nominal rates of returns across assets, and aggregation over 28 reproducible assets. It then re-estimates aggregate capital input in the Canadian Productivity Program to reflect the assumptions used by Diewert and Yu. A comparison of the two capital input estimates between those estimates captures the effect of the choice in each of those areas on the estimate of growth in capital inputs.

Table 1 presents the average annual growth of capital input for the Canadian business sector over the period 1961 to 2011 under alternative assumptions.

The estimate from the Canadian Productivity Program has found capital input increasing at 4.8 per cent per year in the Canadian business sector over the period 1961 to 2011. When the top-down approach as in Diewert and Yu is used, aggregate capital input increased at 4.0 per cent per year over the same period. The difference in the two estimates reflects the effect of reallocation of capital across industries. This result suggests that the effect of reallocation on capital input growth across industries is large. An earlier study (Baldwin and Gu, 2007) found a similar large effect of reallocation across industries.

When the volume of land is assumed constant as in Diewert and Yu, aggregate capital input growth changes little. Next the real rate of return is assumed to be equalized across assets and capital gains are excluded as in Diewert and Yu. This lowers the annual capital input growth estimates. The difference in capital input growth from equalizing nominal rate of return versus real rate of return across assets is due to the rapid growth of high-tech capital assets such as computers and commu-

8 The data at a more aggregate level of assets and industries are published in CANSIM Table 383-0025.

nication equipment. Those assets have slow rates of price increase or even declines in prices, which results in little or negative capital gains. Assuming equal nominal rate of return and including capital gains give rise to relatively higher user costs for those assets than assuming equal real rates of return and excluding capital gains. As a result, growth in capital input from equalizing nominal rates in the Canadian Productivity Accounts is higher than the estimate from equalizing real rates in Diewert and Yu.

Finally, we aggregate investment and capital stock from 28 to 14 reproducible assets, and re-estimate aggregate capital input from 14 reproducible assets plus land and inventory stock as in Diewert and Yu. This is also found to lower capital input growth as shown in Table 1.

Table 1 also presents the estimate of capital input growth from Diewert and Yu. When we adopt the approach used by Diewert and Yu, we essentially replicate their estimates. The remaining small differences come from additional differences between the Canadian Productivity Program and Diewert and Yu, which include differences in depreciation rates, the coverage of the business sector, and treatment of tax parameters.

Table 2 uses the estimates from Table 1 and traces the difference in capital input growth between the Canadian Productivity Program and Diewert and Yu to the differences in the approaches. The capital input growth from the Canadian Productivity Program was higher than that in Diewert and Yu by 1.8 percentage points over the 1961-2011 period. The difference is almost entirely accounted for by three main differences in the two approaches: bottom-up versus top-down approaches (0.8 percentage points); equalizing nominal versus equalizing real rates of returns across assets (0.5 points), and 28 versus 14 types of reproducible assets (0.4 points).

Table 2
Sources of Differences in Capital Input Growth between Diewert and Yu and the Canadian Productivity Program
(percentage points per year)

	1961-2011	1961-1980	1980-2011
CPA minus Diewert and Yu (2012)	1.8	2.4	1.5
Accounted for by:			
Bottom-up vs. top-down approach	0.8	1.2	0.6
Variable land vs. constant land	0.0	-0.1	0.1
Equal nominal vs. equal real rates of return across assets	0.5	0.7	0.3
28 vs. 14 reproducible assets	0.4	0.8	0.1
Unexplained	0.2	-0.2	0.4

There is a residual 0.2 percentage points difference between the two estimates. Our preliminary analysis suggests that the remaining difference is mainly due to difference in the depreciation rates used. The Canadian Productivity Program sets depreciation rates to be constant over time as is done by the U.S. Bureau of Labor Statistics so as to provide comparable multifactor productivity estimate to the United States. In contrast, the estimate used by Diewert and Yu assumes that depreciation rates vary over time.

A major international initiative EU-KLEMS has developed comparable estimates of capital input, labour input and multifactor productivity growth at both the aggregate level and detailed industry level for EU countries, Canada, United States, and a number of other non-EU countries. Similar to the Canadian Productivity Program, the EU-KLEMS has also used the bottom-up approach and included asset-specific capital gains for estimating aggregate capital input (Timmer *et al.*, 2007 and Jorgenson, 2012). EUKLEMS shows lower multifactor productivity growth performance in Canada relative to the United States as does the official data from the two statistical agencies in the two countries (Gu, 2008).

Statistics Canada's productivity program has also investigated the nature of aberrant observations in the underlying KLEMS industry database that produce the rates of return (Macdonald, 2007). Such observations can occur for several reasons. First, changes in classification and methodology can lead to discontinuities over time. Second, disaggregation into finer industry classifications produces data where coherency may be of lower quality. Using these methods, the rates of return in the underlying industry data were smoothed and a number of industries where average levels were unreasonably high or low were replaced with more aggregate sectoral averages. This reduces the difference between the top-down and bottom-up approaches by about half of the 0.8 percentage points reported in column 1 of Table 2.[9]

Multifactor productivity growth estimates are designed to measure the increase in output that is produced beyond that expected from the increase in inputs that were applied to production. Accurate estimates of the latter require estimates of the differences in the productivity contribution (the marginal productivity) of inputs. When inputs are heterogeneous, failure to reflect differences in the productive contribution of different assets will tend to overestimate MFP when inputs with higher marinal productivity such as educated workers and information and communication technology assets have been growing fastest. Failure to capture differences across industries will do the same when the growing industries also have higher marginal productivity. When these differences are not taken into account, MFP estimates will tend to be higher because the MFP estimate will include the effect of these differences.

The differences in the estimates of Statistics Canada's Productivity Program and those of Diewert and Yu arise because the former allow for more differences in the marginal productivity of assets across industries. This partially comes from considering a finer level of asset detail, which when combined with the differences in the user cost of capital increases capital input growth and reduces MFP growth relative to estimates that use less asset detail.

The differences between the two estimates shed light on one of the causes of economic growth that we have previously discussed (Baldwin and Gu, 2007). Output growth does not just come from disembodied technical progress. It also comes from applying more of the types of inputs — skilled labour and rapidly depreciating high tech equipment that are more productive than other inputs. Estimates of MFP that do not take these heterogeneous differences into account are higher because they allocate the impact of this shift in the composition of inputs to MFP growth. The Statistics Canada Productivity Accounts on both the labour and capital side are built from detailed micro data. As such, they enable a large amount of industry and asset detail to be considered in the estimation process. And they show that if this were not used, the estimates of the amount of disembodied technical change, that is MFP growth, would be higher (Baldwin and Gu, 2007).

The question is: what is the correct level of asset and industry detail that should be used? Statistics Canada has chosen to work at a particular level — one that is believed to be supported by the quality of the data and follows international guidelines and practices adopted by other statistical agencies. And in doing so, it is recognized that the data at this level will contain measurement errors. But detailed studies of the differences in the results of working at different levels have been provided to the user community (Baldwin and Gu, 2007). There will, of course, be legitimate differences of opinion on the

9 This is also consistent with the difference that Jorgenson, Ho and Samuels (2012) report for the United States.

appropriateness of the levels at which the analysis should be carried out. The Diewert and Yu results provide readers with additional information that can be used to evaluate the sensitivity of the estimates to alternate assumptions. Having a good idea as to what differences are made by alternate assumptions of how the world operates is one way in which such information can be provided to the user community.[10]

Conclusion

All multifactor productivity programs are analytical in nature. As with other National Accounts summary statistics, they aggregate a large amount of data from different sources to provide summary statistics that attempt to shed light on a particular phenomenon. MFP estimates also require an underlying model of the production process and assumptions about how certain concepts can be measured.

Professional analysts will often recommend different ways to approach the measurement of MFP. Statisticians who are tasked with producing MFP estimates must choose amongst alternate proposed solutions. Statistics Canada has examined the alternatives proposed for the estimation of MFP and chosen a particular set. It has been transparent in doing so. It provides detailed documentation on the methodology used (Baldwin, Gu and Yan 2007). It has discussed the impact of using alternate assumptions. For example, Statistics Canada (2007) discusses the sensitivity of the use of different methods for estimating depreciation from used asset prices on the growth rates of capital and on the estimates of MFP. Baldwin and Gu (2007b) discuss the effects on MFP of estimating the impact of capital gains and using different ways to calculate the growth in capital services— the topic that is raised in the paper of Diewert and Yu. This study also investigated the differences between the top-down approach for the entire business sector and the bottom-up approach using an aggregate set of industries (36 industries at the M level of the Input/Output tables) and reported the differences in the rate of capital growth as 0.6 percentage points for the period 1961-2001. It was pointed out that endogenous rates of return at this level were more variable than the exogenous rate. However, the endogenous rate does not lead to an increase in the volatility of the estimated MFP rate relative to the exogenous rate.

Studies such as those noted above are provided to give guidance to users of the aggregate statistics as to the range within which the aggregate MFP estimates fall when alternate assumptions are used (see also Baldwin and Harchaoui (2002)). And testing the reasonableness of the alternate assumptions has occurred both by examining these assumptions, subjecting them to the scrutiny of Statistics Canada's Advisory Committee, and examining other evidence that corroborates differences in the outcomes produced by the alternative assumptions. For example, the difference between the bottom-up and top-down approaches comes partly from the effect of reallocation. Papers that have examined the impact of reallocation on aggregate industry productivity growth (e.g. Baldwin and Lafrance 2011) using micro level firm data have found that it is large. Work is constantly ongoing looking for ways of improving the program to shed light on the factors behind economic growth.

For example, the accuracy of traditional MFP estimates also depends upon the comprehensive of assets that are considered. Traditionally, official estimates do not take into account the effect of government infrastructure. Macdonald (2008) investigates the impact of public infrastructure on business-

10 For more information on the effect of alternate assumptions on MFP estimates, see Baldwin and Gu (2007).

sector production and Baldwin, Gu and Macdonald (2012) show that the incorporation of this effect would cause traditional estimates of MFP to change by a significant amount. Similar issues arise from the emerging importance of investments in intangible assets (intellectual capital) as a complement to machinery and equipment and structures. Baldwin, Gu, Lafrance and Macdonald (2009) provide estimates of the magnitude of expenditures on intangibles and Baldwin, Gu and Macdonald (2012) investigate how their inclusion would affect the traditional measures of MFP. Baldwin, Gu and Yan (2011) explore how traditional approaches to MFP estimation can be modified to take into account periods of over capacity and how this affects estimates of business sector MFP.

Statistics Canada has chosen to design its estimates around what it sees as best practice elsewhere so that there is broad comparability with other countries-so that cross country comparisons can be made by the research community. But there remain differences that are sometimes important for specific studies. The productivity program has therefore provided studies that adjust remaining differences to facilitate cross country comparisons (Baldwin, Maynard et al., 2005, Baldwin, Gu and Yan, 2008).

Statistics Canada has worked with users from other departments (Finance, Industry, Bank of Canada) who have accessed the underlying confidential data bases to investigate specific issues that have been or relevance to them (e. g. Baldwin, Fisher, Gu, Lee and Robidoux 2008). More recently, Statistics Canada has made all of the data on CANSIM free and the productivity accounts has added to its holdings thereby-providing a KLEMS data base at the industry level covering indices of outputs, labour inputs, capital service growth and materials inputs. We have been adding additional data at the request of users and will continue to do so where it is possible to so without violating the confidentiality provisions of the Statistics Act.

Statistics Canada is constrained by the Statistics Act on the level of detail that can be made public. In a small economy such as Canada, this places greater constraints than for other statistical agencies like the BLS where there are far more firms within an industry than is the case for Canada. As is the custom with the National Accounts, data in the Productivity Accounts is constructed at detailed industry levels that are sometimes confidential under the Statistics Act and then aggregated upwards to levels that can be published.

In keeping with the agency's commitment to providing maximum use of data that has been collected with public funds, while respecting the law on confidentiality, Statistics Canada has established the Canadian Centre for Data Development and Economic Research (CDER) where accredited researchers can access confidential business data under controlled conditions that maintain confidentiality and respect the sensitivity of the data. CDER has already provided access to the federal research community that has allowed them to investigate important issues related to productivity. It is now possible for an extended research community to use these data to answer the type of questions posed in the articles within this issue of the *International Productivity Monitor*.

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Rejoinder to Gu on "Estimating Capital Input for Measuring Business Sector Multifactor Productivity Growth in Canada"

Erwin Diewert[1]
University of British Columbia and University of New South Wales

ABSTRACT

This rejoinder responds to the comments of Wulong Gu (2012) on the article by Diewert and Yu (2012). The paper lays out the algebra behind the Diewert-Yu capital services methodology and the corresponding methodology used by the Statistics Canada Canadian Productivity Program. The large differences in the estimates can mainly be explained by different treatments of the expected capital gains term in user costs and the use of sectoral balancing rates of return versus economy-wide balancing rates of return.

RÉSUMÉ

Cette réplique répond aux commentaires de Wulong Gu (2012) sur l'article d'Erwin Diewert et Emily Yu (2012). L'article examine les calculs algébriques pour les méthodologies pour estimer les services de capital utilisés par Diewert-Yu et par le programme canadien de la productivité. Les grands écarts dans les estimations s'expliquent principalement par les traitements différents du terme des gains en capital escomptés dans les coûts de l'utilisation du capital et l'utilisation des taux de rendement sectoriel par rapport à a un taux de rendement a l'échelle de l'économie.

WULONG GU (2012) HAS PROVIDED a very thoughtful analysis of the differences in methodology for deriving business sector multifactor productivity (MFP) growth using the Statistics Canada Canadian Productivity Program (CPP) bottom-up methodology versus the top-down approach used by Diewert and Yu (2012). He attributes the differences in the overall MFP estimates for the Canadian business sector to the following three main factors:

- The use of the top-down approach involves some aggregation (over industries) bias which the bottom up approach does not have.
- The Diewert-Yu approach estimates a balancing or endogenous real rate of return whereas the CPP approach estimates a balancing or endogenous nominal rate of return.
- The Diewert-Yu approach is subject to some aggregation (over assets) bias that the CPP approach avoids.

1 Erwin Diewert is Professor in the Department of Economics at the University of British Columbia and at the School of Economics at the University of New South Wales. The author thanks the SSHRC of Canada for financial support for this research and he also thanks Don Drummond, Wulong Gu, Mike Harper, Alice Nakamura, Paul Schreyer and Andrew Sharpe for helpful comments. The author would also like to thank Ricardo de Avillez and the CSLS staff. None of the above are responsible for any opinions expressed in this paper. Email: diewert@econ.ubc.ca.

I actually agree with Gu on points 1 and 3 above but what Gu does not mention is that there are some problems with the Statistics Canada methodology which the Diewert-Yu methodology largely avoids. In section one, I lay out the algebra behind the two approaches and show that both approaches involve approximations to the "truth". Section two looks at the sectoral balancing rates of return used by Statistics Canada and concludes that the variability and size of these internal rates of return are the main explanation for the differences in the MFP estimates. Section three addresses some additional issues that Gu raises and section four concludes.

The Algebra Behind User Costs and Endogenous Rates of Return

In order to explain the differences between the Diewert-Yu methodology and the CPP methodology, it will be necessary to introduce some notation.

We want to work out what the value of capital services would be for a business sector that consists of I industries and where there are N assets that are used by these industries. Let P_{ni}^t denote the price of asset n in industry i at the beginning of period t and let K_{ni}^t denote the corresponding beginning of period t capital stock for n = 1,...,N and i = 1,...,I. Define the following variables:

$r_i^t \equiv$ the nominal cost of capital that industry i faces at the beginning of period t;

$\rho_{ni}^t \equiv$ the *expected* rate of price change in asset n for industry i during period t;

$\delta_{ni}^t \equiv$ the depreciation rate for asset n in industry i during period t;

$\tau_{ni}^t \equiv$ the rate of taxation (as a fraction of asset value) on asset n in industry i during period t.

Using the above definitions, the *user cost of asset n in industry i during period t*, U_{ni}^t, is defined as follows:

$$(1)\quad U_{ni}^t \equiv [r_i^t - \rho_{ni}^t + \delta_{ni}^t + \tau_{ni}^t]P_{ni}^t\ ; \quad n = 1,\ldots,N;\ i = 1,\ldots,I\ .$$

Both Diewert and Yu and the CPP would like to construct estimates of the *total value of capital services over all assets and all industries*, $\sum_{n=1}^N \sum_{i=1}^I U_{ni}^t K_{ni}^t$, for period t. I believe that the above approach to measuring capital services is a fairly good approximation to what is international best practice methodology for the determination of the price and quantity of capital services.[2]

The two main problems with this methodology are as follows:

- It is difficult to determine precisely what the correct opportunity cost of financial capital, r_i^t, is for each industry and
- It is difficult to determine exactly how to measure the anticipated capital gains term, ρ_{ni}^t.

Diewert and Yu and the CPP solve the above two problems in different ways as we shall explain below. We first need to introduce some additional notation. Let GOS_i^t denote the gross operating surplus of industry i in period t for i = 1,...,I.[3] We can now explain the Diewert-Yu methodology. We start with the value of business sector capital services, make various simplifying assumptions about the variables defined above and set the resulting approximate value of capital services equal to the value of business sector gross operating surplus. Our key simplifying assumptions are that the nominal cost of capital is the same across industries (so that $r_i^t = r^t$ for i = 1,...,I) and that expected asset appreciation rates are the same across assets and industries (so that $\rho_{ni}^t = \rho^t$ for i = 1,...,I and n = 1,...,N). These are strong assumptions. Some additional simplifying assumptions that we will

2 The basic methodology is due to Jorgenson and Griliches (1967). See also Diewert (1980) and Schreyer (2009). There will be minor variations on the form of the user cost formula from different experts.

3 This is the value of industry i's revenues, less intermediate input cost, less labour cost.

make are: asset depreciation rates, asset prices and asset tax rates are constant across industries so that $\delta_{ni}^t = \delta_n^t$, $P_{ni}^t = P_n^t$ and $\tau_{ni}^t = \tau_n^t$ for i = 1,...,I and n = 1,...,N. Thus the Diewert-Yu value of capital services is equal to:

(2) $\sum_{n=1}^N \sum_{i=1}^I U_{ni}^t K_{ni}^t = \sum_{n=1}^N \sum_{i=1}^I [r_i^t - \rho_{ni}^t + \delta_{ni}^t + \tau_{ni}^t] P_{ni}^t K_{ni}^t$ using definitions (1)
$\approx \sum_{n=1}^N \sum_{i=1}^I [r^t - \rho^t + \delta_n^t + \tau_n^t] P_n^t K_{ni}^t$ using our simplifying assumptions
$= \sum_{n=1}^N [r^t - \rho^t + \delta_n^t + \tau_n^t] P_n^t [\sum_{i=1}^I K_{ni}^t]$
$= \sum_{n=1}^N [r^t - \rho^t + \delta_n^t + \tau_n^t] P_n^t K_n^t$ where $K_n^t \equiv \sum_{i=1}^I K_{ni}^t$
$= \sum_{i=1}^I GOS_i^t$.

Thus the approximate value of capital services is set equal to the business sector sum of the industry gross operating surpluses, which is an equation which can be solved for the *overall business sector real rate of return*, $r^t - \rho^t \equiv r^{t*}$. In our empirical work, these balancing real rates of return ranged between 2.2 per cent and 9.9 per cent with the average rate equal to 6.13 per cent. Note that the Diewert-Yu methodology has solved the problem of generating estimates for r_i^t and the expected capital gains terms ρ_{ni}^t. However, it is clear that the Diewert-Yu methodology is subject to a kind of generalized unit value bias of the type that was described by Gu (2012).[4]

I will now explain how the CPP methodology works.[5] This methodology works on a sectoral level and makes fewer simplifying assumptions. The key assumption that the CPP methodology makes is that *expected capital gains*, ρ_{ni}^t, can be approximated by ex post *actual capital gains*, π_{ni}^t for n = 1,...,N and i = 1,...,I.[6] With this simplifying assumption in hand, we can start with the industry i value of capital services, make the CPP assumption about expected capital gains and set the resulting approximate value of industry i capital services equal to the industry i gross operating surplus:

(3) $\sum_{n=1}^N U_{ni}^t K_{ni}^t = \sum_{n=1}^N [r_i^t - \rho_{ni}^t + \delta_{ni}^t + \tau_{ni}^t] P_{ni}^t K_{ni}^t$; i = 1,...,I
$\approx \sum_{n=1}^N [r_i^t - \pi_{ni}^t + \delta_n + \tau_{ni}^t] P_{ni}^t K_{ni}^t$ using the CPP simplifications
$= GOS_i^t$.

The i equations in (3) can be solved for r_i^{t*}, the industry balancing nominal rates of return.

Comparing the two methodological approaches, it would appear that the CPP bottom-up approach has a clear advantage over the top-down approach, since it makes fewer simplifying assumptions.[7] However, I have two concerns with the CPP approach:

- Assuming that expected capital gains ρ_{ni}^t can be set equal to actual ex post capital gains π_{ni}^t leads to volatile user costs and sometimes negative user costs, which in my view are not plausible. We would like user costs to approximately follow market rents and leasing rates (when available) and these actual rental rates are fairly stable and never negative.
- The balancing industry nominal rates of return r_i^{t*} generated by solving equations (3) are frequently rather extreme; i.e., negative over prolonged periods or very large indeed. Unusual rates of return cannot be regarded as good approximations to the industry's ex ante cost of capital.[8]

4 See Diewert and von der Lippe (2010) for an analysis of the magnitude of "regular" unit value bias.

5 This explanation of course applies to any MFP methodology based on the assumption discussed below.

6 Another not so important simplifying assumption that the CPP methodology makes is to assume that depreciation rates are constant across time and industries so that $\delta_{ni}^t = \delta_n$ for n = 1,...,N, i = 1,...,I and t = 1,...T. Diewert and Yu use another Statistics Canada source (CANSIM Table 310003) for depreciation rates and this alternative source does not assume that asset depreciation rates are constant over time.

7 In fact, many years ago, I advocated the type of bottom-up approach that was described above; see Diewert (1980).

It turns out that at least some of the Statistics Canada balancing rates of return seem to be published as part of the World KLEMS accounts.[9] We will look at these internal rate of return estimates in the following section.

It is easy to rework our results using an exogenous real rate of return rather than the endogenous rates of return we used. Thus if we simply assumed that the real rate of return faced by the aggregate business sector was equal to 6.13 per cent (our sample average real rate of return), then our geometric average rate of MFP growth turns out to be 1.03 per cent per year, the resulting capital services aggregate average geometric growth rate becomes 2.97 per cent per year (compared to the CPP rate of 4.81 per cent per year) and our capital stock aggregate growth rate becomes 2.33 per cent per year (compared to the CPP rate of 3.11 per cent per year). Thus the huge difference in results is not changed by assuming an exogenous real rate of return for the Diewert-Yu top-down methodology.

My summary of the issues raised above is as follows: I agree with Gu that the bottom-up approach is methodologically best, but I disagree with the use of actual capital gains to approximate expected capital gains. As we shall see in the next section, a more serious problem is the substantial sectoral measurement errors that seem to show up in the Statistics Canada estimates of the sectoral balancing nominal rates of return.

Statistics Canada Estimates of Sectoral Nominal Internal Rates of Return

World KLEMS (2012) has a table for the balancing nominal rates of return used by Statistics Canada for 30 business sector industries in Canada for the 1961-2008 period. These data, which are labelled internal rates of return (IRR), are given in three tables in the Appendix. Conceptually, these IRRs are (approximately) equal to the industry balancing nominal rates of return r_i^t that appeared in equations (3) above.

I believe that these IRRs are generally too large and too variable to represent credible nominal opportunity costs of capital for the various industries. In my view, it is these very high and variable internal rates of return that explain most of the differences between the Diewert-Yu MFP estimates and the Statistics Canada estimates. This suggests that the official sectoral MFP estimates may be subject to a considerable amount of measurement error.[10]

Additional Points

Depreciation rates: Gu (2012) noted that the CPP program uses geometric depreciation rates that were constant over the entire sample period. Other divisions at Statistics Canada appear to use variable depreciation rates, as seen in CANSIM Table 310003.[11] We also use variable rates. I think that it is quite sensible to have gradually changing depreciation rates. How-

8 The problem is that all of the measurement errors that are associated with the construction of industry accounts show up in the balancing rate of return. Measurement errors are much larger at the industry level than at business sector level. At the aggregate level, most intermediate input transactions cancel out and hence it is not particularly important that these intermediate input flows are not measured very accurately. Similar problems occur with the allocation of labour effort and capital purchases to industries; it is much easier to do these allocations at the aggregate level than at the industry level.

9 If these rates of return are reasonably accurate, these statistics would be quite important for many policy purposes. Note that our balancing rates of return were not unreasonable but of course, they cover only the entire business sector.

10 A word of caution: it is likely that the official Statistics Canada MFP estimates are based on a more detailed industry classification than was reported to the World KLEMS data base. However, it is also very likely that the more detailed IRRs are generally large and variable.

11 For example, the variable depreciation rates for computers that we obtained from CANSIM Table 310003 started at 28 per cent in 1961, moved up to 60 per cent in 1998 and drifted down to 54 per cent per year in the last year of the series.

ever, this difference in methodology is not big enough to explain the differences in results.[12] A medium term goal for Statistics Canada should be to harmonize their information on capital stocks across divisions.[13]

Different scopes: Diewert-Yu exclude all housing, including rental housing whereas the CPP business aggregate, quite properly includes it. Our reason for excluding rental housing is that there is no accurate information on the structure and land components for rental housing and so it seemed best to us to simply exclude this sector. We did not make an adjustment for the labour input into the rental sector (it will be small) so our MFP growth rate will have a small downward bias from this omission.

The Degree of Disaggregation: Gu notes that Diewert and Yu have only 14 types of reproducible asset whereas the CPP has 28. It would be useful if Statistics Canada published estimates on all 28 assets in a CANSIM Table, at least for the entire business sector. Then all researchers would have the advantages associated with the use of this expanded data base. Currently, the CPP makes available information on only 5 assets in CANSIM Table 3830025 which ends in 2008! I realize that there might be confidentiality problems in releasing data on 28 assets (plus land and inventories) by industry but there should be no problem at the business sector level.

The Land Problem: The price and quantity of business land is poorly measured both by the CPP program and by Diewert and Yu. Improvement of measurement in this area should be a priority of Statistics Canada; i.e., there is no accurate breakdown of the price and quantity of land used for business and residential housing use (the price and quantity of agricultural land is relatively well determined). Another problem with land is that approximating anticipated capital gains for the price of land by the actual ex post capital gains (as happens using the Statistics Canada methodology) can lead to small or negative user costs for land and to a weight for land in overall capital services that is too small. This will tend to (incorrectly in my view) increase the growth of capital services and decrease the rate of growth in MFP.[14]

The Computer Price Problem: Statistical agencies frequently assume very large geometric depreciation rates for computers. If the anticipated capital gains term is included in the user cost of computers, this term will frequently be quite large and will add a fairly large positive term (which essentially reflects obsolescence) into the user cost of computers. When this is combined with a large depreciation rate, there is a chance that the combined effects of depreciation and obsolescence are overdone; i.e. the user cost of computers may become too large using the geometric model of depreciation with either anticipated or actual ex post capital gains in the user cost formula.

A method for checking the reasonableness of the assumed geometric depreciation is to calculate computer capital services using the one hoss shay model. In this model, the computer is assumed to deliver the same physical capital ser-

12 One related point about depreciation that is important enough to change the results is that the Statistics Canada depreciation rates are unusually large by international standards; e.g. U.S. and Australian depreciation rates are generally much smaller. A careful audit of the Statistics Canada procedures for estimating depreciation rates seems called for.

13 The Australian Bureau of Statistics has succeeded in harmonizing their information on capital stocks, flows and depreciation back to 1960. So it can be done!

14 Even using anticipated land price change in the user cost formula can lead to a negative user cost for land services. My solution to this problem is to apply an opportunity cost principle here: the value of land services should be equal to the maximum of the user cost and the price at which the land could be rented. See Diewert (2009), Diewert and Nakamura (2009) and Diewert, Nakamura and Nakamura (2009) for more on this opportunity cost approach to estimating capital services.

vices for all years of use until it is retired.[15] The price, quantity and value of capital services can be calculated using this one hoss shay model of depreciation and then the geometric model of capital services can be calibrated to at least roughly match the one hoss shay counterpart prices, quantities and values of capital services.[16] However, this problem of computer services measurement is not big enough to explain the differences in the two sets of MFP results for Canada.

International Guidelines and Practices: Does the top-down methodology meet international guidelines for best practice in this area? I have conceded that the top-down approach is not the best approach and a bottom-up approach that had *accurate* sectoral data would be preferable.[17] However, the estimates of MFP growth generated by the CPP program are so small, indeed negative since 1977, and the Statistics Canada industry balancing nominal rates of return are so large and variable that they in my view call into question their accuracy. Gu mentions Australia as a country that follows the same methodology as Statistics Canada. However, the Australian statisticians are far from happy with this methodology: they recognize that using ex post capital gains as a proxy for expected capital gains is not the final answer and they also encountered the unusual sectoral rates of return problem.[18] The Australian Statistician, Brian Pink, in a public meeting on November 20, 2012, in Canberra told an audience that there is no universal consensus on user cost methodology and he was open to alternative ideas.

Conclusion

The article by Wulong Gu, explaining the differences between the Diewert-Yu methodology and the Statistics Canada methodology is very useful. It made clear that our methodology is not the final answer to the measurement of a nation's multifactor productivity. However, I hope that in this rejoinder I have made clear that in my view there are some issues with the Statistics Canada methodology, taking into account the accuracy of the underlying sectoral data. To address these concerns, I believe that Statistics Canada will need more resources in order to improve the quality of their sectoral estimates of inputs and outputs.

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15 The algebra of the one hoss shay model is laid out in Diewert (2005).

16 The calibration parameter would be the geometric depreciation rate; i.e. we would choose this rate so that the geometric model approximated the one hoss shay model.

17 Note that the CPP estimates of MFP for an industry could be subject to same criticisms made by Gu of the top-down method as applied to the entire business sector. Thus when Statistics Canada forms industry estimates of capital inputs, to do the job according to best practice methodology, it would need firm by firm estimates of the cost of capital. It is unlikely that this information would be available to Statistics Canada.

18 But the Australian sectoral IRRs are better behaved than the Statistics Canada sectoral IRRs.

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Appendix: List of World KLEMS Industries

The 30 industries are as follows:

1 = Agriculture, hunting, forestry and fishing;

2 = Mining and quarrying;

3 = Food products, beverages and tobacco;

4 = Textiles, textile products, leather and footwear;

5 = Wood and products of wood and cork;

6 = Pulp, paper, paper products, printing and publishing;

7 = Coke, refined petroleum products and nuclear fuel;

8 = Chemicals and chemical products;

9 = Rubber and plastics products;

10 = Other non-metallic mineral products;

11 = Basic metals and fabricated metal products;

12 = Machinery, NEC;

13 = Electrical and optical equipment;

14 = Transport equipment;

15 = Manufacturing NEC; recycling;

16 = Electricity, gas and water supply;

17 = Construction;

18 = Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel;

19 = Wholesale trade and commission trade, except of motor vehicles and motorcycles;

20 = Retail trade, except of motor vehicles and motorcycles; repair of household goods;

21 = Hotels and restaurants;

22 = Transport and storage;

23 = Post and telecommunications;

24 = Financial intermediation;

25 = Real estate activities;

26 = Renting of M&E and other business activities;

27 = Public administration and defence; compulsory social security;

28 = Education;

29 = Health and social work;

30 = Other community, social and personal services.

Appendix Table 1
Internal Rates of Return in Canadian Business Sector Industries (1-10), 1961-2008

	Unweighted Business Sector Average	1	2	3	4	5	6	7	8	9	10
1961	0.256	0.058	0.216	0.338	0.064	0.073	0.109	0.130	0.182	0.211	0.117
1962	0.266	0.088	0.215	0.345	0.121	0.132	0.120	0.117	0.220	0.257	0.160
1963	0.309	0.118	0.232	0.398	0.192	0.209	0.158	0.151	0.299	0.305	0.194
1964	0.285	0.083	0.245	0.403	0.181	0.213	0.149	0.141	0.229	0.339	0.201
1965	0.324	0.116	0.265	0.438	0.213	0.198	0.156	0.137	0.245	0.365	0.234
1966	0.314	0.174	0.226	0.402	0.193	0.174	0.130	0.099	0.210	0.387	0.218
1967	0.274	0.074	0.209	0.382	0.152	0.164	0.070	0.061	0.163	0.354	0.140
1968	0.273	0.069	0.179	0.344	0.173	0.264	0.052	0.032	0.149	0.406	0.156
1969	0.299	0.106	0.204	0.397	0.209	0.267	0.113	0.047	0.207	0.446	0.190
1970	0.285	0.080	0.207	0.370	0.197	0.095	0.117	0.053	0.173	0.388	0.165
1971	0.287	0.072	0.176	0.403	0.223	0.107	0.083	0.067	0.165	0.385	0.217
1972	0.283	0.111	0.173	0.382	0.205	0.254	0.079	0.066	0.155	0.365	0.243
1973	0.357	0.246	0.285	0.509	0.313	0.529	0.215	0.077	0.260	0.400	0.335
1974	0.421	0.341	0.422	0.536	0.386	0.349	0.408	0.174	0.365	0.454	0.390
1975	0.326	0.264	0.377	0.431	0.250	0.153	0.228	0.225	0.217	0.272	0.294
1976	0.256	0.177	0.312	0.398	0.196	0.135	0.151	0.068	0.132	0.218	0.205
1977	0.254	0.135	0.298	0.418	0.212	0.259	0.159	0.095	0.128	0.267	0.196
1978	0.277	0.186	0.297	0.447	0.283	0.390	0.203	0.039	0.170	0.299	0.243
1979	0.309	0.211	0.354	0.454	0.350	0.397	0.278	0.095	0.223	0.338	0.257
1980	0.301	0.187	0.390	0.422	0.372	0.209	0.313	0.131	0.225	0.327	0.226
1981	0.296	0.191	0.323	0.439	0.401	0.097	0.249	0.052	0.204	0.292	0.199
1982	0.220	0.141	0.274	0.408	0.271	-0.044	0.131	0.042	0.115	0.163	0.123
1983	0.178	0.119	0.205	0.355	0.286	0.049	0.064	0.036	0.085	0.158	0.103
1984	0.208	0.101	0.238	0.400	0.312	0.060	0.147	0.045	0.137	0.274	0.154
1985	0.231	0.098	0.213	0.459	0.347	0.134	0.153	0.040	0.172	0.350	0.223
1986	0.230	0.121	0.093	0.456	0.373	0.217	0.170	0.084	0.189	0.281	0.258
1987	0.228	0.102	0.108	0.471	0.367	0.251	0.210	0.013	0.217	0.271	0.317
1988	0.234	0.103	0.124	0.445	0.329	0.137	0.229	0.072	0.311	0.219	0.322
1989	0.227	0.135	0.112	0.444	0.349	0.152	0.188	-0.026	0.321	0.224	0.303
1990	0.180	0.132	0.116	0.437	0.268	0.048	0.113	0.013	0.246	0.194	0.199
1991	0.101	0.085	0.058	0.437	0.188	-0.036	-0.004	0.085	0.155	0.112	0.067
1992	0.135	0.135	0.034	0.478	0.229	0.088	0.025	0.004	0.180	0.214	0.107
1993	0.167	0.149	0.084	0.457	0.269	0.340	0.043	-0.005	0.210	0.272	0.126
1994	0.211	0.172	0.107	0.501	0.303	0.539	0.104	0.028	0.268	0.336	0.169
1995	0.206	0.133	0.076	0.462	0.313	0.298	0.251	0.005	0.347	0.290	0.180
1996	0.197	0.142	0.116	0.443	0.293	0.296	0.175	0.019	0.307	0.365	0.201
1997	0.212	0.132	0.094	0.463	0.350	0.358	0.154	0.020	0.290	0.342	0.238
1998	0.212	0.136	0.061	0.499	0.368	0.345	0.176	0.029	0.248	0.346	0.255
1999	0.215	0.143	0.072	0.436	0.349	0.511	0.139	0.021	0.210	0.319	0.225
2000	0.249	0.107	0.160	0.491	0.465	0.443	0.235	0.049	0.251	0.403	0.273
2001	0.223	0.122	0.115	0.518	0.370	0.382	0.233	0.105	0.232	0.426	0.296
2002	0.217	0.135	0.096	0.478	0.308	0.405	0.180	0.067	0.263	0.406	0.263
2003	0.191	0.125	0.133	0.453	0.250	0.304	0.088	0.048	0.213	0.323	0.237
2004	0.242	0.156	0.203	0.527	0.230	0.505	0.156	0.096	0.238	0.354	0.308
2005	0.236	0.146	0.237	0.527	0.146	0.352	0.159	0.080	0.191	0.362	0.326
2006	0.243	0.119	0.221	0.553	0.140	0.254	0.154	0.079	0.218	0.329	0.343
2007	0.245	0.132	0.189	0.532	0.098	0.194	0.142	0.123	0.190	0.332	0.336
2008	0.240	0.213	0.220	0.563	0.083	0.183	0.149	0.081	0.186	0.264	0.293
Period Average											
1961-2008	0.249	0.138	0.195	0.445	0.261	0.238	0.156	0.069	0.215	0.313	0.226
2000-2008	0.232	0.139	0.175	0.516	0.232	0.336	0.166	0.081	0.220	0.355	0.297

Source: World KLEMS (2012) Data: Canada, CAN Capital 2012, Released July 2012. http://www.world-klems.net/data/index.htm

Appendix Table 2
Internal Rates of Return in Canadian Business Sector Industries (11-20), 1961-2008

	11	12	13	14	15	16	17	18	19	20
1961	0.119	0.248	0.368	0.147	0.012	0.074	0.188	0.695	0.397	0.276
1962	0.143	0.349	0.564	0.216	0.019	0.072	0.139	0.658	0.396	0.258
1963	0.196	0.426	0.555	0.358	0.054	0.076	0.232	0.736	0.448	0.321
1964	0.206	0.441	0.619	0.257	0.057	0.087	0.141	0.622	0.473	0.276
1965	0.267	0.468	0.673	0.365	0.086	0.111	0.241	0.526	0.501	0.300
1966	0.216	0.438	0.604	0.250	0.114	0.097	0.288	0.482	0.581	0.354
1967	0.148	0.369	0.370	0.317	0.087	0.079	0.252	0.408	0.528	0.303
1968	0.159	0.362	0.464	0.342	0.061	0.050	0.325	0.387	0.447	0.308
1969	0.206	0.416	0.527	0.479	0.121	0.086	0.349	0.336	0.534	0.287
1970	0.184	0.324	0.431	0.217	0.117	0.101	0.485	0.362	0.579	0.351
1971	0.168	0.359	0.320	0.392	0.124	0.090	0.397	0.345	0.600	0.343
1972	0.149	0.338	0.465	0.441	0.136	0.099	0.379	0.275	0.652	0.353
1973	0.272	0.474	0.593	0.556	0.272	0.116	0.453	0.257	0.698	0.390
1974	0.371	0.600	0.642	0.535	0.324	0.230	0.682	0.319	0.826	0.447
1975	0.223	0.393	0.517	0.356	0.190	0.178	0.779	0.298	0.693	0.428
1976	0.130	0.346	0.409	0.324	0.151	0.103	0.730	0.177	0.619	0.362
1977	0.173	0.365	0.451	0.325	0.151	0.108	0.656	0.147	0.474	0.280
1978	0.229	0.480	0.439	0.379	0.194	0.124	0.629	0.168	0.463	0.352
1979	0.247	0.603	0.609	0.372	0.232	0.151	0.657	0.233	0.668	0.396
1980	0.272	0.589	0.660	0.153	0.300	0.157	0.725	0.225	0.691	0.421
1981	0.218	0.527	0.617	0.153	0.339	0.150	0.776	0.223	0.723	0.389
1982	0.076	0.335	0.448	0.158	0.206	0.109	0.728	0.190	0.508	0.313
1983	0.054	0.211	0.283	0.215	0.150	0.076	0.592	0.099	0.518	0.256
1984	0.125	0.370	0.452	0.403	0.225	0.089	0.541	0.129	0.588	0.280
1985	0.162	0.431	0.465	0.396	0.295	0.092	0.527	0.091	0.680	0.330
1986	0.144	0.464	0.384	0.228	0.238	0.103	0.522	0.059	0.752	0.311
1987	0.188	0.333	0.424	0.156	0.241	0.097	0.509	0.045	0.69	0.344
1988	0.233	0.400	0.468	0.218	0.250	0.107	0.500	0.046	0.709	0.329
1989	0.191	0.406	0.496	0.292	0.260	0.085	0.548	0.026	0.689	0.305
1990	0.086	0.349	0.405	0.201	0.212	0.101	0.43	0.010	0.580	0.254
1991	-0.01	0.151	0.231	0.107	0.085	0.044	0.306	-0.096	0.424	0.132
1992	0.019	0.209	0.248	0.160	0.156	0.047	0.349	-0.062	0.395	0.165
1993	0.064	0.326	0.339	0.231	0.181	0.086	0.338	-0.042	0.427	0.178
1994	0.137	0.401	0.378	0.343	0.265	0.109	0.352	-0.022	0.536	0.190
1995	0.192	0.472	0.386	0.363	0.280	0.087	0.266	-0.041	0.544	0.190
1996	0.162	0.450	0.364	0.304	0.296	0.109	0.267	-0.076	0.483	0.163
1997	0.214	0.506	0.468	0.280	0.361	0.101	0.251	-0.028	0.544	0.163
1998	0.229	0.467	0.452	0.322	0.404	0.103	0.240	-0.014	0.509	0.168
1999	0.216	0.486	0.603	0.540	0.380	0.084	0.219	-0.005	0.500	0.189
2000	0.287	0.592	0.615	0.514	0.512	0.093	0.233	0.038	0.520	0.230
2001	0.223	0.579	0.128	0.407	0.534	0.079	0.297	0.058	0.500	0.250
2002	0.240	0.481	0.033	0.430	0.508	0.084	0.319	0.088	0.497	0.263
2003	0.178	0.383	0.004	0.312	0.466	0.077	0.311	0.076	0.546	0.273
2004	0.288	0.507	0.105	0.241	0.550	0.116	0.421	0.106	0.641	0.292
2005	0.290	0.512	0.135	0.183	0.483	0.125	0.500	0.115	0.669	0.294
2006	0.344	0.536	0.099	0.137	0.482	0.127	0.531	0.142	0.738	0.305
2007	0.374	0.537	0.127	0.135	0.439	0.112	0.588	0.193	0.744	0.320
2008	0.354	0.490	0.131	0.092	0.429	0.107	0.610	0.214	0.641	0.301
Period Average										
1961-2008	0.195	0.423	0.408	0.298	0.251	0.102	0.433	0.192	0.574	0.291
2000-2008	0.286	0.513	0.153	0.272	0.489	0.102	0.423	0.114	0.611	0.281

Source: World KLEMS (2012) Data: Canada, CAN Capital 2012, Released July 2012. http://www.world-klems.net/data/index.htm

Appendix Table 3
Internal Rates of Return in Canadian Business Sector Industries (21-30), 1961-2008

	21	22	23	24	25	26	27	28	29	30
1961	1.000	0.089	0.042	0.878	0.153	1.000	0.027	-0.023	0.017	0.608
1962	1.000	0.093	0.049	0.733	0.146	0.956	0.026	-0.022	0.016	0.597
1963	1.000	0.115	0.056	0.788	0.167	1.000	0.052	0.015	0.058	0.597
1964	1.000	0.132	0.075	0.606	0.178	0.800	0.037	-0.007	0.029	0.563
1965	1.000	0.151	0.105	0.777	0.180	1.000	0.094	0.037	0.075	0.595
1966	1.000	0.144	0.098	0.817	0.187	1.000	0.078	0.061	0.081	0.532
1967	1.000	0.118	0.115	0.814	0.174	1.000	0.013	0.040	0.068	0.481
1968	0.996	0.102	0.108	0.841	0.133	1.000	0.014	0.002	0.050	0.413
1969	0.924	0.138	0.123	0.762	0.161	0.889	0.049	0.063	0.101	0.456
1970	0.938	0.140	0.123	0.821	0.151	0.902	0.049	0.061	0.102	0.410
1971	0.912	0.139	0.119	0.828	0.172	0.929	0.067	0.065	0.129	0.393
1972	0.773	0.148	0.115	0.726	0.191	0.783	0.065	0.043	0.133	0.390
1973	0.717	0.163	0.116	0.605	0.257	0.791	0.123	0.195	0.282	0.407
1974	0.819	0.246	0.158	0.577	0.257	0.782	0.268	0.185	0.282	0.495
1975	0.620	0.210	0.164	0.607	0.148	0.649	0.124	0.083	0.183	0.381
1976	0.444	0.132	0.120	0.559	0.154	0.564	0.073	0.056	0.174	0.291
1977	0.418	0.143	0.126	0.589	0.112	0.516	0.077	0.077	0.169	0.279
1978	0.409	0.147	0.238	0.557	0.132	0.442	0.082	0.070	0.174	0.296
1979	0.412	0.182	0.134	0.462	0.151	0.439	0.096	0.124	0.205	0.309
1980	0.416	0.179	0.071	0.383	0.158	0.360	0.124	0.119	0.262	0.291
1981	0.393	0.166	0.121	0.461	0.193	0.465	0.151	0.103	0.289	0.294
1982	0.301	0.141	0.174	0.302	0.106	0.449	0.09	0.092	0.251	0.254
1983	0.179	0.091	0.136	0.334	0.120	0.312	0.051	0.007	0.200	0.158
1984	0.171	0.098	0.124	0.235	0.116	0.306	0.045	-0.008	0.157	0.178
1985	0.203	0.117	0.127	0.276	0.111	0.270	0.035	0.026	0.174	0.212
1986	0.209	0.106	0.130	0.358	0.153	0.307	0.026	0.038	0.207	0.243
1987	0.180	0.104	0.107	0.322	0.172	0.226	0.021	0.061	0.209	0.218
1988	0.178	0.117	0.106	0.307	0.137	0.219	0.053	0.072	0.210	0.228
1989	0.183	0.116	0.100	0.247	0.128	0.172	0.053	0.080	0.234	0.227
1990	0.152	0.095	0.106	0.209	0.066	0.144	0.051	0.049	0.206	0.194
1991	0.048	0.060	0.049	0.135	0.099	0.041	-0.005	-0.016	0.153	0.105
1992	0.093	0.069	0.096	0.253	0.080	0.096	0.022	0.020	0.190	0.155
1993	0.097	0.076	0.114	0.317	0.096	0.105	0.020	0.029	0.184	0.163
1994	0.109	0.103	0.119	0.375	0.095	0.114	0.040	0.040	0.204	0.176
1995	0.136	0.085	0.100	0.359	0.070	0.125	0.040	0.050	0.213	0.187
1996	0.107	0.100	0.146	0.332	0.067	0.109	0.046	0.036	0.199	0.163
1997	0.104	0.093	0.123	0.302	0.087	0.159	0.037	0.037	0.235	0.171
1998	0.113	0.079	0.116	0.252	0.081	0.163	0.026	0.030	0.236	0.164
1999	0.124	0.064	0.083	0.161	0.093	0.124	0.033	0.026	0.224	0.164
2000	0.149	0.077	0.083	0.183	0.091	0.126	0.049	0.055	0.252	0.201
2001	0.138	0.069	0.082	0.179	0.091	0.137	0.013	0.036	0.230	0.224
2002	0.137	0.070	0.082	0.171	0.105	0.143	0.023	0.023	0.210	0.238
2003	0.131	0.056	0.061	0.178	0.110	0.110	0.034	0.030	0.200	0.230
2004	0.167	0.073	0.115	0.223	0.118	0.127	0.050	0.063	0.236	0.271
2005	0.155	0.106	0.140	0.231	0.100	0.130	0.058	0.055	0.213	0.276
2006	0.165	0.117	0.189	0.270	0.124	0.127	0.073	0.077	0.203	0.273
2007	0.187	0.098	0.210	0.291	0.121	0.128	0.059	0.090	0.235	0.264
2008	0.181	0.112	0.240	0.296	0.077	0.146	0.093	0.099	0.232	0.241
Period Average										
1961-2008	0.423	0.116	0.117	0.444	0.133	0.435	0.059	0.053	0.179	0.305
2000-2008	0.157	0.086	0.134	0.225	0.104	0.130	0.050	0.059	0.223	0.246

Source: World KLEMS (2012) Data: Canada, CAN Capital 2012, Released July 2012. http://www.world-klems.net/data/index.htm

Comment on "Estimating Capital Input for Measuring Business Sector Multifactor Productivity Growth in Canada"

Paul Schreyer[1]
OECD

ABSTRACT

This article shows that the large difference of 0.8 per cent percentage points per year between top-down estimates of capital input growth obtained by Diewert and Yu and the bottom-up estimates produced by Statistics Canada for the Canadian business sector over the 1961-2011 period can be interpreted as an reallocation effect due either to inefficiencies in production and or a measurement issue. It is also noted that although user costs of capital are officially recognized in the System of National Accounts, there is no single recommendation on the details of implementation and that moving towards such a recommendation is an objective worth pursuing.

RÉSUMÉ

Cet article montre que la grosse différence de 0,8 points de pourcentage par année entre les estimations descendantes de la croissance des intrants de capital obtenues par Diewert et Yu et les estimations ascendantes produites par Statistique Canada pour le secteur des entreprises canadiennes pendant la période 1961 à 2011 peut être interprétée comme un effet de redistribution dû à des pratiques de production inefficaces. On fait remarquer aussi que, bien que les coûts de l'utilisation du capital soient officiellement reconnus dans le Système de comptabilité nationale, il n'y a pas une seule recommandation sur les détails de la mise en œuvre, et qu'en arriver à formuler ce genre de recommandation est un objectif qu'il vaut la peine d'essayer d'atteindre.

GU (2012) IN THIS SYMPOSIUM examines the differences in capital input estimates between the Canadian Productivity Program of Statistics Canada and Diewert and Yu (2012). He finds that the difference in aggregate capital input estimates (and therefore the differences in multifactor productivity (MFP) growth) is largely explained by three factors. First, whereas the Canadian Productivity Program aggregates capital services across industries to derive the capital input measure at the level of the business sector, Diewert and Yu (2012) use a top-down approach and directly compute capital and labour input series at the business sector level. Second, there are differences in the way the price of capital services is computed. Third, the Canadian Productivity Program bases its capital measures on a more detailed list of assets than Diewert and Yu (2012). This note provides some additional comments on the first and second source of differences.

1 The author is Assistant Chief Statistician at the OECD. The views expressed in this article are those of the author and not necessarily those of the OECD or its member countries. E-mail: paul.schreyer@oecd.org

Top-down and Bottom-up Computations of MFP

It is intuitively appealing to start productivity measurement at the industry level by positing the existence of an industry-specific technology and an associated production or cost function. The industry-level approach allows for industry-specific prices of inputs and thus for possible rigidities in factor markets. When, in a second step, growth rates of inputs and outputs are constructed at the level of the business sector, aggregation proceeds using industry-specific prices of inputs (and outputs). This is essentially the approach chosen by the Canadian Productivity Program.

Alternatively, (or rather in addition as I will argue below) an economy-wide MFP measure can be established directly, via Jorgenson's (1966) production possibility frontier (PPF). The PPF relates an economy's output to the set of inputs available in the economy under efficient allocation. MFP growth is measured as the shift of the PPF over time. A key feature of the PPF is that it assumes a single price for each type of input that applies across all uses in different industries. Thus, the PPF constitutes a benchmark, achievable under full mobility of factors in competitive markets. Its exogenous time shift is the top-down productivity computation that corresponds to Diewert and Yu's (2012) measures of Canadian business sector MFP productivity.

Jorgenson, Ho and Stiroh (2005) and Jorgenson and Schreyer (forthcoming) show how the PPF-based productivity measure links up with industry-specific measures. The link is simple and intuitively appealing and has been referred to by Gu (2012) in his comments but is worth spelling out explicitly. Letting ρ be the PPF-based, business sector-wide measure of MFP growth and letting π_j stand for MFP growth in industry j, the following relation holds:

$$\rho = \sum_j w_j \pi_j + \mathrm{REALL}$$

The difference between top-down MFP growth ρ and a weighted average of industry-specific MFP productivity growth (with w_j being each industry's share in total nominal value added) is a 'reallocation' term. REALL quantifies the departure from the assumptions on efficient input markets required for the PPF. It can be shown that the reallocation term is exactly the difference between the input aggregates constructed with industry-specific input prices and the input aggregates constructed with a single input price across industries. REALL will be positive and allocation inefficient if inputs grow more rapidly in those industries that pay relatively higher prices for these inputs than other industries.

But should ρ or $\Sigma w_j \pi_j$ be considered the 'correct' measure of aggregate MFP growth? There is no simple answer here. Rather, each measure provides an answer to a different question. Whereas $\Sigma w_j \pi_j$ is best described as *effective* productivity growth, 'adding up' industry productivity growth, ρ captures *underlying* productivity growth in the sense of a shift of the economy's production possibilities if allocation operates efficiently. As the difference between the two measures has a clear interpretation (and possible policy implications if there are large potential efficiency gains from reallocation) both measures are clearly useful.

That said, the empirical evidence for instance in Jorgenson, Ho, and Samuels (2012) points to reallocation effects that tend to be small, at least for the United States. The significant size of the reallocation effect in the Canadian case (valued by Gu (2012) at 0.8 percentage points per year for capital input over the 1961-2011 period) is worth examining because it either points to significant productivity gains that could be realized in the Canadian economy through reallocation of resources between industries or it reflects a measurement issue associated with large variances of industry-specific input prices.

In the case of capital, input prices correspond to user costs.

User Cost Calculations

Because many capital goods are both owned and used by a particular firm, there is only a limited number of market transactions for the purchase of capital services as would be the case when capital goods are rented out. Absent a market transaction, a price has to be imputed and as is frequently the case, there are several possibilities for imputation. The *OECD Measuring Capital Manual* (Schreyer, 2009) discusses at length the advantages and drawbacks of various approaches and the sensitivity of the resulting aggregates to these choices.

Country practices and practices among researchers vary. While agencies such as the US Bureau of Labor Statistics and the Australian Bureau of Statistics follow a similar approach towards calculating user cost as the Canadian Productivity Program, this is, for instance, not the case for the Netherlands, Korea and for the OECD's MFP measurement work. In the end, the choice is often made on pragmatic grounds, including the ease with which results can be communicated to users.[2]

At this stage, there is no single method that constitutes an international recommendation or standard. The current debate shows that it may be worth pursuing this objective and to go beyond the recent achievement of having capital services officially recognized as part of the UN System of National Accounts. The OECD would certainly be willing to contribute to this objective.

Debates such as the one at hand are welcome and important as they sharpen our understanding of issues and bring out new evidence. More often than not, there is no single correct answer to one question but several answers to several questions. This is the nature of the beast 'productivity measurement' and if questions and answers can be clarified through constructive debate, much will have been achieved.

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2 In the course of a recent study on Korea (Cho, Kim and Schreyer, 2012) we examined the various possibilities for deriving user cost measures. In the end, the choice fell on using a real balancing rate, akin to the approach adopted by Diewert and Yu (2012). The single most important reason for this choice was the fact that the new Korean dataset includes capital services from land whose real price showed a strong upward trend over an extended period. Explicit inclusion of these real price changes in the user cost formula for land would have led to negative prices for capital services from land in a significant number of years which is a result that is difficult to interpret. Consequently, the real balance rate method which is a simplified user cost approach (also discussed in OECD, 2009) was selected. A similar result would have been achieved by selecting an exogenous real rate of return that is equal across assets. In both cases, the assumption is made that the best guess for the expected price change of an asset is the overall rate of inflation.

Difficulties Assessing Multifactor Productivity for Canada

Michael J. Harper[1]

Alice O. Nakamura and Lu Zhang
University of Alberta

ABSTRACT

In 2011, Canada's business sector multifactor productivity (MFP) index, as estimated by Statistics Canada, was below that for 1977, a third of a century earlier. Over these years, public policies were enacted to try to improve Canada's productivity. Yet the nation's MFP continued to fall, relative to both the past and Canada's main trading partners. Policymakers and business decision makers need to know whether Canada's MFP statistics accurately reflect the nation's productivity. We argue that they do not.

RÉSUMÉ

En 2011, l'indice de la productivité multifactorielle (PMF) du secteur des entreprises du Canada tel qu'estimé par Statistique Canada en 2011 était inférieur à celui de 1977, plus d'une trentaine d'années plus tôt. Pendant des années les politiques publiques ont été développées pour améliorer la productivité du Canada. Pourtant, l'indice du PMF continue à decliner, par rapport au passé et aux principaux partenaires commerciaux du Canada. Il est crucial pour les responsables des politiques et les décideurs des milieux d'affaires de savoir si la situation reflète fidèlement le rendement du Canada sur le plan de la PMF. Nous soutenons que cela n'est pas le cas.

IN 2011, CANADA'S BUSINESS SECTOR multifactor productivity (MFP) index, as estimated by Statistics Canada, was 94.8, which is lower than the value of 97.6 for 1977. For years now, governments in Canada have sought to improve the nation's productivity. Don Drummond (2006 and 2011) and Paul Boothe and Richard Roy (2008) describe some of the policy measures. Yet, as Drummond (2011:4) laments, "multifactor productivity did not grow at all." Drummond notes that the implementation of a large number of market-oriented policies by governments in Canada over the past several decades was expected to boost productivity

1 Michael J. Harper retired in 2011 from his position as Associate Commissioner for Productivity and Technology of the U.S. Bureau of Labor Statistics (BLS) which he had held since 2006. At the BLS he was involved in developing the Bureau's measures of multifactor productivity. Alice Nakamura is a professor in the Department of Finance and Statistical Analysis in the Alberta School of Business at the University of Alberta. Lu Zhang is a doctoral student in the same department. The authors thank Munir Sheikh, Barbara Fraumeni, Steve Landefeld, Wulong Gu, Erwin Diewert, Phil Davidson, Don Drummond, Larry Shute and especially Andrew Sharpe for comments. This research was supported in part by the Social Sciences and Humanities Research Council of Canada (SSHRC). SSHRC has been actively encouraging efforts by Canadian scholars to learn from practices in other nations. The authors, as individuals, are solely responsible for the contents of the paper. E-mails: mike-harper.econ@gmail.com; alice.nakamura@ualberta.ca; and lu.zhang@ualberta.ca.

growth. But this did not happen. In this article, we suggest that one reason for this situation may be that measurement issues have resulted in officially measured productivity growth underestimating true productivity growth.

We note that MFP statistics are fragile. They draw on a wide range of economic statistics, including estimates of output and labour and capital input as well as price information for these components. John Baldwin (2012) points out that the Statistics Canada productivity program integrates data from different sources that are not all perfectly comparable.

MFP growth rates are often of the order of only 1 to 2 per cent per year. The MFP growth rate is defined as the output growth rate minus the input growth rate. So, suppose output grew 4 per cent per year over a 50 year period, and input grew 3 per cent. Thus MFP grew at a 1 per cent rate. Now suppose the statistical agency overstates input growth by 1 percentage point. Then the measured input growth rate would be 4 per cent instead of 3 per cent. Looking at the input series, it would not necessarily be obvious that something was wrong. However, the same error would lead to no measured MFP growth! The point is that seemingly odd MFP results should lead us to examine the data and methods utilized.

Gu (2012:50) writes that, "since Canadian productivity performance is often compared to the productivity performance in the United States, the methodology behind the estimates for Canada should be comparable to the largest extent possible to that used by the U.S. Bureau of Labor Statistics (BLS)." Thus we begin with a brief review of the history of the BLS productivity program. We follow with a discussion of the rates of return used in computing the capital services input for MFP statistics. Next we introduce the EU KLEMS and World KLEMS data bases.

The official Statistics Canada and Bureau of Labor Statistics (BLS) MFP statistics are examined together with the MFP statistics for Canada and the United States given on the EU KLEMS and World KLEMS websites. The MFP estimates of Diewert and Yu (2012) are also examined. They find that the MFP performance of the Canadian business sector has been reasonably satisfactory over the past five decades – a striking difference from what the official MFP statistics for Canada show. Finally, we also compare the rates of return produced by Statistics Canada with the Canadian rates for the return on assets (ROA) for selected industries. The ROA statistics are widely used in corporate finance. We then give our conclusions.

A History of Transparency in the BLS Productivity Program

The BLS multifactor productivity program, established in 1983, carries out the computations needed for estimation of MFP for the United States at a highly detailed industry level.[2] The BLS does its calculation using data published by other U.S. statistical agency offices (e.g. the Bureau of Economic Analysis (BEA)). The source data have already met all confidentiality tests. Hence, the BLS need not suppress any part of the data or calculations. The data used in these calculations and the results are posted at two links.[3] This sharing was instituted when these MFP measures were created 25 years ago to enable economists outside the BLS to assess BLS methods and replicate results. By 2010, the BLS was posting on its website all the detailed information behind

2 For more on the origins of the BLS MFP program, see BLS (1983 and 2003), Dean and Harper (1998), Gullickson and Harper (1987), Harper (1983), and Harper, Berndt and Wood (1989). Material on the origins of the methods can also be found in Diewert (1980, 2001, 2005, and 2006), Diewert and Lawrence (2000), Diewert and Nakamura (2007), Jorgenson (1963), Jorgenson and Griliches (1967), and Schreyer (2001 and 2009).

its MFP statistics on the same day it released an update.[4]

The provision of full data and details for the U.S. BLS statistics has proven to be important for both U.S. economic policy and data quality improvement. For example, in 1996, Federal Reserve Board Chairman Alan Greenspan contended that U.S. output and productivity were, in fact, growing faster than shown by the official estimates. The ensuing debate led to close examination of the methods and data used in producing these estimates. Outcomes that ensued were:

- The BLS undertook to account for its "top-down" MFP data by also constructing "bottom-up" industry-level MFP data. Using the parallel data sources and methods at the industry level, the BLS was able to reconstruct its aggregate growth rates for each of three separate time periods to within two-tenths of a percentage point.[5]
- Gullickson and Harper (1999) found suspiciously low MFP growth in several service industries, and identified correctable measurement problems in each.
- BEA made several methodological changes to the U.S. National Accounts.

There were lasting benefits from some of these efforts. For instance, the BLS has continued to compare its official "top-down" measures to a revamped industry model that yields "bottom-up" measures and the two continue to closely agree: an important consistency check.[6]

The Rate of Return Used in Measuring the Capital Input Component of MFP

The most intricate part of the BLS MFP productivity calculation is the capital input model. BLS, like Statistics Canada and the other national statistics agencies, uses annual data on investment by type of asset and by industry, and investment goods prices to create an annual model of real capital inputs. This involves computing capital stocks, depreciation rates, and asset revaluation rates by asset and by industry, and rates of return (both endogenous and exogenous) by industry. This information is used, in turn, to compute rental prices and cost-share weights for each asset type within each industry.

In MFP measurement, the cost of capital plays two main roles. First, it is used in calculating capital inputs. Second, capital's income share is the weight for capital when it is aggregated with labour into total input.

Firms own different types of assets of various ages. Examples of types include buildings, computers, other machinery, and land. Assets of each type are measured by adding up assets of all ages in inflation-adjusted real terms. The result is an asset-type capital stock. The best practice method for doing cross-asset aggregation is to calculate a Törnqvist index using capital rental prices to construct cost-share weights for the various asset types. Each asset-type rental price is an estimate of the cost of owning that asset.[7]

3 Data for manufacturing are at ftp://ftp.bls.gov/pub/special.requests/opt/mp/prod3.renprmfg.zip and for non-manufacturing at ftp://ftp.bls.gov/pub/special.requests/opt/mp/prod3.renprnonmfg.zip. Users are given not only the computational methods and the results used in compiling the MFP statistics, but also intermediate computations that were deemed to be implausible results, and hence were disregarded in the MFP calculations. The intermediate results, say, for the internal rates of return can be identified by comparing the entries in the first and second of the tables where the rates of return computed and used are given.

4 The current data can be accessed at http://www.bls.gov/mfp/mprdload.htm.

5 This decomposition is found in Gullickson and Harper (1999:57).

6 The most recent example of this is Harper, Khandrika, Kinoshita and Rosenthal (2010:27).

7 The data collected allow an estimate to be made of asset holdings, whether or not the assets were put to active use. Theoretically, of course, an estimate of asset usage would be preferred.

Estimates of what is referred to as the rate of return are a key component in these calculations.

Many official statistics agencies use a pre-specified interest rate for the above-mentioned rate of return such as the rate for a high-grade bond. This is the exogenous (or ex ante) approach. However, some experts argue that a balancing rate should be computed instead by comparing the actual property income earned by all assets to the total capital stock. This is called the internal rate of return (also the endogenous or ex post) approach (Schreyer, 2009, chapter 18). Gu (2012:50) notes an advantage of endogenously determined internal rates of return (IRRs) is that they permit development of productivity accounts that are fully integrated with the industry accounts for a nation. While agreeing in principle, Schreyer (2001 and 2009) cautions that the data requirements are also more demanding and that missing and erroneous capital data can result in biased IRRs.

The Statistics Canada productivity program uses an internal rate of return approach. The BLS also computes IRRs. However, for some industries in some years, the computed IRRs are judged by the BLS to be implausible. The BLS has found that when negative, very low or very high, or volatile IRRs are used, the Törnqvist calculation of the index of real capital can be greatly affected. So the BLS, in fact, uses what we refer to as a pragmatic blend of internal and external rates of return.[8]

The EU KLEMS and World KLEMS Data Bases

In producing Canada's official MFP statistics, the Statistics Canada productivity group states it has followed the methods of EU KLEMS and World KLEMS.[9] There are numerous references in Gu (2012) to EU KLEMS, but little information about what this is. It is a project to build a database for the analysis of productivity and growth. Initially financed by the European Commission, it was developed by a consortium of 15 organisations from across the European Union (EU), and with the active support of some of the EU national statistical agencies and the OECD.[10]

EU KLEMS has created two databases: the "analytical module" and the "statistical module." The analytical module includes capital services series that are based on what are described by the EU official statistics agency, Eurostat, as "pioneering assumptions." The statistical module is a sub-set of the analytical module, containing the data accepted by the national statistical agencies of participant countries. Eurostat recommends the use of EU KLEMS data only for growth and productivity analysis, noting that the EU KLEMS data lack consistency with parts of the official national accounts statistics. For example, final consumption expenditure estimates from the EU KLEMS data set differ significantly from official figures.

Data provided by Statistics Canada through 2004, including MFP statistics and the IRRs behind these estimates, are included in the EU

8 When the BLS introduced its industry-based capital calculations in 1991, it assumed a 3.5 per cent real rate of return wherever an exogenous rate was needed. The BLS subsequently replaced this arbitrary exogenous rate with an empirically-based rate calculated for each asset type at the private business level. What is important in this context is simply to note that the BLS procedure, in this regard, is very different from the Statistics Canada procedure. Baldwin and Gu (2007:16) state that Australia also uses an internal rate of return approach for their productivity accounts. While true, it is also the case that the Australian Bureau of Statistics (2007) has experienced problems with this approach. The report of MacGibbon (2010) on New Zealand's aborted attempts to follow Australia in using internal rates of return is also of interest in this regard.

9 Information on EU KLEMS can be accessed at http://www.euklems.net and World KLEMS at http://www.worldklems.net.

10 http://epp.eurostat.ec.europa.eu/portal/page/portal/eu_klems/introduction

Table 1
MFP Growth Rates for Canada and the United States
(compound annual growth rates, per cent)

	Canada				United States		
	Market Economy		Business Sector		Market Economy		Business Sector
	EU KLEMS	World KLEMS	Statistics Canada	Diewert and Yu	EU KLEMS	World KLEMS	BLS
1961-2004	..	0.77	0.43	1.23	..	0.77	1.26
1961-1970	..	1.82	1.25	2.44	..	0.74	2.08
1970-2004	0.45	0.49	0.21	0.91	0.86	0.77	1.04
1970-1995	0.31	0.35	0.08	0.88	0.55	0.58	0.79
1995-2004	0.84	0.87	0.56	1.01	1.74	1.32	1.76
2004-2007	..	-0.40	-0.54	-0.16	..	0.48	0.61
2007-2009	..	-2.21	-2.33	-2.04	..	..	-0.99
2009-2011	..	..	0.91	1.58	..	..	1.84
2010	..	..	1.72	1.49	..	..	3.40
2011	..	..	0.11	1.67	..	..	0.29

Notes: The World KLEMS data goes back to 1961 for Canada and the United States. EU KLEMS contains data for Canada and the United States (SIC based) for 1970-2004. There has been special interest in what happened to MFP growth before and after the mid-1990s, and in the years leading up, to during, and since the recent financial crisis. These are the reasons for the choice of periods for which growth rates are shown in this table. The EU KLEMS and World KLEMS MFP growth rates are for the market economy; the official Statistics Canada and BLS MFP statistics are for the business sector.

KLEMS analytical database. In addition, data provided by Statistics Canada through 2008, including the IRRs, are on the World KLEMS website.[11] There are links on EU KLEMS to World KLEMS, and vice versa. The two projects are related conceptually too, but also differ in potentially important ways. These are valuable international data compilation and research efforts; the importance of these projects, and of the participation by Statistics Canada in the projects, is illustrated by our use of the data from the project websites.

Statistics Canada and BLS MFP Estimates versus EU KLEMS and World KLEMS Estimates

Table 1 shows that the BLS MFP growth rates for the United States of 1.26 per cent and 0.61 per cent per year over the 1961-2004 and 2004-2007 periods are well above the official Canadian MFP growth rates of 0.43 and -0.54 per cent, respectively. This pattern continues for 2007-2009 and 2009-2011.

The market sector EU KLEMS and World KLEMS MFP growth rates for Canada are fairly similar to the official Canadian rates. However, from Table 1 we see that the EU KLEMS and World KLEMS rates for the United States are lower than the official BLS rates.[12]

Note also the similarities between the summary rates we have calculated and show in Table 1 for MFP statistics for Canada from Diewert and Yu (2012) and the official MFP statistics for the United States. While beyond the scope of this article to further substantiate, our view at this point is that the Diewert-Yu MFP statistics

11 Data can be found on the World KLEMS website for the following nine countries (when the estimates were prepared by an official statistical agency, the name of the agency is given in parentheses): the Netherlands (Statistics Netherlands), the United Kingdom, Germany, Italy (the Italian National Institute of Statistics), France, Austria, Spain, Canada (Statistics Canada), and the United States. The link for the source for the U.S. data is to Dale Jorgenson at Harvard. Also, links are given for directly downloading KLEMS data from the Australian Bureau of Statistics and from other organizations for China, Japan and Korea. http://www.worldklems.net/data/index.htm.

12 This finding is contrary to earlier results of Gu (2008).

behave more as one would expect, given other economic indicators such as profitability for Canada and the United States, than the official Statistics Canada MFP statistics.

The IRRs Given on EU KLEMS and World KLEMS for Canada the United States

According to the tables on the EU KLEMS and World KLEMS websites, Canada's industries sometimes had negative rates of return.[13] Also, the IRRs for a considerable number of industries are over 40 per cent for multiple years, which we regard as implausible (the World KLEMS IRRs for Canada are reproduced in Diewert (2012:Appendix Tables 1-3). Using rates of return that are negative or unreasonably large or volatile can contribute to overstated capital input growth and understated MFP growth.

Gu (2012:55-56) reports that getting rid of "unreasonably high or low" IRRs that were used by the Canadian Productivity Program (CPP) in producing the official Canadian MFP statistics reduced the difference between the official CPP capital input growth figures and those of Diewert-Yu by 0.4 percentage points, half of the total difference caused by switching from a "bottom-up" to a "top-down" approach. This suggests to us that a significant share of the difference between the official MFP statistics for Canada and the United States arises from this same factor. Relatedly, Schreyer (2012:74) writes that "The significant size of the reallocation effect in the Canadian case (valued by Gu (2012) at 0.8 percentage points per year for capital input over the 1961-2011 period)" may reflect "a measurement issue associated with large variances of industry-specific input prices." Schreyer notes that, in the case of capital, input prices correspond to user costs, and the IRRs are a main component of those. However, none of us have access to the data or computational details needed to properly explore possible problems with Canada's official MFP statistics.

Gu (2012:59) states that Statistics Canada cannot release the details of its MFP calculations like the BLS does because of a combination of the Canadian Statistics Act and the smaller size of the economy. While confidentiality of source information is important, we argue that it cannot be an argument for suppressing this information. We must find ways to achieve both the objectives of confidentiality and transparency.

An example of where Statistics Canada could be more transparent is in publishing its IRRs on its own website along with, or soon after, publication of the MFP statistics released, with the most recent release being for 2011. The rates of return published for Canada on the World KLEMS website only go through year 2008. The fact that Statistics Canada has published the IRRs for their MFP statistics on the publically accessible EU KLEMS and World KLEMS websites suggests there are no problems arising from the Canadian Statistics Act that prevent the publication, at least, of up-to-date IRRs.

A Look at How the Statistics Canada IRRs Compare with Canadian ROAs

As others have also suggested, Baldwin and Gu (2007:14) write that the IRRs might be thought of as either the opportunity cost of using capital or financing costs. In this case, these rates of return should be broadly comparable in terms of the values with industry estimates of rates of return (ROA), a commonly used prof-

13 Canadian IRRs are given through 2004 in the 2008 release for EUKLEMS at http://www.euklems.net/data/08i/input/can_capital_input_08I.xls. Canadian rates of return are given as part of the 2012 release for World KLEMS at http://www.worldklems.net/data/index.htm under the very last tab, labelled IRR. The values as of November 26, 2012, go to 2008.

itability measure showing the amount of profits generated by each dollar of assets. In Appendix Table 1, the ROA values shown range from -0.3 per cent to 17.8 per cent. These rates are in almost all cases lower than the IRRs found in the same table, and in many cases substantially lower. The BLS rates of return used in their MFP computations are generally between a small positive per cent and 15 per cent.

Conclusions

In a much cited paper, Erwin Diewert and Kevin Fox (1999) ask: "Can measurement error explain the productivity paradox?" Though Diewert and Fox were referring to a different paradox, their question applies as well to the one that is our focus in this article, and our answer is "probably so." This is the new research perspective we bring to Canada's long standing alleged productivity malaise; this is our response to the challenge of explaining Canada's poor productivity growth eloquently posed by Don Drummond in his 2011 "Confessions" paper. Our conclusions:

- The large differences between the MFP statistics for Canada and the United States, despite the many similarities of the economies over much of their shared history, might be a warning sign, we believe, of underlying problems with the data or the methodology utilized for the official Canadian and/or the official BLS MFP statistics (U.S. data problems are being actively investigated by a large U.S. project that is a continuation of an earlier one in which Harper, Nakamura, and Diewert are participating).[14]
- We find the gaps between the stated procedures for MFP estimation used by Statistics Canada and the BLS are substantial.
- In our view, productivity debate in this country would benefit if Statistics Canada adopted a practice of greater transparency by providing along with its MFP releases all IRRs and compilation details used for the agency's MFP estimates.

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14 See http://www.bea.gov/papers/pdf/bea_2010_conference%20papers_final.pdf, http://www.upjohn.org/Research/GlobalIssues/Globalization and http://www.upjohn.org/Research/GlobalIssues/Productivity. Papers arising from this U.S.-based project, to be released in 2013, address the question of whether Canada, in fact, has had dismal labour productivity performance relative to the United States. Even if it were agreed that Canada's MFP performance has been reasonably satisfactory, all concur that it would still be a serious problem if Canada's labour productivity compared to the United States has, in fact, been as poor as what the official labour productivity statistics for the two countries currently show.

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Appendix Table 1
Internal Rates of Return and Returns on Assets for Canadian Industries, 2000-2008

	2000		2002		2004		2006		2008	
	IRR	ROA	IRR	ROA	IRR	ROA	IRR	ROA	IRR	ROA
Agriculture, Hunting, Forestry and Fishing	0.107	0.052	0.134	0.040	0.204		0.119		0.213	
Mining and Quarrying	0.156	0.014	0.098	0.008	0.196		0.221		0.220	
Food, Beverages and Tobacco	0.490	0.069	0.477	0.072	0.527		0.553		0.563	
Textiles, Textile , Leather and Footwear*	0.465	0.076	0.308	0.066	0.258	0.041	0.140	0.041	0.083	0.032
Pulp, Paper, Paper , Printing and Publishing*	0.244	0.062	0.191	0.046	0.167	0.038	0.154	0.040	0.149	0.032
Coke, Refined Petroleum And Nuclear Fuel	0.049	0.162	0.067	0.111	0.089	0.178	0.079	0.165	0.081	0.145
Chemicals and Chemical Products*	0.251	0.086	0.264	0.075	0.257		0.218		0.186	
Rubber And Plastics*	0.402	0.086	0.405	0.075	0.378		0.329		0.264	
Other Non-Metallic Mineral	0.267	0.093	0.256	0.104	0.286	0.100	0.343	0.111	0.293	0.106
Basic Metals and Fabricated Metal	0.287	0.075	0.240	0.061	0.294		0.344		0.354	
Machinery, Nec*	0.564	0.082	0.457	0.068	0.488		0.536		0.490	
Electrical and Optical Equipment*	0.565	0.086	0.021	-0.003	0.078	0.027	0.099	0.060	0.131	0.044
Manufacturing Nec; Recycling	0.511	0.088	0.507	0.082	0.526	0.061	0.482	0.063	0.429	0.041
Electricity, Gas and Water Supply	0.094	0.068	0.085	0.061	0.119	0.063	0.127	0.068	0.107	0.064
Construction	0.233	0.038	0.318	0.052	0.423	0.055	0.531	0.077	0.610	0.081
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale Of Fuel*	0.038	0.051	0.088	0.059	0.107	0.057	0.142	0.065	0.214	0.060
Transport and Storage*	0.077	0.046	0.070	0.057	0.083		0.117		0.112	
Post and Telecommunications*	0.052	0.050	0.047	0.047	0.063	0.047	0.189	0.101	0.240	0.097
Financial Intermediation*	0.178	0.025	0.165	0.019	0.219	0.026	0.270	0.028	0.296	0.022
Real Estate Activities	0.091	0.049	0.105	0.052	0.117	0.046	0.124	0.042	0.077	0.039

Notes:

1. Canadian industry rates of return from 2000 to 2004 are from the March 2008 release of EUKLEMS: http://www.euklems.net/. Canadian industry rates of return in 2006 and 2008 are from World KLEMS: http://www.world-klems.net/data/index.htm. These two datasets provide mostly comparable industry rates of returns. The differences during the overlapping years are no bigger than 0.052.
2. The Canadian industry return on assets is defined as the ratio of profits over assets. The "operating profits/loss" are v3871168-v3871216 from CANSIM Table 1800-003 "Financial and Taxation Statistics for enterprises, by North American Industry Classification System (NAICS)". The "assets" are v3869008-v3869056 from the same table.
3. Using the corresponding industry classification table provided by Statistics Canada (http://www.euklems.net/data/08i/sources/can_sources_08I.pdf), we identified 20 corresponding industries in CANSIM Table 1800-003. The other ten NAICS industries listed in the industry classification table are not in CANSIM Table 1800-003. Among these 20 identified industries, ten of them involve a certain level of estimation. For example, "electrical and optical equipment" is defined as NAICS 334+3351+3353+3359, while we use 334+335 since the more detailed classification is not available. We put asterisks on the estimated industries.
4. CANSIM Table 1800-003 started in 1999, and some of the industries are terminated after 2002. This is why 8 industries have missing ROAs in 2004 and after.
5. The data source of profits and assets are the financial statements of enterprises in the "Quarterly Survey of Financial Statement"(http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=2501&lang=en&db=imdb&adm=8&dis=2.

The Long-term Outlook for Productivity and Per Capita Income Growth for Canada: A Comparison with Selected G-20 Countries

Peter Jarrett[1]
OECD

Abstract

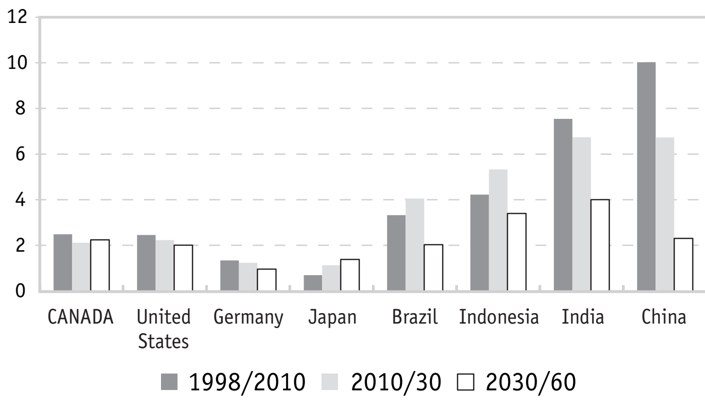
This paper describes a possible long-run scenario for selected OECD and major emerging market economies. It compares outcomes for Canada against these countries' performance in a variety of dimensions that together determine productivity and output growth based on a production-function approach. It concludes that Canada should enjoy reasonable productivity and output growth in the coming half century, despite the less favourable outlook for the age structure of the population. It goes on to suggest three areas where policymakers should focus their attention: seeking more vigorous product market competition; reforming the tax system with a view to removing unnecessary distortions and emphasising the importance of tertiary education and innovation across a broad range of policy areas. It finishes with a call for the establishment of a publicly funded productivity commission, to assess existing policies and proposed changes through a productivity, innovation and competitiveness lens.

Résumé

Cet article décrit un scénario à long terme qui pourrait se produire pour certains pays de l'OCDE et certaines économies de marché émergentes. Il compare les résultats pour le Canada à la performance de ces pays, sous divers rapports qui, ensemble, déterminent la croissance de la production et de la productivité, au moyen d'une démarche production-fonction. Il conclut que la croissance de la production et de la productivité devrait se maintenir raisonnablement bien au Canada au cours du prochain demi-siècle, bien que les perspectives soient moins favorables en ce qui concerne la structure démographique. Il propose ensuite trois domaines auxquels les décideurs devraient prêter attention: favoriser une concurrence plus vigoureuse entre les produits sur les marchés, réformer le système fiscal afin de faire disparaître les distorsions inutiles et mettre l'accent sur l'importance de l'éducation tertiaire et de l'innovation dans un large éventail de domaines stratégiques. Il termine en demandant que soit créé une commission de la productivité financée par les deniers publics qui évaluerait les politiques actuelles et proposerait des changements dans une optique de productivité, d'innovation et de compétitivité.

1 The author is Head of Division, Country Studies Branch in the Economics Department at the OECD. He would like to thank Calista Cheung for useful comments. The views expressed in this paper are those of the author and do not necessarily represent those of the OECD or its member countries. Email: peter.jarrett@oecd.org.

Chart 1
Output Growth in Selected G-20 Countries
Average annual rate of growth (per cent)



IT IS NO SURPRISE TO READERS of the *International Productivity Monitor* to learn that Canada's potential growth rate had slowed considerably even before the financial crisis of the past five years. OECD estimates show that it fell from 3¼–3½ per cent per year during the five years ending in 2001 to about 2¾ per cent per year in the following five years and 1¾ per cent per year in the most recent five years. Similar slowdowns, even if less pronounced, have been observed in most other OECD countries. Part but by no means all of that is attributable to slower population increases. The rest is due to shrinking gains in labour utilisation and human capital but most disturbingly also to a complete disappearance of multifactor productivity gains. The result is that labour productivity growth has dried up. But most economists do not believe that this is our fate and that we are entering a second Dark Age. Is there reason for hope?

This article has two objectives. First, it will describe the results of one recent attempt by my colleagues in the OECD Economics Department – undertaken before the October 2012 historical revision to the Canadian productivity figures – to put together a long-term scenario for OECD and key partner countries out to the year 2060 (OECD, 2012c). The key features of this scenario are described in the Appendix. The second is to follow up with a brief discussion of our policy recommendations for how to pick up the pace of productivity growth in Canada based on the empirical record of what works across OECD countries, as argued in our *Economic Survey of Canada* (OECD, 2012b) and the series of *Going for Growth* publications (OECD, 2012a).

A Possible Long-run Scenario for Selected OECD and Major Emerging Market Economies

In this section I will examine the scenario for Canada and compare its outcomes with selected G-20 partners both in and outside the OECD area with a particular focus on productivity performance. Data are for the total economy.

The scenarios are broken down for two periods: first the initial 20 years (2010-2030) and then the final 30 years (2030-2060). Average annual output growth in Canada is expected to be fairly constant across the two sub-periods at around 2 per cent, slightly less than what has been achieved over the 1998-2010 period as the demographic structure turns less favourable (Chart 1).[2]

The story is only slightly different for the United States where output growth is expected to slow a bit less at first but again in the latter period to a rate slightly lower than Canada's. Germany has the same pattern but with much lower growth rates. Japan actually has the reverse, with growth expected to rebound from the recent past and again in the long term. Turning to a few of the emerging market economies covered by the OECD projections, we see that growth is expected to ease already in the 2010-

2 As the year 2000 was a cyclical peak and 2010 was not, 1998 was chosen as the initial year of the historical period to reduce distortions related to comparing points at different phases of the business cycle.

2030 period in China and India, but to pick up in Brazil and Indonesia. Beyond 2030 all four are predicted to suffer a marked slowdown, especially China. Nonetheless, these countries will represent 57 per cent of the total output of the proxy for world GDP (OECD plus eight non-OECD G-20 countries) in 2060, up from just 35 per cent in 2011 and 51 per cent in 2030.

These output growth scenarios are built up from a production-function approach. Let us begin with the physical capital input (Chart 2).[3] Canada's growth in capital input has been rapid by G-7 standards, but its advantage over the other OECD comparator countries is expected to slip as the capital intensity level, defined as the ratio of capital to output, slowly stabilises under the influence of rising real costs of capital globally in line with a generalized fall in saving rates. All the emerging market economies are expected to enjoy rapid growth in physical capital for some time before slowing later in the century.

Our production function also includes human capital, defined in terms of average years of educational attainment for the population aged 25 to 64, as a separate factor input.[4] Increases have been fairly small for the advanced OECD countries like Canada, whose outcome is in the middle of the pack (Chart 3). But rates of increase for human capital in the emerging market countries have been several times larger than in developed countries. While these growth rates are expected to slow down in most cases (India is the exception), they are projected to remain much more dynamic as mean educational attainment in these countries continues to catch up to developed country levels.

Chart 2
Physical Capital Growth in Selected G-20 Countries
Average annual rate of growth (per cent)

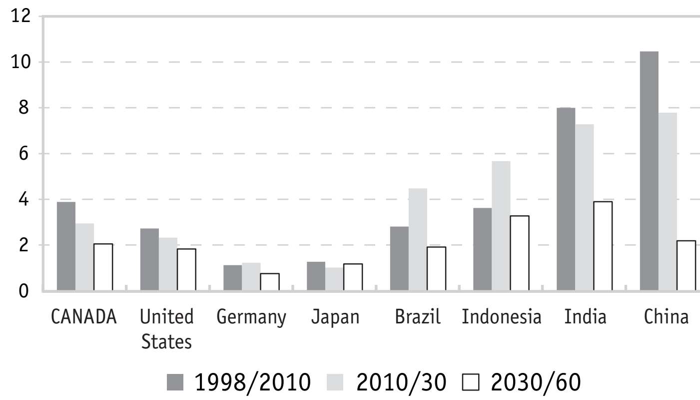
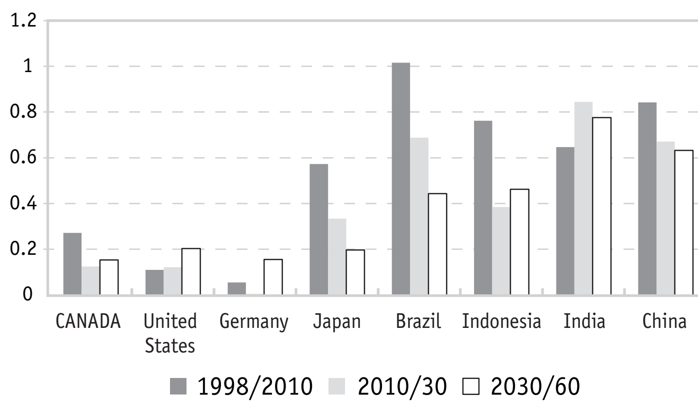


Chart 3
Human Capital Growth in Selected G-20 Countries
Average annual rate of growth (per cent)



When it comes to multifactor productivity growth (MFP)[5] (labour-augmenting technical progress) on the other hand Canada's record since 1998 has been disappointing, with essentially no growth whatsoever on average in recent years (Chart 4). This is similar to Japan, and even Brazil to some extent, but well behind the United States and Germany and especially the

3 Physical capital is defined in terms of capital stock, not capital services. It includes inventories, but excludes land.

4 The human capital estimates are based on returns derived from Mincerian wage equations for the 25-29 age group. The returns are used to transform the annual figures into stock figures, that are then comparable to the physical capital estimates expressed in monetary terms. The OECD builds up the stock measure and then pushes them forward through time as the cohort ages.

5 This concept is referred to as labour efficiency in OECD (2012c).

Chart 4
Multifactor Productivity Growth in Selected G-20 Countries
Average annual rate of growth (per cent)

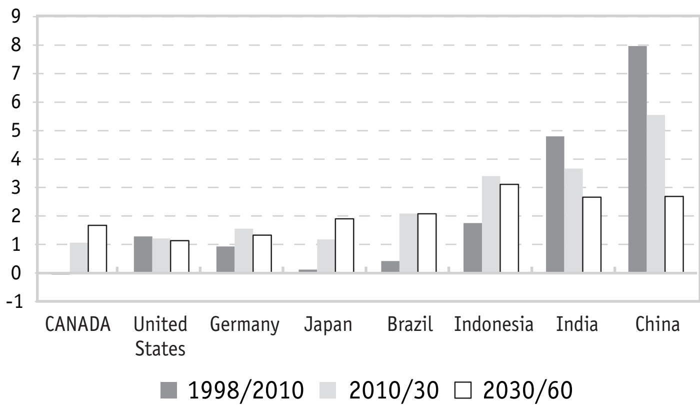
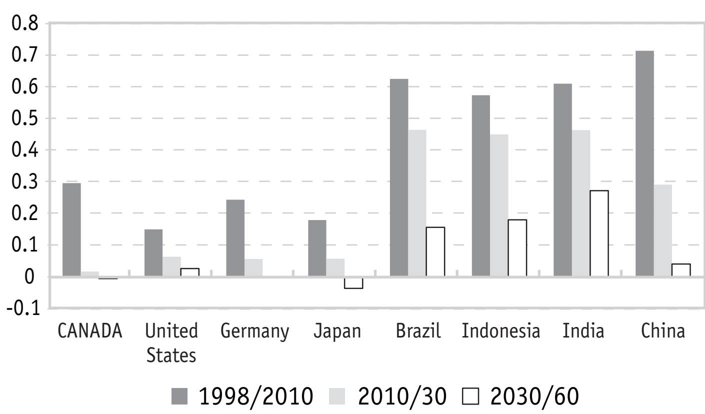


Chart 5
Growth of the Working-age Population Share (15-64) in Selected G-20 Countries
Average annual rate of growth (per cent)



Asian powerhouses of Indonesia, India and China. Even if convergence to the world technology frontier does not completely explain the heterogeneity of historical patterns, our projections assume that catch-up should be the main driver going forward, with the result that the sharp disparity between countries is expected to narrow. There will be gradual improvement in Canada (with multifactor productivity gains averaging around 1.5 per cent per year through to 2060) and Japan and the convergence process working to brake progress in India and especially China. By 2030-2060 Indonesia will be enjoying the fastest rates of MFP growth.The pick-up in multifactor productivity in Canada reflects a return to its predicted growth path after underperformance in the 1998-2010 period.[6]

Canada, like New Zealand, represents a bit of a conundrum in terms of its productivity performance. Even though the profession has still not been able to do a good job in identifying the reasons for the productivity slowdown, we have no alternative but to resort to the international evidence of what theory and data tell us is best practise. And then we can only hope that very long lags imply that the payoff to Canada's steadily increasing adherence to such policies will eventually become manifest.

The growth in labour input can be disaggregated into a series of components. The most exogenous is changes in the demographic structure of the population, that is the rate of change in the working-age population (15-64, share expressed in terms of per cent rather than percentage points). Canada has had a slight advantage over the other large OECD countries in recent years, but that will quickly be eliminated as the population ages and baby boomers retire (Chart 5). Even high levels of immigration are unable to change that outlook. Indeed, Canada's population will age comparatively quickly. This can be seen by examining its old-age dependency ratio (the ratio of the share of the popula-

6 The OECD model includes a catch-up equation whereby each country has its own level of multifactor productivity and converges on this level. The OECD model could not explain why multifactor productivity growth did so poorly in Canada during the recent historical period and therefore projects that it will return to its predicted long-term path. This is an optimistic projection. What held multifactor productivity back in the recent past, which we are unable to identify, may continue to do so in the future. For a discussion of the model, see Johansson *et.al.* (2012).

tion 65 and over to that aged 15-64), which is projected to move from very near the OECD average at present to a clearly higher-than-average outcome already in 2030.

Not all those of working age actually are in the labour market for a variety of reasons. One is the age distribution within the working-age group: those of prime age (25-54) have the highest participation rates by far. Another is the long-term trend increase in educational attainment, which is assumed to continue, even if at a much slower pace than over the past decades in Canada and less so than in most of these comparator countries. A third is the legal pensionable age, which is assumed to be broadly indexed to longevity.

Canada has benefited from favourable labour force participation developments, but with unchanged policies that would be expected to reverse in the future before edging up again (Chart 6); Germany has a similar pattern. The United States has had a poor record of late, but its participation is expected to bottom out before eventually beginning to rise again. Canada's advantage over the United States in terms of the employment-to-population ratio will soon begin to reverse and eventually grow to an equally large disadvantage. Japan has suffered a great deal, but most of that is behind it. China and India have also experienced declining participation, but only China's decline is expected to continue. Participation will restrain labour input growth in Brazil and Indonesia, especially in the more distant future.

The final component of the volume of labour input is the structural unemployment rate, also known as the non-accelerating inflation rate of unemployment (NAIRU), which determines the share of the labour force that can be employed without inflationary or deflationary strains emerging. All countries have only very small contributions from this factor (Chart 7). They have been modestly positive – structural unemployment has been falling – in Canada, Germany, Brazil and India and negative in the United States, Japan, China and, especially, Indonesia. In the future they are assumed to be essentially zero.

Putting it all together one can derive the usual measure of labour productivity, defined as output per worker, that is embedded in these data. It is widely known that Canada's productivity performance over the past decade or so has been disappointingly slow, with labour productivity at

Chart 6
Labour Force Participation Rate Growth in Selected G-20 Countries
Average annual rate of growth (per cent)

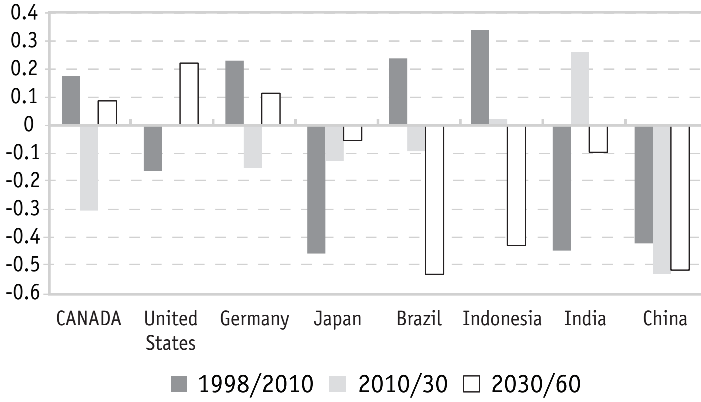


Chart 7
Growth of the Structural Unemployment Rate in Selected G-20 Countries
Average annual rate of growth (per cent)

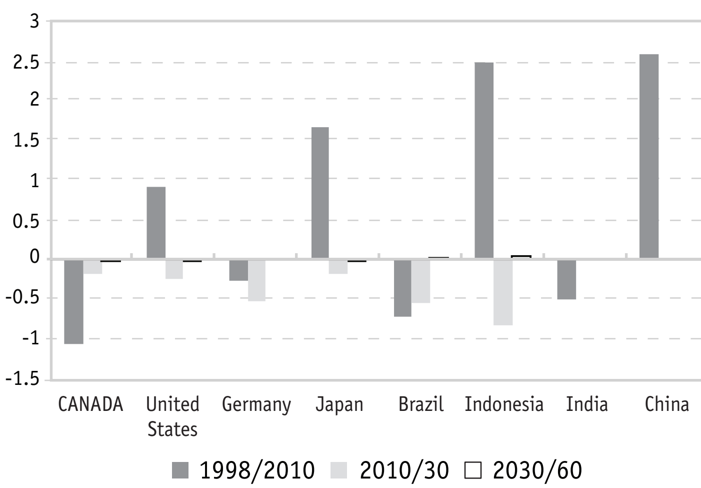


Chart 8
Labour Productivity Growth in Selected G-20 Countries
Average annual rate of growth (per cent)

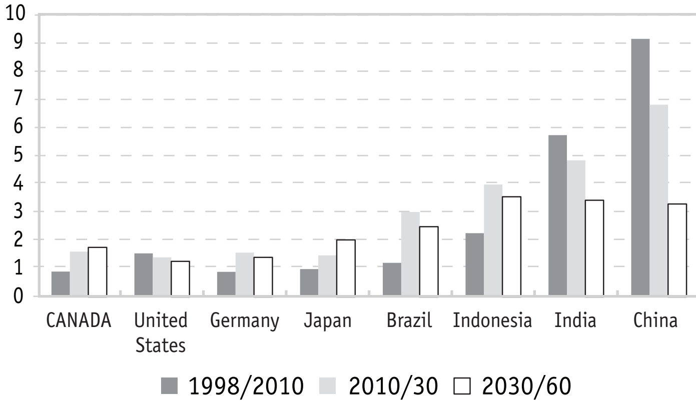
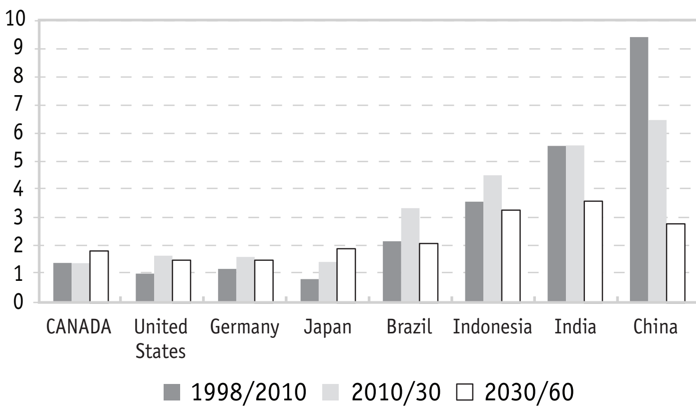


Chart 9
Real GDP Per Capita Growth in Selected G-20 Countries
Average annual rate of growth (per cent)



less than 1 per cent per annum on average. This should improve somewhat in the future, reaching 1.7 per cent on average over the next half century (2010-2060) (Chart 8).[7]

It is interesting to note that Dungan and Murphy (2012:51) project that output per worker in Canada will advance at a 1.5 per cent average annual rate to 2040, quite similar to the OECD projection. However, unlike the OECD MFP growth projection of 1.5 per cent, Dungan and Murphy see MFP growing only at a 1.0 per cent average annual rate, with capital intensity growth adding 0.5 percentage points per year to labour productivity growth (compared to 0.2 per cent in the OECD projection).

Elsewhere, the United States, whose productivity record has been clearly superior to Canada's, is projected to lose much of that advantage in the future, mainly because of a reversal in relative capital intensity in favour of Canada. Both Germany and Japan are also expected to pick up the pace of their labour productivity gains and surpass those in the United States. The story in the four large emerging-market economies is mixed. China and India, which have made rapid strides in catching up to the labour productivity levels of the developed countries, are expected to lose some of that momentum as their shortfalls shrink. Indonesia, on the other hand, will gradually join them as another Asian tiger economy and even move to the forefront in terms of labour productivity growth in the 2030-2060 period. Brazil will remain an intermediate case, with a clear acceleration in labour productivity growth beyond the moderate growth rate experienced in the 1998-2010 period, but without reaching the rates recorded by its Asian counterparts.

Finally, these series can be used to generate per capita income/output projections. Due to deterioration in the demographic outlook and in physical and human capital growth as well as a peaking of the participation rate, actual per capita output increases in Canada are at best likely to be sustained at about 1½ per cent per year in the next two decades (Chart 9). There is a slight pick-up in the 2030-2060 period to around 1¾ per cent per year. This scenario relies on the

7 The benefits of greater productivity growth are massive. In its recently released discussion paper on the economic and fiscal implications of Canada's aging population, Finance Canada (2012:34) points out that an increase in productivity growth to 1.9 per cent per year, in line with the top G-7 performer (the United States) over the past decade, would increase real income per capita by another $18,900, or 28 per cent, by 2050. This productivity number is close to the OECD projection.

projected acceleration in multifactor productivity growth.

The story is not all that different for the United States and Germany, though the drivers are somewhat different. The gap in Canada's per capita GDP with the United States is projected to expand slightly to nearly a quarter in 2035 and then to halve in size by 2060 as the improvement in relative capital per worker comes to dominate the deterioration in labour force participation. On the other hand, Japanese per capita income gains are projected to equal and then ultimately surpass those in the other OECD majors owing to stabilizing labour force participation and improved productivity trends. Per capita growth in China, the catch-up star, will fall back once most convergence in productivity levels has been achieved, and after 2030 the fastest gains will be recorded in India and Indonesia. Again, Brazil's performance will be mid-way between those of the OECD countries and those of the major emerging market economies.

What Can Canada Do To Improve its Long-term Productivity and Per Capita Income Growth?

The OECD sees Canada's policy priorities for improving its productivity performance as lying principally in three main areas (OECD, 2012a). Without any special rank ordering, a first would be to strengthen the degree of competition in product markets, even if Canada is one of the OECD's top-ranked countries in this dimension. There is considerable evidence, Canadian and otherwise, that more vigorous competition, especially in upstream markets (Cette *et al*., 2012), either from a liberal domestic regulatory environment (*e.g.* Conway and Nicoletti, 2007; Clark and da Silva, 2009) or from a more open trading regime (several articles by John Baldwin and colleagues and Trefler, 2004) has benefits in terms of both static allocative efficiency and dynamic gains in productivity (Sharpe, 2010).

Industries that are most in need of regulatory reform are agricultural sectors subject to supply management (mainly dairy, which also may prove to be a stumbling block in crucial free trade negotiations), professional services (still somewhat balkanized, despite the Agreement on Internal Trade, AIT), electricity (most provinces other than Alberta still impose inefficient regulation in this sector, and the energy chapter of the AIT has still not been finalized) and postal services (few countries still give their heritage state-owned enterprise as broad a monopoly as Canada). A related productivity-sapping weakness is the series of restrictions on foreign direct investment, especially from the United States (Ng and Souare, 2011; Audet and Gagné, 2010), mainly in energy, airlines, finance, electricity, broadcasting and telecommunications, although the government has announced its intention to remove those applying to telecom firms holding less than 10 per cent of the market in the near future.

A second area where policy changes could have a measurable impact on productivity would be taxation. Any reductions in the tax wedge would help to boost labour force participation and lower structural unemployment. In addition, the OECD strongly supports the Harmonized Sales Tax and was therefore saddened by the recent decision to abandon it in British Columbia as well as by the failure of certain other provinces to adopt it. On the income tax front there remain a number of inefficient and distortive tax expenditures that could be reconsidered to allow rates to be cut. As in other countries housing is still unduly favoured over other forms of investment, although the distortion is less severe. Nonetheless, taxes on property remain an excellent base because of its immobility and impossibility to hide and one that lines up well with ability to pay if properly designed.

Another underutilized base in Canada is environmental taxes, which the latest OECD figures (from 2009-10)[8] show to be among the lowest in the OECD at less than 4 per cent of total tax revenue, compared to about 7 per cent for the average OECD country and as much as 15 per cent in Turkey. The question of a carbon or more general greenhouse gas emissions tax remains controversial in Canada and abroad. But the theory is clear that Canada's approach of implementing sectoral standards and regulation is inefficient, since it will not allow the marginal cost of emissions reductions to be equalized in general across the economy. Those who oppose taxes no matter what the base can, of course, support equivalent permit trading. The OECD approach is that the proceeds from a carbon tax would not necessarily go to pay for higher spending but rather to allow further cuts in taxes that serve to distort behaviour in welfare-harming ways, especially those that apply to saving, investment and labour supply.

The third broad policy area in which we have come to believe Canada could do better with important payoffs on the productivity front is tertiary education and innovation (Cheung *et al.*, 2012; Bibbee, 2012). Of course, Canada already enjoys very high attainment at the tertiary level by OECD standards; but few graduates go beyond a first degree; not enough managers have integrative business school training (Moldoveanu and Martin, 2008) or any university education at all (Bloom, 2011); too little in the way of entrepreneurial skills are taught; academics and businesses need to discover what each has to offer in collaborative efforts; foreign students are still relatively untapped as a source of future skilled immigrants; and greater differentiation between tertiary institutions that engage in research and those that focus primarily on teaching would promote greater quality and efficiency based on comparative advantage.

Canada's long-standing paucity of business-financed R&D has been much studied of late. The federal government's strategy had been to provide extremely generous tax incentives – only France and Spain offer anything that could compete with the Scientific, Research and Experimental Development tax credit. Following the recent report of a commission chaired by Thomas Jenkins (IPFSRD, 2011), the federal government wisely decided to adopt a more balanced position and shift some public resources back to grant programmes. However, it enlarged the gap between the small and large-firm subsidy rates and removed capital spending from the base for all firms, which risks distorting factor choice and biasing spending towards labour-intensive industries. The already numerous grant programmes should be systematically evaluated, with the least efficient being culled.

Nevertheless, innovation is much more than invention achieved by R&D. It is achieved by good ideas in other directions than new high-tech products put in place by innovative start-ups. The question of the adequacy of Canada's financial markets in their financing of such endeavours is open. Venture capital remains in the doldrums, and other early-stage capital is also not all that plentiful: taking their volumes together relative to GDP, Canada ranked only 14th out of 27 OECD countries in 2009.

Conclusion

It seems like during most of my long career as an economist that a multitude of economists have been trying to figure out why Canada's productivity growth has not been faster, with a lengthening list merely of review articles. Some progress has indeed been made over the years, but much remains unexplained. This article does not purport to provide any new answers to the conundrum, though I am not so shy as to refuse to proffer any policy recommendations, since

8 Available at http://www2.oecd.org/ecoinst/queries/index.htm.

that is our bread and butter here at the OECD. Hence, one last piece of advice: there used to be a body called the Economic Council of Canada, which was wound up 20 years ago after 30 years of yeoman's service to the nation. It strikes me – and others (Competition Policy Review Panel, 2008; IPFSRD, 2011) – that something akin to it would be useful going forward to assess key policies and proposed measures and catalyse reform efforts through a productivity, innovation and competitiveness lens, as is done in Australia and New Zealand.

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Appendix
Methodology for Long-Term Macroeconomic Projections

While there is no single theory of economic growth, there is wide support for models in which each country would be expected to converge to its own steady-state trajectory of GDP per capita determined by the interface between global technological development and country-specific structural conditions and policies (so-called conditional convergence). In the long-run, all countries are expected to grow at the same rate determined by the worldwide rate of technical progress, but cross-country GDP per capita gaps would remain, mainly reflecting differences in technology levels, capital intensity and human capital.

The supply side of the economy consists of a standard aggregate Cobb-Douglas production function with constant returns to scale featuring physical capital, human capital, and labour as production factors plus technological progress (so-called multifactor productivity). Multifactor productivity growth is measured as the difference between growth in output and total inputs. These components of the production function are projected to 2060 in order to construct measures of potential GDP measured in terms of constant 2005 USD purchasing power parities (PPPs) (see Easterly and Levine, 2001; OECD, 2003; Duval and de la Maisonneuve, 2010; and Fouré *et al.*, 2010 for similar approaches). The projections for all components to 2013 are mostly consistent with the May 2012 *OECD Economic Outlook* projections, although some elements of the short- term non-OECD projections are taken from IMF (2012). An exception is the projection of human capital, which starts in 2011 as there is no short- term forecast available.

The fiscal side of the model ensures that government-debt-to-GDP ratios stabilize over the medium term via fiscal closure rules for the primary balance, which either stabilize debt through a gradual improvement in the primary balance or target a specific (usually lower) debt-to-GDP ratio. Debt service responds to changes in market interest rates, but with lags which reflect the maturity structure of debt. Higher debt levels are assumed to entail higher country- specific fiscal risk premia (Égert, 2010; Laubach, 2009). A further interest-rate adjustment that is equal across all countries ensures that global saving and investment are aligned.

Private saving rates for OECD countries are determined by demographic factors including old-age and youth dependency ratios, fiscal balances, the terms of trade, productivity growth, net oil balances and the availability of credit (Kerdrain *et al.*, 2010). Total saving is the sum of public and private saving, although there is a 40 per cent offset of any improvement in public saving from reduced private saving due to partial Ricardian equivalence (*e.g.* Röhn, 2010). For non-OECD countries, the total savings rate is modelled by developments in old-age and youth dependency ratios, the terms of trade, the availability of credit, the level of public expenditure (a proxy for public social protection) and productivity growth. Investment projections are backed out from projected capital stocks assuming that depreciation remains stable at recent historical levels. There is no influence from structural policies on investment, except indirectly to the extent that they boost output, although this ignores some evidence to suggest that reforms to product market regulation and employment protection legislation can boost investment rates (Alesina *et al.*, 2005; Egert, 2009; Kerdrain *et al.*, 2010). Indeed, Cette *et al.* (2012) have recently shown that upstream product market regulations limit R&D and ICT capital stocks and curb productivity in 15 OECD countries, including Canada; moreover, the estimated effect on Canada is one of the largest in their sample.

Structural policies play an important role in shaping the long-run projections for growth and fiscal and global imbalances. The baseline long-run scenario incorporates a number of policy developments in several areas:

- The share of average life expectancy devoted to participation in the labour market is assumed to remain constant, hence the legal pensionable age is implicitly assumed to be indexed to longevity. In addition, recently legislated pension reforms that involve an increase in the normal retirement age by 2020 are assumed to be implemented as planned.
- Educational attainment continues to converge across countries relying implicitly on an expansion of education systems, particularly in countries with currently low educational attainment levels, and projected labour force participation depends on developments in educational attainment.
- Countries with relatively stringent product market and trade regulations are assumed to gradually converge towards the average regulatory stance observed in OECD countries in 2011. For other countries regulations remain unchanged. This implies faster MFP growth in countries where the regulatory stance is currently more stringent than the OECD average.
- For non-OECD countries, a gradual increase in public spending on social protection is assumed, amounting on average to an increase of four percentage points of GDP to a level of provision similar to the average OECD country. It is further assumed that this is financed in a way in which there is no effect on public saving.
- Private credit as a share of GDP is projected on the basis that countries gradually converge on the U.S. level of financial development with the gap assumed to close at 2 per cent per annum. For example, this means that for an average of the BRIC countries, the availability of credit rises from just over one-third of that in the United States in 2010, to around three-quarters in 2060.

Further details of the methodology used to make the long-term projections, including the parameterization of the links between structural factors and the components of GDP, including via new regression estimates are provided in Johansson *et al.* (2012).

Sectoral Contributions to Labour Productivity Growth in Canada: Does the Choice of Decomposition Formula Matter?

Ricardo de Avillez[1]
Centre for the Study of Living Standards

ABSTRACT

Using three decomposition formulas (TRAD, CSLS, and GEAD), this article estimates sectoral contributions to business sector labour productivity growth in Canada during the 2000-2010 period. Although at the aggregate economy level there was substantial agreement among the three formulas, contribution estimates varied widely at the sectoral level. In particular, there were significant differences in the estimated contributions of construction, manufacturing, and mining and oil and gas extraction. Ultimately, these differences reflect the fact that traditional decomposition formulas (TRAD and CSLS) and the GEAD formula measure different economic phenomena. Instead of seeing estimates constructed by the GEAD and traditional formulas as "competing" narratives, the article concludes it is more useful to see them as providing complementing stories about the role of different sectors in driving aggregate labour productivity growth.

RÉSUMÉ

Utilisant trois formules de décomposition (TRAD, CSLS et GEAD), cet article estime la contribution des secteurs à la croissance de la productivité du travail dans le secteur des entreprises au Canada au cours de la période 2000-2010. Bien qu'au niveau agrégé de l'économie, les trois formules aient donné des estimations largement semblables, les estimations varient considérablement à l'échelle des secteurs. Il existe en particulier de grandes différences entre les estimations pour les secteurs de la construction, de la fabrication, et de l'exploitation minière et de l'extraction du pétrole et du gaz. En fin de compte, ces différences viennent de ce que les formules de décomposition traditionnelles (TRAD et CSLS) et la formule GEAD mesurent des phénomènes économiques différents. Plutôt que de considérer les estimations données par la formule GEAD et les formules traditionnelles comme "concurrentes", l'article conclut qu'il est plus utile de considérer comme complémentaire ce qu'elles nous disent sur le rôle des différents secteurs dans la croissance de la productivité agrégée du travail.

1 Ricardo de Avillez is an economist at the Centre for the Study of Living Standards. This article, written under the supervision of Andrew Sharpe, is an abridged version of De Avillez (2012). The author would like to thank Erwin Diewert, Marshall Reinsdorf, and Jianmin Tang for their comments, corrections, and suggestions. Email: ricardo.avillez@csls.ca.

AN IMPORTANT PART of productivity analysis is the estimation of sectoral contributions to aggregate labour productivity growth. Several decomposition formulas have been developed for this purpose. Unfortunately, different decomposition formulas frequently yield significantly different results. The objective of this article is to compare estimates produced by three such formulas in the case of labour productivity growth in the Canadian business sector during the 2000-2010 period.

In the past 20 years, statistical agencies around the world have increasingly favoured chained indexes in place of fixed-base indexes when calculating real output. The advantages of chained indexes over their fixed-base counterparts are well established in the economics literature (see, for instance, Whelan (2002)), but a few points are worth highlighting here. Generally speaking, real output estimates in constant prices – i.e. calculated using fixed-base indexes – use relative prices from an arbitrarily chosen base period as the basis for comparison with all the other periods; on the other hand, real output estimates in chained prices – i.e. calculated using chained indexes – take into account the fact that relative prices are constantly changing. The growth rate of real output in constant prices depends on the choice of the base year, becoming increasingly "unbalanced" as one moves further and further away from it. This does not happen with real output in chained prices, since relative prices are updated every period. Thus, in general, chained indexes produce better quality estimates of real output.

A disadvantage of using chained indexes, however, is that real output estimates cease to be additive. When real output is computed using fixed-base Laspeyres quantity and Paasche price indexes,[2] aggregate real output is exactly equal to the sum of its individual components. This is not true when chained indexes are used. In this case, aggregate real output is equal to the sum of its individual components *only* for the chosen reference year (when real output is also equal to nominal output). The difference between the two increases as one moves away from the reference year.

Even though statistical agencies have updated their methods, productivity analysts still often use techniques that *assume* real output is additive. This is particularly true when it comes to decomposition formulas used to find sectoral or regional contributions to aggregate labour productivity growth. Labour productivity estimates are constructed using real output and labour input estimates. Since official real output estimates are now calculated mainly with chained indexes, labour productivity growth decomposition formulas that assume real output in constant prices generate sectoral or regional contributions that do not sum up *exactly* to aggregate labour productivity growth.

Tang and Wang (2004) addressed this issue with their Generalized Exactly Additive Decomposition (GEAD) formula. By taking into account changes in relative prices, the GEAD formula is able to generate sectoral contribution estimates that are perfectly additive irrespective of how real output is calculated. Despite this clear advantage over other decomposition formulas, the GEAD formula is still not widely used by productivity analysts, possibly due to some of its results being perceived as counterintuitive.

Dumagan (2012) compared the GEAD formula to a traditional decomposition formula (TRAD) that assumed real output in constant prices. He concluded that the GEAD formula produced superior estimates from both an

2 A Laspeyres formula uses base period prices (or quantities, in the case of a price index) as weights, whereas a Paasche formula uses current period prices (or quantities, in the case of a price index) as weights. The Fisher formula is a geometric average of the Laspeyres and Paasche formulas. For a discussion on these and other index number formulas, as well as on many topics central to index number theory, see Diewert (1993).

empirical and an analytical point of view. The purpose of this article is to expand Dumagan's investigation on how estimates produced by the GEAD formula compare to those produced by traditional labour productivity growth decomposition formulas. In order to do so, a third decomposition formula is added to the mix and sectoral contribution estimates for all three formulas are analysed in the case of labour productivity growth in the Canadian business sector during the 2000-2010 period.

This article is organized as follows. Section two presents the TRAD decomposition formula, a variation of that formula developed by the Centre for the Study of Living Standards (CSLS), and the GEAD formula. Section three compares the sectoral contributions calculated by the three formulas for the Canadian business sector during the 2000-2010 period. Section four concludes.

Decomposing Aggregate Labour Productivity Growth

This section describes three formulas commonly used to calculate sectoral contributions to aggregate labour productivity growth. The first decomposition formula is the TRAD formula, which, according to Dumagan (2012), can be traced back to Denison (1962). It assumes that real output is measured in constant prices – more specifically, using fixed-base Laspeyres quantity and Paasche price indexes – so that aggregate real output corresponds to the sum of sectoral real output. A second decomposition formula, referred to here as the CSLS decomposition, was developed by the Centre for the Study of Living Standards (CSLS) and is used in several of its articles and reports, including Sharpe (2009), Sharpe (2010), and Sharpe and Thomson (2010). The CSLS formula is essentially a variation of the TRAD formula. It also assumes real output in constant prices, but differs significantly from the TRAD formula in the way it accounts for the contribution of each sector to aggregate productivity growth. Finally, the last formula was developed by Tang and Wang (2004) (see also Diewert (2008) for an alternative formulation) and is perfectly additive regardless of how real output is measured. Following Dumagan (2012), the Tang and Wang decomposition is referred to here as the Generalized Exactly Additive Decomposition (GEAD) formula.[3]

This section is divided into three parts, the first of which presents the TRAD formula, while the second and third parts describe the CSLS and GEAD formula, respectively. This section draws from Dumagan (2012), especially regarding the choice of notation of the TRAD and GEAD formulas.

TRAD Decomposition

The TRAD decomposition formula is widely used to measure the contribution of different sectors to aggregate productivity growth (see, for example, Dekle and Vandenbroucke (2006), IMF (2006), and Usui (2011)). The underlying assumption of this formula is that real output is calculated in constant prices using fixed-base Laspeyres quantity and Paasche price indexes at both the aggregate and sectoral levels. When this happens, the sum of sectoral real output (net of intermediate inputs, i.e. value added) X_t^{*i} is equal to the economy's real output X_t^*, i.e. $X_t^* = \Sigma_i X_t^{*i}$, where the superscript $i=1,2,\ldots, N$ denotes the sector and the subscript $t=1, 2,\ldots, T$ denotes the time period. Defining labour productivity as output per unit of labour input, aggregate labour productivity is $Z_t^* = \frac{X_t^*}{L_t}$ and sectoral productivity is $Z_t^{*i} = \frac{X_t^{*i}}{L_t^i}$ where L_t and L_t^i represent labour input used in

3 The reader should bear in mind that there are many other labour productivity decompositions that are not discussed or used in this article. See, for instance, Nordhaus (2001), Reinsdorf, Diewert and Ehemann (2002), Diewert (2008), and Reinsdorf and Yuskavage (2010)

the aggregate economy and in sector i (respectively) such that $L_t = \Sigma_i L_t^i$. In this case, since real output is additive:

$$Z_t^* = \frac{X_t^*}{L_t} = \frac{\Sigma_i X_t^{*i}}{L_t} = \frac{\Sigma_i Z_t^{*i} L_t^i}{L_t} = \Sigma_i Z_t^{*i} l_t^i \quad (1)$$

where $l_t^i = \frac{L_t^i}{L_t}$.

Thus, aggregate labour productivity Z_t^* is equal to the weighted sum of sectoral labour productivity Z_t^{*i} across all i's, where the weights l_t^i are each sector's labour input shares. Sectoral contribution to aggregate labour productivity growth can be computed by looking at productivity changes (G_t^*) between two periods of time:

$$G_t^* = \frac{Z_t^* - Z_{t-1}^*}{Z_{t-1}^*} = \frac{\Sigma_i (Z_t^{*i} l_t^i - Z_{t-1}^{*i} l_{t-1}^i)}{Z_{t-1}^*} \quad (2)$$

With some algebraic manipulations, the above formula becomes:[4]

$$G_t^* = \Sigma_i \left[\frac{X_{t-1}^{*i}}{X_{t-1}^*} G_t^{*i} + \frac{Z_{t-1}^{*i}}{Z_{t-1}^*} \Delta l_t^i + \frac{Z_{t-1}^{*i}}{Z_{t-1}^*} \Delta l_t^i G_t^{*i} \right] \quad (3)$$

where $G_t^{*i} = \frac{Z_t^{*i} - Z_{t-1}^{*i}}{Z_{t-1}^{*i}}$.

Equation (3) is the TRAD decomposition formula. According to this formula, sectoral contributions to aggregate productivity growth can be broken down into three effects. The first term of equation (3) represents the *within-sector effect (WSE)*.[5] As the name implies, it measures the contribution to aggregate productivity growth due *solely* to productivity increases experienced by individual sectors. If sectoral labour shares remain unchanged over time ($\Delta l_t^i = 0$), the second and third terms of equation (3) equal zero and the contribution of each sector collapses to the first term, which is the sectoral labour productivity growth weighted by the sector's share in aggregate *real* output ($\frac{X_t^{*i}}{X_t^*}$).

The other two terms of equation (3) represent two different sectoral reallocation effects. The second term of equation (3) captures the *reallocation level effect (RLE)*.[6] As Denison (1962) realized, aggregate labour productivity can increase even when sectoral labour productivity remains constant, as long as labour moves from sectors with below average labour productivity levels towards sectors with above average labour productivity levels. In the TRAD decomposition, this effect is positive when $\Delta l_t^i > 0$. The ratio between the sector's labour productivity level and the aggregate labour productivity level scales the magnitude of the effect, either increasing it (when $\frac{Z_t^{*i}}{Z_t^*} > 1$) or decreasing it (when $\frac{Z_t^{*i}}{Z_t^*} < 1$).[7]

The third term is the *reallocation growth effect (RGE)*. It captures a phenomenon similar to Baumol's cost disease (Baumol (1967) and Baumol, Blackman, and Wolff (1985)) – that is, the propensity of labour to move towards sectors where labour productivity is stagnant or declining ($G_t^{*i} \leq 0$). In the TRAD decomposition, this effect will be positive either when labour has moved towards a sector with positive labour productivity growth ($\Delta l_t^i > 0$ and $G_t^{*i} > 0$) or when labour has moved away from a sector with negative labour productivity growth ($\Delta l_t^i < 0$ and $G_t^{*i} < 0$). The magnitude of the reallocation growth effect depends not only on Δl_t^i and G_t^{*i} but also on the ratio between the sector's labour productivity level and the aggregate labour productivity level ($\frac{Z_t^{*i}}{Z_t^*}$).

4 For a detailed derivation of the TRAD formula, see Dumagan (2012).

5 Tang and Wang (2004) call this effect the "pure productivity growth effect"', while Dumagan (2012) labels it the "within-sector productivity growth effect".

6 Tang and Wang (2004) name this effect the "relative size change effect", noting that it was an "analog of the Denison effect in Nordhaus (2002)" (p.427). Dumagan (2012), in turn, calls this effect the "static structural reallocation effect".

7 Tang and Wang (2004) simply label this effect as the "interaction term", while recognizing that it is similar to the Baumol effect in Nordhaus (2002). Dumagan (2012) refers to this effect as the "dynamic structural reallocation effect'".

CSLS Decomposition

Like the TRAD formula, the CSLS decomposition formula also assumes real output in constant prices calculated using fixed-base Laspeyres quantity and Paasche price indexes, so that sectoral real output sums up to aggregate real output. Starting from equation (1), the *absolute* change in labour productivity between two periods of time is:

$$\Delta Z_t^* = Z_t^* - Z_{t-1}^* = \Sigma_i (Z_t^{*i} l_t^i - Z_{t-1}^{*i} l_{t-1}^i) \tag{4}$$

With some algebraic manipulations, equation (4) becomes:

$$\Delta Z_t^* = \Sigma_i \Delta Z_t^{*i} l_{t-1}^i + \Sigma_i Z_{t-1}^{*i} \Delta l_t^i + \Sigma_i \Delta Z_t^{*i} \Delta l_t^i \tag{5}$$

Subtracting $\Sigma_i Z_{t-1}^* \Delta l_t^i$ and $\Sigma_i \Delta Z_t^* \Delta l_t^i$ from equation (5), it becomes:[8]

$$\Delta Z_t^* = \Sigma_i \Delta Z_t^{*i} l_{t-1}^i + \Sigma_i (Z_{t-1}^{*i} - Z_{t-1}^*) \Delta l_t^i + \Sigma_i (\Delta Z_t^{*i} - \Delta Z_t^*) \Delta l_t^i \tag{6}$$

Equation (6) is the CSLS decomposition formula. Note that, while the TRAD decomposition stated the contribution of individual sectors in terms of percentage points (relative to the per cent growth in aggregate labour productivity), the CSLS formula looks at absolute changes, i.e. increases in constant dollars per unit of labour. The CSLS formula can be easily modified so that sectoral contributions are stated in percentage points; one needs only divide both sides of equation (6) by Z_{t-1}^*:

$$G_t^* = \frac{Z_t^* - Z_{t-1}^*}{Z_{t-1}^*} = \frac{\Sigma_i \Delta Z_t^{*i} l_{t-1}^i}{Z_{t-1}^*} + \frac{\Sigma_i (Z_{t-1}^{*i} - Z_{t-1}^*) \Delta l_t^i}{Z_{t-1}^*} + \frac{\Sigma_i (\Delta Z_t^{*i} - \Delta Z_t^*) \Delta l_t^i}{Z_{t-1}^*} \tag{7}$$

Analogous to the TRAD decomposition, the first term of the CSLS decomposition formula accounts for the WSE, while the two other terms represent the RLE and the RGE, respectively. Although the CSLS formula appears to specify the WSE differently – with sectoral labour shares (l_t^i) instead of real output shares ($\frac{X_t^{*i}}{X_t^*}$) used as weights – the two formulas actually have the same WSE. Recalling that $G_t^{*i} = \frac{Z_t^{*i} - Z_{t-1}^{*i}}{Z_{t-1}^{*i}}$, the first term of equation (7) can be rewritten as

$$\Sigma_i \frac{\Delta Z_t^{*i} l_{t-1}^i}{Z_{t-1}^*} = \Sigma_i \frac{Z_{t-1}^{*i} l_{t-1}^i}{Z_{t-1}^*} \frac{\Delta Z_t^{*i}}{Z_{t-1}^{*i}} = \Sigma_i \left(\frac{\frac{X_{t-1}^{*i}}{L_{t-1}^i} \frac{L_{t-1}^i}{L_{t-1}}}{\frac{X_{t-1}^*}{L_{t-1}}} \right) G_t^{*i} = \Sigma_i \left(\frac{X_{t-1}^{*i}}{X_{t-1}^*} \right) G_t^{*i} \tag{8}$$

which corresponds to the TRAD's WSE.

The crucial difference between the two formulas lies in how the RLE and RGE are specified and interpreted. Much like in the TRAD decomposition, the CSLS's RLE captures aggregate labour productivity changes caused by labour input shifts to sectors with above- or below-average labour productivity levels. In the CSLS decomposition, this effect is positive either when a sector with above-average labour productivity level ($Z_t^{*i} > Z_t^*$) experiences an increase in its labour input share ($l_t^i > l_{t-1}^i$) or when a sector with below-average labour productivity level ($Z_t^{*i} < Z_t^*$) experiences a reduction in its labour input share ($l_t^i < l_{t-1}^i$). In both the TRAD and CSLS formulas, the magnitude of the RLE is a function of Δl_t^i. In the case of the TRAD formula, however, the effect depends on the *ratio* between the sectoral labour productivity level and the aggregate labour productivity level, while in the CSLS formula it depends on the *absolute difference* between the two.

The third term of the CSLS decomposition formula represents the RGE, which measures the impact of shifts of labour input to sectors with above- or below-average labour productivity growth. This effect is positive either when $\Delta l_t^i > 0$ and $\Delta Z_t^{*i} - \Delta Z_t^* > 0$ or when $\Delta l_t^i < 0$ and $\Delta Z_t^{*i} - \Delta Z_t^* < 0$. Both the TRAD's and the CSLS's RGE are a function of Δl_t^i. The difference between the two is reflected, once again, by the fact that the TRAD's RGE

8 As Sharpe (2010) notes, because $\Sigma_i \Delta l_t^i = 0$, the terms $Z_{t-1}^* \Delta l_t^i$ and $\Delta Z_t^* \Delta l_t^i$ both sum to zero when aggregated across all sectors.

depends on the ratio between a sector's labour productivity level and the aggregate labour productivity level, whereas the CSLS's RGE is a function of the difference between sectoral labour productivity growth and aggregate labour productivity growth.

GEAD Decomposition

The TRAD and the CSLS decompositions share a common assumption: that real output is measured in constant prices using fixed base Laspeyres quantity and Paasche price indexes. This guarantees that real aggregate output is equal to the sum of real sectoral output, which leads to equation (1). The Generalized Exactly Additive Decomposition (GEAD) formula has a different starting point. Noting that:

1 Aggregate nominal output (Y_t) is always additive across sectors ($Y_t = \Sigma_i Y_t^i$, where Y_t^i represents nominal output of sector *i*);
2 By definition, $Y_t = P_t X_t$ and $Y_t^i = P_t^i X_t^i$ where X_t and X_t^i are aggregate and sectoral real output (respectively) and P_t and P_t^i are their corresponding price indexes;

then $Y_t = \Sigma_i Y_t^i = \Sigma_i P_t^i X_t^i$. Defining relative prices (ρ_t^i) as the ratio between prices in sector *i* and economy-wide prices so that $\rho_t^i = \frac{P_t^i}{P_t}$, it can be noted that the relationship between aggregate labour productivity ($Z_t = \frac{X_t}{L_t}$) and sectoral labour productivity ($Z_t^i = \frac{X_t^i}{L_t^i}$) is:

$$Z_t = \frac{X_t}{L_t} = \frac{\frac{Y_t}{P_t}}{L_t} = \frac{\Sigma_i Y_t^i}{P_t L_t} = \frac{\Sigma_i P_t^i X_t^i}{P_t L_t} = \Sigma_i \frac{P_t^i L_t^i X_t^i}{P_t L_t L_t^i} = \Sigma_i \rho_t^i l_t^i Z_t^i \tag{9}$$

While equation (1) holds only when output is calculated using fixed base Laspeyres quantity and Paasche price indexes, equation (9) is true regardless of the index number formula used to calculate real output, because $Y_t = P_t X_t$ and $Y_t^i = P_t^i X_t^i$ *always* hold. In particular, equation (9) is true when chained index number formulas are used to measure real output, in which case the additivity of real output does not hold ($X_t \neq \Sigma_i X_t^i$).

Plugging equation (9) into equation (2) and performing some algebraic manipulations, the expression becomes:[9]

$$G_t = \Sigma_i \left[\frac{Y_{t-1}^i}{Y_{t-1}} G_t^i + \frac{Z_{t-1}^i}{Z_{t-1}} (\rho_t^i l_t^i - \rho_{t-1}^i l_{t-1}^i) + \frac{Z_{t-1}^i}{Z_{t-1}} (\rho_t^i l_t^i - \rho_{t-1}^i l_{t-1}^i) G_t^i \right] \tag{10}$$

where G_t and G_t^i are defined analogously to G_t^* and G_t^{*i}, with the only difference that now there is no restriction on how real output is computed (which is why the * is dropped). Equation (10) is the GEAD formula. The similarities – as well as the differences – between equation (10) and equation (3) are immediately noticeable. Much like the TRAD and CSLS decompositions, the GEAD breaks down sectoral contribution into three effects: WSE, RLE, and RGE. The first term of the GEAD represents the WSE. Notice that, while in the TRAD formula the WSE was defined as sectoral labour productivity growth weighted by the sector's *real* output share ($\frac{X_t^i}{X_t}$), in the GEAD sectoral growth is weighted by the sector's *nominal* output share ($\frac{Y_t^i}{Y_t}$).

Regarding the reallocation effects, the GEAD's RLE and RGE do not depend only on how sectoral labour input shares changed over time (as was the case in the TRAD decomposition), but also on relative price movements. Thus, a decline in a sector's labour input share can be offset by an increase in the sector's relative prices. In the GEAD formula, a sector will have a positive RLE when $\rho_t^i l_t^i > \rho_{t-1}^i l_{t-1}^i$. The RGE will be positive either when $\rho_t^i l_t^i > \rho_{t-1}^i l_{t-1}^i$ and $G_t^i > 0$ or when $\rho_t^i l_t^i < \rho_{t-1}^i l_{t-1}^i$ and $G_t^i < 0$. If there are no movements in relative prices ($\rho_t^i = 1$, for all *t*), then the GEAD

9 For a detailed derivation of the GEAD formula, see Tang and Wang (2004), Dumagan (2012), or De Avillez (2012).

formula becomes equal to the TRAD formula.[10]

Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, 2000-2010

This section looks at how different sectors contributed to aggregate labour productivity growth in Canada during the 2000-2010 period according to the TRAD, CSLS, and GEAD decomposition formulas. The section is divided into four parts. The first part provides a brief overview of the data used in this article. The second part describes nominal output, real output, prices, labour input, and labour productivity trends observed in Canada during the 2000-2010 period for both the business sector as a whole and two-digit NAICS sectors. The third part analyses sectoral contribution estimates to aggregate labour productivity growth in the Canadian business sector during the 2000-2010 period. Six sets of estimates are presented. The fourth part discusses which of the three formulas produces "better" estimates.

Data

Statistics Canada constructs productivity estimates for the Canadian business sector, two-digit NAICS sectors, and three-digit NAICS subsectors. These estimates span a variable period of time, depending on which program they belong to – estimates from the multifactor productivity program currently go all the way back to 1961 and up to 2011 (CANSIM Table 383-0021), while estimates from the labour productivity program span the 1997-2011 period (CANSIM Table 383-0011). Both sets of productivity estimates use real GDP in chained 2002 dollars.

Since Statistics Canada constructs real GDP estimates in both constant 2002 dollars and chained 2002 dollars, an option would have been to use Statistics Canada's official productivity numbers and calculate a new set of productivity estimates using real GDP in constant 2002 dollars. Doing so, however, could create additional problems. In particular, there is no guarantee that data adjustments made by Statistics Canada would have been replicable, causing our labour productivity estimates in constant prices to not be perfectly comparable to the official Statistics Canada estimates in chained prices. In order to circumvent this problem, two sets of labour productivity estimates – one in chained 2002 dollars and the other in constant 2002 dollars – were constructed by the author using Statistics Canada data on nominal GDP, real GDP, and hours worked. These estimates span the 2000-2010 period and refer to the Canadian business sector as a whole and two-digit NAICS sectors. Details on how these estimates were constructed can be found in De Avillez (2012).

Output, Prices, Labour Input, and Labour Productivity Trends in Canada, 2000-2010

Nominal GDP in the Canadian business sector increased at an average annual rate of 4.10 per cent during the 2000-2010 period (Table 1). Nominal GDP growth was particularly strong in mining and oil and gas extraction (8.88 per cent per year) and construction (8.22 per cent per year). Due to this above-average growth, the nominal GDP of the two sectors as a share of business sector GDP increased substantially – in

10 Diewert (2008) notes the difficulty in interpreting the GEAD's RLE and RGE as actual reallocation effects, since the effects of changes in labour shares are mixed with the effects of changes in relative prices. Thus, he proposes an alternative formulation of the GEAD formula, where the two reallocation effects are replaced by a labour input effect and a price effect. Although Diewert's formulation of the GEAD breaks down sectoral contributions into terms that have a more straightforward interpretation, the overall sectoral contributions estimated by his formula will be exactly the same as those estimated by the original GEAD formula.

Table 1

Nominal GDP in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010

	Nominal GDP, 2000 ($ millions) Y^i_{2000}	Nominal GDP, 2010 ($ millions) Y^i_{2010}	Ave. Annual Growth (%)	Nominal GDP Shares, 2000 (%) $\frac{Y^i_{2000}}{Y_{2000}}$	Nominal GDP Shares, 2010 (%) $\frac{Y^i_{2010}}{Y_{2010}}$
Business sector industries	769,682	1,141,075	4.10	100.0	100.0
Agriculture, forestry, fishing and hunting	22,137	24,996	1.60	2.9	2.2
Mining and oil and gas extraction	60,906	110,904	8.88	7.9	9.7
Utilities	26,242	33,811	2.63	3.4	3.0
Construction	49,648	107,125	8.22	6.5	9.4
Manufacturing	187,462	164,007	-1.22	24.4	14.4
Wholesale trade	50,931	80,680	4.78	6.6	7.1
Retail trade	51,311	86,503	5.39	6.7	7.6
Transportation and warehousing	43,896	67,064	4.38	5.7	5.9
Information and cultural industries	32,150	53,228	5.18	4.2	4.7
FIRE	108,272	180,127	5.23	14.1	15.8
Professional, scientific and technical services	43,566	76,907	5.87	5.7	6.7
ASWMRS	20,367	37,712	6.44	2.6	3.3
Arts, entertainment and recreation	7,009	10,858	4.53	0.9	1.0
Accommodation and food services	23,263	33,621	3.78	3.0	2.9
Other Private Services	42,522	73,532	5.63	5.5	6.4

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

the case of mining and oil and gas extraction from 7.9 per cent in 2000 to 9.7 per cent in 2010, while in construction from 6.5 per cent to 9.4 per cent. At the same time, nominal GDP in the manufacturing sector fell 1.22 per cent per year, causing a marked decline in the sector's share of business sector nominal GDP, from 24.4 per cent in 2000 to 14.4 per cent in 2010.[11]

Table 2 presents two sets of price deflators, the first one calculated using a fixed-base Paasche price index and the second one calculated using a chained Fisher price index. It is clear from the numbers that, for the time period in question, the differences between the two sets of deflators are minor. The only two sectors where there is a (potentially) significant difference between price deflators are manufacturing (which saw prices rising 0.70 per cent per year according to the constant price deflator and 0.44 per cent per year according to the chained price deflator) and wholesale trade (1.52 per cent per year versus 1.93 per cent per year).

Almost 60 per cent of the total increase in business sector nominal GDP was caused by rising prices. At the business sector level, prices rose at an average annual rate of 2.38 per cent according

11 Instead of using only starting and end points of a particular series, growth rates presented in this article were calculated as the period average of annual growth rates, e.g. for the 2000-2010 period, reported growth rates are the average of the annual growth experienced in 2001, 2002, ..., 2010. This ensures that growth rates are consistent with our estimates of sectoral contributions to aggregate labour productivity growth, which were calculated on a year-to-year basis. Although sectoral contribution estimates could have been calculated for the entire 2000-2010 period, since contributions are crucially dependent of output and labour shares in the *initial period*, large swings in these shares in subsequent periods could bias estimated contributions significantly.

Table 2

Implicit Price Deflators for Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010

	Prices, 2000 (2002 = 100) P^{i}_{2000}	Prices, 2010 (2002 = 100) P^{i}_{2010}	Ave. Annual Growth (%)	Relative Prices, 2000 (%) ρ^{i}_{2000}	Relative Prices, 2010 (%) ρ^{i}_{2010}
A) Constant 2002 Dollars					
Business sector industries	98.0	123.7	2.38	100.0	100.0
Agriculture, forestry, fishing and hunting	84.1	87.1	0.63	85.9	70.4
Mining and oil and gas extraction	116.7	201.8	7.79	119.1	163.2
Utilities	97.5	111.2	1.39	99.5	89.9
Construction	96.1	147.6	4.44	98.1	119.3
Manufacturing	98.3	105.3	0.70	100.4	85.1
Wholesale trade	99.4	115.4	1.52	101.4	93.3
Retail trade	99.1	114.0	1.42	101.2	92.2
Transportation and warehousing	94.1	122.6	2.69	96.0	99.1
Information and cultural industries	100.1	123.4	2.12	102.1	99.7
FIRE	97.6	116.8	1.81	99.6	94.5
Professional, scientific and technical services	95.3	128.3	3.03	97.2	103.8
ASWMRS	93.9	124.8	2.90	95.8	100.9
Arts, entertainment and recreation	91.8	122.5	2.95	93.7	99.0
Accommodation and food services	95.3	127.8	2.98	97.3	103.3
Other Private Services	93.2	128.9	3.30	95.1	104.2
B) Chained 2002 Dollars					
Business sector industries	98.0	123.2	2.33	100.0	100.0
Agriculture, forestry, fishing and hunting	86.6	90.6	0.70	88.4	73.5
Mining and oil and gas extraction	118.2	201.8	7.77	120.6	163.8
Utilities	95.2	110.5	1.58	97.1	89.7
Construction	95.9	145.8	4.33	97.8	118.3
Manufacturing	99.2	103.6	0.44	101.2	84.1
Wholesale trade	97.0	117.3	1.93	98.9	95.2
Retail trade	97.7	114.5	1.61	99.6	92.9
Transportation and warehousing	94.5	122.7	2.66	96.3	99.6
Information and cultural industries	99.7	123.5	2.18	101.7	100.3
FIRE	98.0	117.1	1.80	99.9	95.1
Professional, scientific and technical services	94.6	129.0	3.16	96.5	104.7
ASWMRS	93.6	124.7	2.92	95.5	101.2
Arts, entertainment and recreation	91.4	122.5	2.99	93.3	99.5
Accommodation and food services	95.5	127.4	2.93	97.4	103.4
Other Private Services	93.2	129.8	3.37	95.1	105.3

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

to the constant price deflator and 2.33 per cent according to the chained price deflator. The sectors that saw the most significant price increases were mining and oil and gas extraction (7.77-7.79 per cent per year) and construction (4.33-4.44 per cent per year). Although prices in manufacturing increased at a much slower rate than overall business sector prices, the fact that they did increase implies that real GDP growth in the sector was even lower than nominal GDP growth.

In fact, this is exactly what Table 3 shows, with real GDP in the manufacturing sector declining 1.85 per cent per year according to the constant price deflator or 1.64 per cent

Table 3
Real GDP in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010

	Real GDP, 2000 ($ millions) X^i_{2000}	Real GDP, 2010 ($ millions) X^i_{2010}	Ave. Annual Growth (%)	Real GDP Shares, 2000 (%) $\frac{X^i_{2000}}{X_{2000}}$	Real GDP Shares, 2010 (%) $\frac{X^i_{2010}}{X_{2010}}$
A) Constant 2002 Dollars					
Business sector industries	785,491	922,567	1.65	100.0	100.0
Agriculture, forestry, fishing and hunting	26,312	28,711	1.11	3.3	3.1
Mining and oil and gas extraction	52,183	54,958	0.60	6.6	6.0
Utilities	26,914	30,403	1.28	3.4	3.3
Construction	51,655	72,576	3.56	6.6	7.9
Manufacturing	190,617	155,727	-1.85	24.3	16.9
Wholesale trade	51,256	69,891	3.22	6.5	7.6
Retail trade	51,766	75,893	3.92	6.6	8.2
Transportation and warehousing	46,670	54,719	1.65	5.9	5.9
Information and cultural industries	32,126	43,152	3.03	4.1	4.7
FIRE	110,890	154,182	3.36	14.1	16.7
Professional, scientific and technical services	45,731	59,929	2.76	5.8	6.5
ASWMRS	21,697	30,208	3.42	2.8	3.3
Arts, entertainment and recreation	7,634	8,864	1.53	1.0	1.0
Accommodation and food services	24,406	26,313	0.77	3.1	2.9
Other Private Services	45,633	57,042	2.26	5.8	6.2
B) Chained 2002 Dollars					
Business sector industries	785,057	926,103	1.70	100.0	100.0
Agriculture, forestry, fishing and hunting	25,549	27,593	0.95	3.3	3.0
Mining and oil and gas extraction	51,519	54,967	0.71	6.6	5.9
Utilities	27,560	30,602	1.12	3.5	3.3
Construction	51,757	73,467	3.67	6.6	7.9
Manufacturing	188,914	158,307	-1.64	24.1	17.1
Wholesale trade	52,511	68,802	2.80	6.7	7.4
Retail trade	52,536	75,564	3.72	6.7	8.2
Transportation and warehousing	46,472	54,647	1.67	5.9	5.9
Information and cultural industries	32,242	43,084	2.97	4.1	4.7
FIRE	110,515	153,801	3.37	14.1	16.6
Professional, scientific and technical services	46,068	59,612	2.63	5.9	6.4
ASWMRS	21,750	30,248	3.40	2.8	3.3
Arts, entertainment and recreation	7,665	8,861	1.49	1.0	1.0
Accommodation and food services	24,362	26,395	0.82	3.1	2.9
Other Private Services	45,622	56,654	2.19	5.8	6.1

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

per year according to the chained price deflator. It is interesting to note, also, that most of the nominal GDP growth experienced by the mining and oil and gas extraction sector was due to price increases. Real GDP growth in the sector was only 0.60-0.71 per cent per year during the 2000-2010 period. The construction sector, on the other hand, saw not only rapid price increases but also fast real GDP growth. The sector had the second highest real growth rate among all two-digit NAICS sectors (3.56-3.67 per cent per year), only behind retail trade (3.72-3.92 per cent per year). Other sectors that experienced robust real GDP growth were FIRE (3.36-3.37 per cent per year) and administration and support, waste management and remediation services (ASWMRS) (3.40-3.42 per cent per year). At the business sector level, real GDP grew at an average annual rate of 1.65-1.70 per cent during the 2000-2010 period.

While nominal GDP in mining and oil and gas extraction as a share of business sector GDP increased substantially from 2000 to 2010, the sector's real GDP share actually fell during the period, from 6.6 per cent in 2000 to 5.9-6.0 per cent (depending on which deflator is used). Manufacturing also saw a marked decline in its real GDP share, from 24.1-24.3 per cent to 16.9-17.1 per cent, although the magnitude of this decline was not as marked as it was in nominal terms. The construction sector's real GDP share, on the other hand, increased in the period, from 6.6-6.7 per cent to 7.9 per cent. Another interesting development was the increase in the FIRE sector's real GDP share, from 14.1 per cent to 16.6-16.7 per cent.

Hours worked in the Canadian business sector increased at an average annual rate of 0.78 per cent during the 2000-2010 period (Table 4). Hours worked saw particularly fast growth in mining and oil and gas extraction (3.91 per cent per year), construction (3.66 per cent per year), and ASWMRS (3.37 per cent per year). Conversely, agriculture, forestry, fishing and hunting (-2.91 per cent per year) and manufacturing (-2.50 per cent per year) experienced a decline in total hours worked.

The changes in sectoral hours worked as a share of total hours worked in the business sector during the 2000s were not as drastic as those seen in terms of nominal GDP or real GDP shares. The two most significant changes were in construction, where the hours worked share increased from 8.3 per cent in 2000 to 11.0 per cent in 2010, and manufacturing, where the share decreased from 18.3 per cent to 13.1 per cent.

Using our two sets of real GDP estimates and hours worked, labour productivity estimates were constructed for the business sector and two-digit NAICS sectors in Canada from 2000 to 2010 (Table 5). During the period, labour productivity in the Canadian business sector grew at an average annual rate of 0.86 per cent according to the constant 2002 dollar estimates – from $35.57 per hour in 2000 to $38.74 per hour in 2010 – and 0.91 per cent according to the chained 2002 dollar estimates – from $35.55 per hour to $38.89 per hour. This difference is so small, however, that it seems safe to assume it is not particularly relevant.

Since labour input is the same for both sets of labour productivity estimates, the sole source of differences between the two sets of estimates is real output. Thus, exactly as seen when price deflator and real output trends were discussed, there were only two sectors where a substantial difference in labour productivity growth rates could be observed: first, wholesale trade, where labour productivity grew 3.27 per cent per year according to the constant dollar estimates, but only 2.86 per cent per year according to the chained dollar estimates; and second, manufacturing, where labour productivity growth was 0.61 per cent per year according to the constant dollar estimate and 0.85 per cent per year according to the chained dollar estimate. For all the other sectors, the differences in labour productivity growth between the two sets of estimates were minor.

During the 2000-2010 period, the two-digit NAICS sector that experienced the fastest

Table 4

Hours Worked in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010

	Hours Worked, 2000 (millions) L^i_{2000}	Hours Worked, 2010 (millions) L^i_{2010}	Ave. Annual Growth (%)	Hours Worked Shares, 2000 (%) l^i_{2000}	Hours Worked Shares, 2010 (%) l^i_{2010}
Business sector industries	22,083	23,812	0.78	100.0	100.0
Agriculture, forestry, fishing and hunting	997	737	-2.91	4.5	3.1
Mining and oil and gas extraction	324	461	3.91	1.5	1.9
Utilities	167	202	2.02	0.8	0.8
Construction	1,833	2,610	3.66	8.3	11.0
Manufacturing	4,037	3,114	-2.50	18.3	13.1
Wholesale trade	1,597	1,584	-0.04	7.2	6.7
Retail trade	2,754	3,145	1.36	12.5	13.2
Transportation and warehousing	1,412	1,479	0.51	6.4	6.2
Information and cultural industries	631	691	0.95	2.9	2.9
FIRE	1,644	1,937	1.66	7.4	8.1
Professional, scientific and technical services	1,566	1,926	2.11	7.1	8.1
ASWMRS	1,014	1,406	3.37	4.6	5.9
Arts, entertainment and recreation	370	459	2.28	1.7	1.9
Accommodation and food services	1,660	1,713	0.34	7.5	7.2
Other Private Services	2,076	2,348	1.25	9.4	9.9

1 FIRE Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

labour productivity growth was agriculture, forestry, fishing and hunting (4.12-4.25 per cent per year), followed by wholesale trade (2.86-3.27 per cent) and retail trade (2.35-2.54 per cent). Conversely, the sectors that saw the worst labour productivity performances were mining and oil and gas extraction (-2.80/-2.63 per cent per year), arts, entertainment and recreation (-0.65/-0.61 per cent), and utilities (-0.66/-0.51 per cent).

In terms of labour productivity levels, the sectors with the highest levels in 2010 were utilities ($150.51-151.50 per hour), mining and oil and gas extraction ($119.21-119.23 per hour), and FIRE ($79.40-79.60 per hour). The lowest labour productivity levels could be found in accommodation and food services ($15.36-15.41 per hour), arts, entertainment and recreation ($19.31 per hour), and ASWMRS ($21.49-21.51 per hour).

Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, 2000-2010

Using the TRAD, CSLS, and GEAD decomposition formulas, contributions of two-digit NAICS sectors to business sector labour productivity growth in Canada during the 2000-2010 period were calculated. Two sets of estimates were constructed for each of the three formulas – one using real output in constant 2002 dollars (Table 6) and the other using real output in chained 2002 dollars (Table 7). A comparison between Tables 6 and 7 shows that, while the estimated sectoral contributions differ significantly from formula to formula, the differences due to the use of real GDP in constant prices or in chained prices are relatively small and do not alter the overall results of each decomposition formula. The main difference between the two

Table 5
Labour Productivity in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010

	Labour Productivity, 2000 ($ per hour) Z^i_{2000}	Labour Productivity, 2010 ($ per hour) Z^i_{2010}	Ave. Annual Growth (%)	Relative Labour Productivity, 2010 (%) $\frac{Z^i_{2000}}{Z_{2000}}$	Relative Labour Productivity, 2010 (%) $\frac{Z^i_{2010}}{Z_{2010}}$
A) Constant 2002 Dollars					
Business sector industries	35.57	38.74	0.86	100.0	100.0
Agriculture, forestry, fishing and hunting	26.39	38.96	4.25	74.2	100.6
Mining and oil and gas extraction	161.06	119.21	-2.80	452.8	307.7
Utilities	161.16	150.51	-0.51	453.1	388.5
Construction	28.18	27.81	-0.10	79.2	71.8
Manufacturing	47.22	50.01	0.61	132.7	129.1
Wholesale trade	32.10	44.12	3.27	90.2	113.9
Retail trade	18.80	24.13	2.54	52.8	62.3
Transportation and warehousing	33.05	37.00	1.17	92.9	95.5
Information and cultural industries	50.91	62.45	2.13	143.1	161.2
FIRE	67.45	79.60	1.69	189.6	205.4
Professional, scientific and technical services	29.20	31.12	0.65	82.1	80.3
ASWMRS	21.40	21.49	0.06	60.2	55.5
Arts, entertainment and recreation	20.63	19.31	-0.61	58.0	49.8
Accommodation and food services	14.70	15.36	0.45	41.3	39.6
Other Private Services	21.98	24.29	1.02	61.8	62.7
B) Chained 2002 Dollars					
Business sector industries	35.55	38.89	0.91	100.0	100.0
Agriculture, forestry, fishing and hunting	25.63	37.44	4.12	72.1	96.3
Mining and oil and gas extraction	159.01	119.23	-2.63	447.3	306.6
Utilities	165.03	151.50	-0.66	464.2	389.5
Construction	28.24	28.15	0.00	79.4	72.4
Manufacturing	46.80	50.84	0.85	131.6	130.7
Wholesale trade	32.88	43.44	2.86	92.5	111.7
Retail trade	19.08	24.03	2.35	53.7	61.8
Transportation and warehousing	32.91	36.95	1.20	92.6	95.0
Information and cultural industries	51.10	62.35	2.07	143.7	160.3
FIRE	67.22	79.40	1.70	189.1	204.2
Professional, scientific and technical services	29.42	30.95	0.52	82.7	79.6
ASWMRS	21.45	21.51	0.05	60.3	55.3
Arts, entertainment and recreation	20.72	19.31	-0.65	58.3	49.6
Accommodation and food services	14.68	15.41	0.50	41.3	39.6
Other Private Services	21.98	24.13	0.95	61.8	62.0

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

sets of estimates is simply that sectoral contributions calculated using the TRAD and CSLS formulas do not sum up to business sector labour productivity growth when real GDP is in chained 2002 dollars. Given that these are minor differences, this section focuses on the first set of estimates, which uses real GDP in constant 2002 dollars.

At the aggregate economy level, the TRAD and CSLS formulas tell exactly the same story. According to both formulas, the entirety of business sector labour productivity growth in Canada during the 2000-2010 period (0.86 per cent per year) is explained by within-sector effects (WSE). In fact, the WSE contribution was higher than actual labour productivity growth –

Table 6
Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, Real GDP in Constant 2002 Dollars, 2000-2010

	TRAD				CSLS				GEAD			
	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE
A) Percentage Point Contributions												
Business sector industries	0.86	0.95	-0.03	-0.06	0.86	0.95	-0.03	-0.06	0.86	0.82	0.23	-0.18
Agriculture, forestry, fishing and hunting	0.00	0.13	-0.11	-0.01	0.15	0.13	0.03	-0.01	-0.05	0.10	-0.14	-0.01
Mining and oil and gas extraction	-0.01	-0.18	0.20	-0.03	-0.06	-0.18	0.15	-0.03	0.26	-0.25	0.65	-0.14
Utilities	0.01	-0.02	0.04	-0.01	0.01	-0.02	0.04	-0.01	-0.02	-0.02	0.02	-0.01
Construction	0.19	-0.01	0.21	0.00	-0.08	-0.01	-0.06	0.00	0.36	-0.02	0.39	0.00
Manufacturing	-0.56	0.11	-0.67	0.00	-0.04	0.11	-0.15	0.00	-0.83	0.10	-0.93	-0.01
Wholesale trade	0.17	0.23	-0.06	0.00	0.22	0.23	0.00	0.00	0.11	0.23	-0.11	-0.01
Retail trade	0.23	0.18	0.04	0.00	0.15	0.18	-0.03	0.00	0.15	0.18	-0.02	0.00
Transportation and warehousing	0.05	0.07	-0.02	0.00	0.07	0.07	0.00	0.00	0.07	0.06	0.00	0.00
Information and cultural industries	0.10	0.09	0.01	0.00	0.09	0.09	0.00	0.00	0.09	0.09	0.00	0.00
FIRE	0.39	0.25	0.14	0.00	0.32	0.25	0.07	0.00	0.30	0.24	0.05	0.00
Professional, scientific and technical services	0.12	0.04	0.08	0.00	0.02	0.04	-0.02	0.00	0.16	0.03	0.13	0.00
ASWMRS	0.08	0.00	0.08	0.00	-0.05	0.00	-0.05	0.00	0.09	0.00	0.09	0.00
Arts, entertainment and recreation	0.01	-0.01	0.01	0.00	-0.02	-0.01	-0.01	0.00	0.01	-0.01	0.02	0.00
Accommodation and food services	0.00	0.01	-0.01	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.00	0.00
Other Private Services	0.09	0.06	0.03	0.00	0.04	0.06	-0.02	0.00	0.14	0.06	0.08	0.00
B) Per Cent Contributions												
Business sector industries	100.0	110.1	-3.6	-6.6	100.0	110.1	-3.6	-6.6	100.0	94.9	26.5	-21.4
Agriculture, forestry, fishing and hunting	0.3	14.5	-13.1	-1.1	16.9	14.5	3.4	-1.0	-5.5	11.7	-15.7	-1.5
Mining and oil and gas extraction	-1.6	-21.1	22.8	-3.3	-7.1	-21.1	17.3	-3.4	30.1	-29.4	75.2	-15.7
Utilities	1.7	-2.4	5.2	-1.0	0.7	-2.4	4.1	-1.0	-2.0	-2.2	1.8	-1.5
Construction	22.3	-1.7	24.1	-0.1	-8.8	-1.7	-6.7	-0.4	41.8	-2.5	44.8	-0.5
Manufacturing	-64.7	13.0	-77.8	0.1	-4.1	13.0	-17.6	0.4	-96.3	12.2	-107.6	-0.9
Wholesale trade	19.3	26.7	-6.9	-0.4	26.1	26.7	-0.2	-0.4	12.2	26.1	-13.2	-0.6
Retail trade	26.4	21.4	4.9	0.0	17.8	21.4	-3.6	0.0	17.8	20.9	-2.9	-0.3
Transportation and warehousing	5.8	7.8	-1.9	-0.2	7.9	7.8	0.2	-0.2	7.8	7.5	0.4	-0.1
Information and cultural industries	11.3	10.6	1.1	-0.3	10.9	10.6	0.6	-0.3	10.1	10.6	-0.1	-0.4
FIRE	45.3	29.3	15.9	0.1	37.2	29.3	7.9	0.0	34.7	28.3	6.1	0.3
Professional, scientific and technical services	13.9	4.2	9.7	0.0	2.3	4.2	-1.8	0.0	18.5	4.0	14.5	0.0
ASWMRS	9.1	0.2	9.0	-0.1	-6.3	0.2	-6.2	-0.2	10.8	0.1	10.7	-0.1
Arts, entertainment and recreation	0.8	-0.7	1.7	-0.1	-2.0	-0.7	-1.2	-0.1	1.4	-0.7	2.3	-0.2
Accommodation and food services	0.0	1.5	-1.5	0.0	3.8	1.5	2.3	0.0	2.1	1.5	0.5	0.0
Other Private Services	10.2	6.9	3.3	0.0	5.0	6.9	-2.0	0.1	16.6	6.7	9.7	0.2

1 TC - Total Contribution; WSE - Within-Sector Effect; RLE - Reallocation Level Effect; RGE - Reallocation Growth Effect.

2 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

3 Growth rates calculated as the arithmetic average of annual growth rates.

0.95 percentage points or 110.1 per cent of business sector labour productivity growth. Aggregate labour productivity growth was dampened by negative reallocation level (RLE) and reallocation growth (RGE) effects, with the RLE reducing growth by 0.03 percentage points (-3.6

Table 7
Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, Real GDP in Chained 2002 Dollars, 2000-2010

	TRAD				CSLS				GEAD			
	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE
A) Percentage Point Contributions												
Business sector industries	0.87	0.96	-0.03	-0.06	0.87	0.96	-0.03	-0.06	0.91	0.84	0.27	-0.20
Agriculture, forestry, fishing and hunting	0.00	0.12	-0.11	-0.01	0.14	0.12	0.03	-0.01	-0.05	0.10	-0.13	-0.01
Mining and oil and gas extraction	-0.01	-0.17	0.20	-0.03	-0.05	-0.17	0.15	-0.03	0.27	-0.23	0.65	-0.15
Utilities	0.01	-0.03	0.04	-0.01	0.00	-0.03	0.04	-0.01	-0.02	-0.02	0.02	-0.01
Construction	0.20	-0.01	0.21	0.00	-0.07	-0.01	-0.06	0.00	0.36	-0.01	0.38	0.00
Manufacturing	-0.51	0.17	-0.67	0.00	0.02	0.17	-0.15	0.00	-0.82	0.15	-0.97	-0.01
Wholesale trade	0.14	0.20	-0.06	0.00	0.20	0.20	0.00	0.00	0.11	0.20	-0.08	-0.01
Retail trade	0.21	0.17	0.04	0.00	0.14	0.17	-0.03	0.00	0.16	0.17	-0.01	0.00
Transportation and warehousing	0.05	0.07	-0.02	0.00	0.07	0.07	0.00	0.00	0.07	0.07	0.00	0.00
Information and cultural industries	0.10	0.09	0.01	0.00	0.09	0.09	0.00	0.00	0.09	0.09	0.00	0.00
FIRE	0.39	0.25	0.14	0.00	0.32	0.25	0.07	0.00	0.30	0.25	0.06	0.00
Professional, scientific and technical services	0.11	0.03	0.08	0.00	0.01	0.03	-0.02	0.00	0.16	0.03	0.14	0.00
ASWMRS	0.08	0.00	0.08	0.00	-0.05	0.00	-0.05	0.00	0.09	0.00	0.09	0.00
Arts, entertainment and recreation	0.01	-0.01	0.01	0.00	-0.02	-0.01	-0.01	0.00	0.01	-0.01	0.02	0.00
Accommodation and food services	0.00	0.01	-0.01	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.00	0.00
Other Private Services	0.08	0.06	0.03	0.00	0.04	0.06	-0.02	0.00	0.15	0.05	0.09	0.00
B) Per Cent Contributions												
Business sector industries	100.0	110.5	-3.2	-7.3	100.0	110.5	-3.2	-7.3	100.0	92.3	30.0	-22.3
Agriculture, forestry, fishing and hunting	-0.1	13.8	-12.7	-1.1	16.5	13.8	3.7	-1.0	-5.1	10.9	-14.8	-1.3
Mining and oil and gas extraction	-0.6	-19.7	22.7	-3.6	-6.2	-19.7	17.3	-3.7	29.4	-25.6	72.0	-17.1
Utilities	1.0	-3.1	5.1	-1.0	-0.1	-3.1	4.1	-1.0	-1.7	-2.7	2.6	-1.6
Construction	23.2	-0.9	24.2	-0.1	-7.8	-0.9	-6.5	-0.4	40.1	-1.5	42.1	-0.5
Manufacturing	-58.5	19.3	-77.5	-0.4	1.9	19.3	-17.5	0.0	-90.8	16.8	-106.7	-0.9
Wholesale trade	15.9	23.2	-6.8	-0.5	22.7	23.2	-0.1	-0.4	11.9	21.8	-9.3	-0.6
Retail trade	24.6	19.7	4.9	0.0	16.1	19.7	-3.6	0.0	17.3	18.4	-1.0	-0.2
Transportation and warehousing	5.9	8.0	-1.9	-0.2	8.1	8.0	0.3	-0.2	7.7	7.3	0.4	-0.1
Information and cultural industries	11.0	10.3	1.0	-0.3	10.5	10.3	0.5	-0.3	9.8	9.9	0.3	-0.3
FIRE	45.0	29.2	15.7	0.1	37.0	29.2	7.8	0.0	33.6	27.1	6.3	0.2
Professional, scientific and technical services	12.9	3.3	9.6	0.0	1.4	3.3	-1.9	-0.1	17.9	3.0	14.9	0.0
ASWMRS	9.0	0.1	8.9	-0.1	-6.3	0.1	-6.2	-0.2	10.4	0.1	10.4	-0.1
Arts, entertainment and recreation	0.8	-0.8	1.7	-0.1	-2.1	-0.8	-1.2	-0.1	1.4	-0.7	2.3	-0.2
Accommodation and food services	0.2	1.7	-1.5	0.0	3.9	1.7	2.3	0.0	2.1	1.6	0.5	0.0
Other Private Services	9.7	6.4	3.3	0.0	4.4	6.4	-2.0	0.1	16.0	6.0	9.9	0.2

1 TC - Total Contribution; WSE - Within-Sector Effect; RLE - Reallocation Level Effect; RGE - Reallocation Growth Effect.

2 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

3 Growth rates calculated as the arithmetic average of annual growth rates.

per cent) and the RGE accounting for a 0.06 percentage point (-6.6 per cent) reduction in growth.

The differences between the two formulas emerge when the role of each two-digit NAICS sector in explaining business sector labour productivity growth is analysed separately. In the TRAD formula, the FIRE sector was responsible for almost half of aggregate labour productivity growth – 0.39 percentage points or 45.3 per cent of overall growth. Retail trade (0.23 percentage points or 26.4 per cent of total growth), construction (0.19 percentage points or 22.3 per cent), and wholesale trade (0.17 percentage points or 19.3 per cent) were also fundamental in driving aggregate labour productivity growth in the period. The economy's labour productivity performance was hindered, however, by the massive negative contribution of the manufacturing sector (-0.56 percentage points or -64.7 per cent of total growth), which was caused by a very strong (and negative) RLE. Other than manufacturing, the only sector which had a negative (albeit very small) contribution to business sector labour productivity growth was mining and oil and gas extraction.

In the CSLS formula, FIRE is still the sector with the highest contribution to business sector labour productivity growth (0.32 percentage points or 37.2 per cent of total growth), although its contribution is smaller than it was in the TRAD formula. Other sectors that played an important role in driving aggregate labour productivity growth according to the CSLS formula were wholesale trade (0.22 percentage points or 26.1 per cent of total growth), retail trade (0.15 percentage points or 17.8 per cent), and agriculture, forestry, fishing and hunting (0.15 percentage points or 16.9 per cent). Note that, while construction had an important positive contribution in the TRAD formula, it had a *negative* contribution in the CSLS formula (-0.08 percentage points or -8.8 per cent of total growth). Furthermore, the contribution of manufacturing in the CSLS formula, while still negative, was not nearly as strong as it was in the TRAD formula (-0.04 percentage points or -4.1 per cent of total growth). It is interesting to note, also, that five out of the 15 two-digit NAICS sectors had a negative contribution to aggregate labour productivity growth according to the CSLS formula (versus two in the TRAD formula).

Recalling our discussion about each decomposition formula in the previous section, it is clear that these differences are caused solely by how the RLE and RGE are calculated in the TRAD and CSLS formulas. Take the case of the construction sector, for instance, which had a positive RLE in the TRAD formula and a negative one in the CSLS formula. Since there was an increase in the sector's labour share (from 8.3 per cent in 2000 to 11.0 per cent in 2010) during the period, the TRAD formula sees the sector's RLE as positive. The CSLS formula, on the other hand, attributes to the sector a negative RLE because of its below-average labour productivity level.

What explains, however, the huge differences in the manufacturing sector's RLE? In the TRAD formula, the sector's RLE contributed -0.67 percentage points to aggregate labour productivity growth, while in the CSLS formula it contributed only -0.15 percentage points. This difference is explained by the fact that the TRAD formula depends on the ratio between the labour productivity level in manufacturing and in the business sector, whereas in the CSLS formula it depends on the difference between the two. Overall, as shown by Table 6, the TRAD formula produces RLE estimates with much higher magnitudes than the CSLS formula.

The GEAD formula provides a very different perspective on sectoral contributions to business sector labour productivity growth. First, at the aggregate economy level, the magnitude of the WSE in the GEAD formula is noticeably smaller than that of the TRAD and CSLS formulas (0.82 percentage points versus 0.95 percentage points). This difference is driven by the fact that, in the GEAD formula, the within-sector effect is determined by nominal shares instead of real shares.

While the WSE still accounts for almost the entirety of business sector labour productivity growth in the period (94.9 per cent), the joint reallocation effects (RLE + RGE) now have a small positive contribution (5.1 per cent). More precisely, the RLE now has a positive sign, while the RGE retains its negative sign. What is more, the magnitude of both reallocation effects under the GEAD formula is significantly higher than in the other two formulas. In the GEAD formula, the RLE explained 0.23 percentage points of total labour productivity growth versus -0.03 percentage points in the TRAD and CSLS formulas. The same applies for the RGE, which explained -0.18 percentage points of aggregate productivity growth in the GEAD formula versus -0.06 percentage points in the TRAD and CSLS formulas.

According to the GEAD formula, the three sectors that contributed the most to business sector labour productivity growth were: construction (0.36 percentage points or 41.8 per cent of total growth), FIRE (0.30 percentage points or 34.7 per cent), and mining and oil and gas extraction (0.26 percentage points or 30.1 per cent).[12] In general, all sectors had positive contributions, with the exception of utilities; agriculture, forestry, fishing and hunting; and manufacturing. Of these three sectors, manufacturing was the only one where the magnitude of the contribution actually mattered, reducing aggregate labour productivity growth by -0.83 percentage points (or 96.3 per cent of total growth). Much like the TRAD formula, this was caused by a massive RLE – in fact, the RLE in the GEAD formula was even larger than that of the TRAD formula.

Three Decomposition Formulas, Three Stories

The comparison between the estimates produced by the TRAD, CSLS, and GEAD formulas highlights an important problem: despite some similarities, all three decomposition formulas paint very different pictures of which sectors drove labour productivity growth in the Canadian business sector during the 2000-2010 period. Why are estimated contributions so different? Which set of estimates provides a more accurate picture of economic reality?

The differences between the TRAD and CSLS formulas are caused solely by the way each formula assigns sectoral contributions due to reallocation effects. In the TRAD formula, for instance, a sector's RLE will be positive as long as its labour share increases, regardless of whether the sector had above-average or below-average labour productivity level. In the CSLS formula, however, a sector with below-average labour productivity level will have a negative RLE if its labour share increases.

In our opinion, the way the TRAD formula deals with reallocation effects is quite problematic. At the aggregate level, if labour moved to sectors with below-average labour productivity level (growth), the sign of the overall RLE (RGE) would be negative. Sectors with below-average labour productivity levels that experienced an increase in their labour share would, however, have a *positive* RLE (which would be offset by the negative RLE of the sectors with above-average labour productivity that experi-

12 It is interesting to note that, for the 2000-2008 period, the contribution of mining and oil and gas extraction to business sector labour productivity growth was much higher. According to our GEAD formula estimates, the sector accounted for 0.77 percentage points of the average annual labour productivity growth of 0.90 per cent experienced by the Canadian economy in the period, slightly over 80 per cent of total growth. This impressive contribution of the mining and oil and gas sector to aggregate labour productivity growth was caused by the spike in oil prices in 2008. Our estimates are consistent with those seen in Almon and Tang (2011) (see Appendix Table in De Avillez (2012)).

enced a reduction in their labour share). The CSLS formula prevents this from happening by making reallocation effects a function of the difference between a sector's labour productivity level (growth) and the aggregate labour productivity level (growth).

Despite this advantage, some of the results of the CSLS formula can also be considered counterintuitive. When labour moves from a sector with below-average labour productivity level towards a sector with above-average labour productivity level, for instance, *both* sectors will have a positive RLE. The positive RLE of the low productivity sector, which seems unwarranted, happens exactly because people are leaving the sector. Although this dynamic represents a limitation of the CSLS formula, we still believe that the CSLS formula produces better reallocation effect estimates than the TRAD formula. Because of how they are specified, the CSLS reallocation effects tend to be well distributed among sectors, which minimizes the impact of strange reallocation dynamics, while the TRAD's reallocation effects tend to be concentrated in specific sectors, magnifying the dynamic discussed in the previous paragraph. In the end, however, an argument can be made for the impossibility of assigning reallocation effects across sectors in a definitive way.

The TRAD and CSLS formulas – which represent the "traditional" formulas analysed in this article – differ from the GEAD formula because they do not incorporate *price effects* into sectoral contributions. Sectoral contributions to aggregate labour productivity growth are calculated based solely on sectoral labour productivity and labour shares. In this sense, the TRAD and CSLS formulas capture only *quantity effects*. Sectoral contributions in both formulas represent how the increase in the volume of goods and services produced per hour in a particular sector (along with labour movements) affects the increase in the *volume* of goods and services produced per hour at the aggregate level. These formulas can therefore be seen as measuring the impact of (sectoral) *real* variables on aggregate labour productivity growth.

In the case of the GEAD formula, estimated contributions have a different meaning. A sector's contribution to aggregate productivity growth, while obviously dependent on the sector's labour productivity growth (and labour movements), is also dependent on how the economy values that sector's output, which is determined by relative prices. By incorporating price effects into contributions, the GEAD formula captures the overall *economic significance* of different sectors to aggregate labour productivity growth.

The case of the Canadian mining and oil and gas extraction sector clearly illustrates the difference between the GEAD and the other two decomposition formulas analysed in this article. In the CSLS and TRAD formulas, mining and oil and gas extraction had a *small*, *negative* contribution to business sector labour productivity growth during the 2000-2010 period. According to the GEAD formula, however, the sector had a *large*, *positive* contribution.

Looking only at real variables, mining and oil and gas did indeed contribute very little to overall business sector labour productivity growth in Canada during the 2000-2010 period. Real GDP in the sector increased only 0.60 per cent per year (versus 1.65 per cent per year at the business sector level); the sector's labour share did increase, from 1.5 per cent in 2000 to 1.9 per cent in 2010, but remained quite small; and labour productivity in the sector experienced a sharp drop of 2.80 per cent per year (versus an increase of 0.86 per cent per year at the business sector level). These developments are captured by the TRAD and CSLS formulas and result in a small, negative contribution of mining and oil and gas to business sector labour productivity growth.

When relative prices are included in the equation, the story looks very different. Mining and oil and gas prices roughly doubled during the period, increasing 7.79 per cent per year, while business sector prices rose only 2.38 per cent per year. The GEAD formula captures this shift in relative prices, which was more than enough to offset the lacklustre productivity performance of the mining and oil and gas extraction sector, causing it to have a large, positive contribution to business sector labour productivity growth. Thus, the GEAD formula captures the fact that mining and oil and gas extraction played a fundamental role in driving economic growth in Canada during this past decade.

The above discussion underlines that sectoral contributions calculated by the TRAD and CSLS formulas are not strictly comparable with those calculated by the GEAD formula. In the first two formulas, sectoral contributions are a function only of real variables, whereas in the GEAD formula they are also a function of changes in relative prices. From this perspective, it is impossible to say which set of estimates provides a more accurate picture of economic reality because the GEAD formula is, ultimately, measuring something very different from the TRAD and CSLS formulas.

Conclusion

This article analysed sectoral contributions to business sector labour productivity growth in Canada during the 2000-2010 period using three different decomposition formulas – TRAD, CSLS, and GEAD. The first two formulas assume real output in constant prices, while the GEAD formula does not make any particular assumption regarding how real output estimates were constructed. All three formulas break down sectoral contributions into within-sector, reallocation level, and reallocation growth effects. The TRAD and CSLS formulas produce the exact same estimates of within-sector effects, but allocate sectoral contributions due to the reallocation effects in different ways. The GEAD formula differs from the first two formulas in that it takes into account how movements in relative prices impact the three effects.

During the 2000-2010 period, business sector labour productivity increased at an average annual rate of 0.86 per cent (or 0.95 per cent, depending on how real GDP is calculated). At the aggregate economy level, the TRAD and CSLS formulas tell the same story, with the within-sector effect accounting for over 100 per cent of labour productivity growth in the period and the negative reallocation effects actually hindering growth. In terms of sectoral contributions, there were also important similarities between the estimates produced by the two formulas. In both formulas, FIRE was the sector that had the highest positive contribution to business sector labour productivity growth. Other sectors that played an important role in both formulas were wholesale and retail trade.

There were also, however, important differences in how the TRAD and CSLS formulas allocated sectoral contributions to business sector labour productivity growth. In the TRAD formula, construction had a strong, positive contribution to aggregate productivity growth, whereas in the CSLS formula the sector actually dampened productivity growth. Conversely, the CSLS formula attributes a somewhat important role to agriculture, forestry, fishing and hunting, whereas in the TRAD formula the sector's contribution is zero. The biggest difference between the two formulas can be seen in the role of manufacturing. In the TRAD formula, the reduction of the manufacturing sector's labour share caused a massive, negative reallocation level effect, which was more than enough to offset the sector's positive within-sector effect. In the CSLS formula, the sector also experienced a negative reallocation effect, but its magnitude was much lower – less than one fourth of the magnitude of the TRAD's RLE – with the total contribution of the manufacturing sector to aggregate labour productivity growth being only slightly negative.

The story told by the GEAD formula, in turn, is quite different from that of the other two formulas. At the aggregate economy level, the within-sector effect is still the main driving force of business sector labour productivity growth, but the magnitude of the effect is lower than it was in the TRAD and CSLS formulas. Furthermore, the joint reallocation effects are actually positive. Construction, FIRE, and mining and oil and gas had the highest contributions to aggregate labour productivity growth, while manufacturing was the "villain" of the story, with a huge negative contribution to productivity growth.

The three decomposition formulas provide alternative narratives as to which sectors drove aggregate productivity growth in Canada over the past decade. Some parts of these three narratives point in the same direction. In particular, at the aggregate economy level, all three formulas show that most (if not all) of labour productivity growth was caused by within-sector productivity improvements, with sectoral reallocation either hindering productivity growth or improving it by a very small margin. When it comes to assessing the role of each individual sector in aggregate labour productivity growth the room for agreement is much smaller. It is true that there is some agreement regarding the importance of FIRE. Nevertheless, the differences appear to be much more significant. What is the actual role of construction, manufacturing, or mining and oil and gas extraction in explaining business sector labour productivity growth? Which formula produces more accurate estimates?

Although estimates produced by the CSLS and TRAD formulas can be compared – and, in our opinion, the CSLS formula assigns reallocation effects in a more logical way than the TRAD formula – they are not strictly comparable to estimates calculated using the GEAD formula. In the TRAD and CSLS formulas, sectoral contributions reflect only the impact of *real* variables on aggregate labour productivity growth, whereas in the GEAD formula they also incorporate the effect of changes in *relative prices* to capture the overall economic significance of different sectors in the economy. This explains why, in the GEAD formula, mining and oil and gas had such a strong contribution to business sector labour productivity growth, despite the sector's lacklustre productivity performance.

From this perspective, it is impossible to say which set of estimates provides a more accurate picture of economic reality because the GEAD formula is, ultimately, measuring something very different from the TRAD and CSLS formulas. Instead of seeing estimates constructed by the GEAD and traditional formulas as "competing" narratives, it is more useful to see them as providing complementing stories about the role of different sectors in driving aggregate labour productivity growth.

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The Political Economy of Economic and Productivity Growth: An Interview with Daron Acemoglu and James Robinson, Authors of *Why Nations Fail*

Christopher Ragan[1]
McGill University

ABSTRACT

In fast-growing developing countries, rapid productivity growth is largely driven by economic growth. Consequently, an understanding of the reasons for this strong productivity growth requires a broader perspective on the dynamics of the overall growth process. In early 2012 Daron Acemoglu, an economist at MIT and James A. Robinson, a political scientist and economist at Harvard University, published W*hy Nations Fail: The Origins of Power, Prosperity, and Poverty*. With great historical detail, the book makes the case that it is man-made economic and political institutions that underlie economic success by creating incentives for wealth creation, rewarding innovation and allowing widespread participation in economic opportunities. This article is an edited transcript of an interview with the two authors on the major issues addressed in their book.

RÉSUMÉ

Dans les pays en développement rapide, la forte croissance de la productivité est largement due à la croissance économique. Il faut donc pour comprendre les raisons de cette forte croissance de la productivité une perspective élargie sur la dynamique du processus global de la croissance. Au début de 2012, Daron Acemoglu, économiste à l'Institut de technologie du Massachussett (MIT), et James A. Robinson, politicologue et économiste à l'Université Harvard, ont publié *Why Nations Fail: The Origins of Power,* Prosperity, and Poverty. À l'aide d'une analyse historique fouillée, ce livre montre que ce sont les institutions économiques et politiques de l'être humain qui sous-tendent la réussite économique, parce qu'elles incitent à créer de la richesse, qu'elles récompensent l'innovation et qu'elles permettent à un grand nombre de tirer parti des possibilités économiques. Cet article est une transcription révisée d'une entrevue avec les deux auteurs sur les enjeux principaux abordé dans leur livre.

IN FAST-GROWING DEVELOPING countries like India and China, rapid productivity growth is largely driven by economic growth, resulting in rapid increases in the average living standards of the population. Consequently, an understanding of the reasons for this strong productivity growth requires a broader perspective on the dynamics of the overall

1 The interviewer teaches in the Department of Economics at McGill University. He would like to thank Pierre Fortin for suggesting the idea of this interview and setting it up. Email: Christopher.ragan@mcgill.ca.

growth process. In March 2012 two academics, Daron Acemoglu, an economist at MIT and James A. Robinson, a political scientist and economist at Harvard University, published *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (New York: Crown Business).[2] With great historical detail, the book makes the case that it is man-made economic and political institutions that underlie economic success by creating incentives for wealth creation, rewarding innovation and allowing widespread participation in economic opportunities.

On June 29, 2012 in Montreal, Christopher Ragan from McGill University had the opportunity to meet with both Acemoglu and Robinson to discuss their thesis that it is institutions that largely determine economic growth. This article is an edited transcript of the interview.

Inspiration

Chris Ragan (CR): Your book *Why Nations Fail* is essentially attempting to answer Adam Smith's question regarding the wealth of nations. Why do some countries succeed and other countries fail? What inspired you intellectually to write this book?

Daron Acemoglu (DA): It's probably quite similar for both of us because we were both interested in economic development. We both came into economics trying to understand the wealth of nations. After thinking about this problem a little bit, working on it from different angles, we independently and then together came to the conclusion that institutions and the politics of institutions played a central role. We could not go very far without understanding why countries were adopting different policies and different institutions and that these institutions and policies were endogenous. They were not God-given things falling from heaven. Our interest in history came out of that whole perspective.

James A. Robinson (JR): Yes, I think we both had this idea that the discussion in economics was completely lacking this historical angle and that it was terribly unsatisfactory. I remember, earlier this year, we were both at a conference and somebody was going on about Haiti and wondering why it was such a mess. How could you possibly think about such a question without recognizing the history of the country? You can't look only at the last 20 years of data and talk about that problem.

CR: You have to swim pretty hard against the current in the economics profession to be so inspired by the historical and political connections – and by the political economy. We all have our primary intellectual influences. Who were yours?

DA: I think the work of Douglass North and Joel Mokyr have been the biggest influences.

JR: And also work by Robert Bates on comparative political economies in Africa, in particular his book *(Markets and States in Tropical Africa)*. I read that book when I was a graduate student at Yale. It just brought all of these things together in a very articulate way.

The Big Picture

CR: Let me turn now to some definitions and the big picture. For those people who don't yet know anything about your book, how do you describe the central message?

DA: The central message is that institutions shape the incentives that ultimately determine prosperity. But more importantly those institutions have to be understood within the political context because they are shaped by who has political power and how

2 The authors of the book maintain a blog related to the book at http://whynationsfail.com/

political power is exercised in a nation. And that is essential for our understanding of institutions because they really determine the distribution of resources in a society as much as the growth potential.

CR: You make a key distinction between inclusive institutions and extractive ones. What do those terms mean? Can you give me an example of each to illustrate?

JR: That's the dichotomy we find useful. But in reality I suppose there are shades of gray. An example of an extractive institution is some form of labour coercion, like slavery. In the first chapter of the book we try to motivate the concepts through these examples rather than just going into definitions. We compare North America and South America to illustrate extractive and inclusive economic and political institutions. Colonial Latin America would be characterized as having various extractive systems such as labour coercion, forced purchases of goods, and mercantilistic restrictions on trade. These institutions are extracting value out of others and concentrating their value in the hands of a small, elite class.

The inclusive economic institutions are those that allow people to use their talent and skills in any way they want. Consider the evidence on patenting from the 19th century, and the backgrounds of the famous innovative inventors in the United States. If you look at their social backgrounds, you see people coming from all over the social spectrum. There is a huge talent in society but you have to have a set of institutions that can allow society to harness that talent.

CR: You argue that growth is still possible amidst extractive institutions but that it is not sustainable. Why is it possible but not sustainable?

DA: I think you can look at it two ways. One is that extractive institutions are bad for the citizens. On the other hand, of course, you could say that they shouldn't be bad for growth because, after all, if I am doing the extraction I have an incentive to make this country as rich as possible. But our argument is that this generally does not work because it does not encourage creative destruction. If I am really doing the extraction, I am standing at the top of the institution and I am going to be afraid of new technologies that are going to displace me economically. Even more importantly, I am going to be afraid of technologies or institutional changes or organizational changes that will reduce my political power. So those are the main reasons why extractive economic institutions with the support of extractive political institutions are not conducive to sustained economic growth.

Some growth is what we call catch-up growth. Essentially you don't need innovation, or creative destruction. You take the existing technologies, either in your country or on the world technology frontier, and you apply them. The main example in the book is the Soviet Union, which was clearly another example of an extractive political institution under the control of the Communist party, with a lot of coercion and threats and executions. And in the economy there was no private property, but still the Soviet Union achieved very rapid growth rates for over 40 years. But of course the Soviet Union also illustrates why that sort of growth is not sustainable: we can threaten people to move from agriculture to industry but you can't threaten them to become creative.

CR: What do you mean by "political centralization", and why is this important?

JR: We emphasize that this distinction between extractive and inclusive economic institutions is crucial for generating prosperity. But what lies behind this is the set of political institutions. In the chapter on the Americas we say that what is really crucial is how extractive political institutions appear in South America while you have these inclusive political institutions in North America. So what are inclusive political institutions? Well, we emphasize two things. One is this broad distribution of political rights and political powers in society. The second is that it must be in conjunction with an effective centralized state to channel the distributed political power in socially desirable directions.

DA: One of the most important aspects is that when you don't have political centralization, you essentially have no unified markets and no property rights beyond perhaps a very narrow sphere. And given the importance that we place on the incentives induced by property rights and the allocation of talent, that becomes a major impediment to growth. Effective enforcement of property rights needs to be based on centralized political power because otherwise it would not function.

CR: Your theory seems to pit the power elites against the people. Is there an overlap here with Marx?

DA: Yes, there is overlap with Marx but I think it is also very different. Both of us found Marx to be very restrictive in emphasizing, to us, the less interesting and less important part which is the effect of the means of production and economic structure on everything else. To us, what is much more important is who has political power, who forms a coalition with whom than what technology does and what the ownership structure is. They all emanate from who has political power and how that political power is manipulated. So that's why, in some societies, class is totally irrelevant but who the politicians are is extremely relevant. But in other societies, class may become relevant because it is what coalitions form around. Part of the traditional elite may become politically very powerful and then ally with all of the key political players.

Multiple Determinants

CR: There is an ongoing debate about what really matters for development. Some people say it is geography, some people say it's culture, some people say it's access to resources. You say it's institutions. I think of this in terms of a well-specified regression equation. Does your argument in favour of institutions mean that you think the estimated regression coefficients on the other things are zero?

JR: Yes!

CR: Really?

DA: The partial R^2 is small – small for the other determinants and larger for institutions. And it's not just what we say in the book. We have written a lot of empirical papers, some with Simon Johnson, with regression equations of that form and tried to estimate them and that's the basic outcome.

But there is one thing that people get confused about and perhaps we can clarify it here. Many people wonder how we can say that geography does not matter because we have all these examples where geography influences institutions. The point is, first, that if the only effect of geography is working through institutions, then it really is the institutions that matter. And, second, whenever you look at the details, it becomes very clear that the impact of geography on institutions is very contingent. If history had been different, the effect would have been different. Sometimes diamonds are bad for institutions, sometimes they are good for institutions. That is the contingent aspect that we are talking about.

CR: Does your thinking connect to the whole idea of the "resource curse"?

JR: We don't think there is a resource curse. Whether or not resources are a curse is totally contingent on institutions.

CR: Who are your biggest intellectual opponents? Who are the people, academics or otherwise, who pick up your book and say that you're wrong?

DA: Everybody!

CR: So who are they? What's their argument?

JR: The dominant school in development economics today – they say this is fun but you can't say anything at this level. It's too grand.

DA: Too ambitious, too sweeping.

JR: The fact of the matter is that there are often big regularities at this level of analysis. If you are a social scientist and you see big regularities, you are supposed to try to explain them. Of course, the methodology is complicated and establishing causality is very difficult. But we have to try to tackle these things.

Transition and Evolution

CR: You talk a lot about feedback loops. Vicious cycles with extractive institutions and virtuous cycles with inclusive institutions. What are the dynamic forces creating these feedback loops?

JR: We make much out of this dichotomy between inclusive and extractive institutions, both economic and political. Once your society is set up like that, there is considerable feedback. So, for example, in an extractive society where political power is narrowly concentrated and economic institutions are designed to channel wealth and political power to some group of people, then that system has a tendency to persist over time. You have a narrowly defined political elite and they construct a society to concentrate resources. That tends to perpetuate their power over time. So they are able to carry on with this extractive type of society. Similarly, inclusive institutions create a very different sort of feedback than when political power is broadly distributed, wealth is broadly distributed and that makes it more difficult for some narrow elite to mount a coup or otherwise establish an extractive kind of society.

CR: So suppose we begin in one of these vicious cycles. In order to make a transition to a more successful economy, you are going to need a shock to the system. Your theory uses the notion of a "critical juncture". What's your favourite example?

DA: Critical junctures are big shocks that disrupt the balance. In the book, we give a lot of different examples of critical junctures. The Black Death killed half of the population in many parts of Europe. It was a huge negative shock. Or it could be a positive shock like the opening of Atlantic trade. These events force a change or create an instability.

JR: As a result of that instability, sometimes change occurs and sometimes it doesn't. The Black Death did not lead to the collapse of feudalism everywhere, but it created an imbalance that people reacted to one way or another.

CR: Does your theory inevitably lead to the conclusion that without a critical juncture the only way out of a vicious cycle is a revolution?

DA: I think the distinction between revolutions and non-revolutionary changes is more about the incentives of the elite. The way we think about it is that changes happen almost always with some sort of conflict, with some sort of demands from those who don't have political power – they demand to share political power or to increase their political power. But there are two broad responses of the elite. One is to give in, as happened in the United States and Britain. That leads to a process of gradual change and that can happen very slowly, without a critical juncture. The second response is the kind we saw in the Russian revolution or are seeing today in Libya or Syria. What we see is that the elites say "no, we are going to fight it out". And in that case, either the elite wins or sometimes it will lead to a much more violent radical revolution which unfortunately also has in it the roots of its own demise.

CR: You talk in your book about Botswana's success story after its independence in 1966. But it sounds like it relied on the dumb luck of having a wonderful leader at that time. Does it come down to the luck of the draw?

JR: I think it's true that Botswana had great leadership after its independence – Seretse Khama and others. But it also had great leadership during the colonial period and even before the colonial period. Seretse Khama's grandfather, King Khama the Great, implemented all sorts of reforms in the 19th century. He adopted Christianity, he tried to modernize institutions, he gave up all of his supernatural stuff, he secularized the state. It's incredibly interesting what went on in the 19th century.

Official Foreign Aid

CR: Let me bring this to policy regarding foreign aid. What do your arguments imply for official foreign aid to developing countries? Is it useless unless the recipient countries have largely inclusive institutions in place?

DA: It depends on what you mean by useless. If you are one of those few remaining people who believe that foreign aid is going to transform the world, then yes, our story is bad news. But I think the point of foreign aid is not to transform the world but instead to help the suffering of very unfortunate people.

JR: Much foreign aid might get wasted, but lots can be spent on fixing roads, or putting a roof on a school, or building wells.

DA: But it's important to do no harm. If you give your foreign aid to the Egyptian military, for example, you are doing harm.

CR: Would it make sense for CIDA or other official development agencies to try to help the developing countries build the institutions they need? Is this possible?

DA: If you are going to use your aid in order to build some sort of more vibrant civil society organization, that might work. But the moment this starts working in Egypt, people will go to jail. So I don't know…

JR: I think exactly how you do that in any specific country is very context specific. There's no simple formula for building more inclusive institutions in a country.

CR: Do most official aid organizations think that it is formulaic or do they recognize that it's context specific?

DA: I think they give lip service to the idea that it's not formulaic but when it comes to implementation they apply their formulas.

CR: I like to think of a continuum in the modern thinking on development and foreign aid. At one end is Jeff Sachs who says that big aid is good and effective, and at the other end is Dambisa Moyo who appears to be against all of it. Somewhere in between are Bill Easterly and Paul Collier. Where are you guys on this continuum?

DA: I think we are close to Paul Collier. Aid does help in alleviating some poverty but it is not a silver bullet for economic development. Far from it.

JR: But we also don't agree with this view that foreign aid is the source of all problems for poor countries. Dambisa Moyo in *Dead Aid* argues that aid causes all of Africa's problems, but that's just ludicrous.

Life in the Developed Countries

CR: How about life in the developed countries? Does your theory say much about what Canada or France or Australia can do to improve their lives today? Don't these countries already have most of the inclusive institutions that you think are valuable and necessary, or can we actually do better?

DA: There is considerable heterogeneity among the inclusive institutions that have developed over the last 200 years. Look at Sweden versus the United States. These different institutions do create different incentives and have different implications. We don't discuss this in the book because that's an entirely different topic. Part of the reason why we don't get into it is because these differences are reasonably small. In England versus Sweden, they have more or less the same income per capita, although very different inequality and poverty measures. This is definitely not to mean that the institutions in these countries are unimportant. They should be studied and I am sure that there are aspects of some national institutions that are very dysfunctional. This is true in the United States, and probably in Canada too. This is definitely true of the United Kingdom.

JR: Explaining the differences between rich countries requires a more specific theory than we have in the book. Ours is aimed at explaining the big differences between rich and poor countries.

CR: We all know that income inequality has been rising over the past three decades, in the United States, Canada, and most of Western Europe. Is that increasing concentration of economic power going to threaten these inclusive institutions?

DA: Yes and we have written other pieces saying so. But it is not so much the economic inequality *per se*, it is the implication of the economic inequality for the growing political inequality. The real problem is that the very rich become politically more and more influential.

Predictions

CR: When you talk about China's development successes since 1970, you talk about the distinction between economic and political institutions. How do you describe its remarkable performance over the past four decades?

JR: I think it fits very well with our whole thesis. It is absolutely clear that the acceleration in Chinese growth coincides with reforms that move economic institutions in a more inclusive direction. It started with agriculture in 1978, and then incentives in the rural sector, and then it started moving into industry. What doesn't fit in the theory is that this move toward inclusive economic institutions takes place while the political system is still very extractive. China was an incredibly poor economy in 1978 with hideously misallocated resources. Like the Soviet Union was when Stalin took over. Stalin had a much more centralized, top-down way of doing this whereas the Chinese have been able to get the state out of it and they allowed the market to work better. But the idea that China's success is because of the Communist party is insane – it is in spite of it.

DA: Yes, many of the major Chinese reforms in the rural sector were not really so much designed by the Communist party but permitted by the Communist party.

CR: So China has gone only half-way. Is this why you are pessimistic about the future – because they need to take the second step to go all the way?

DA: According to our theory, China will not catch up to the West. Its catch-up growth will come to an end unless they take that next step. China's next phase will have to be much more based on innovation-based creative-destruction growth and that's going to be difficult unless they have the politically inclusive institutions.

CR: How about Russia? What's your view of Russia 20 years after the fall of communism?

DA: Oligarchy. The KGB controls the state.

CR: And your thoughts for Russia's future?

DA: The KGB controls the state!

The Economics Profession

CR: Do economists need to pay more attention to politics and history?

DA: Yes, absolutely.

CR: Should we be going back to departments of political economy?

DA: No, but politics and history have to be part of the economics departments.

CR: So how are you going to make the profession pay more attention to history and politics?

DA: By making history more interesting. I think the profession does pay more attention to history right now than it used to. Look at the number of papers published in the *American Economic Review* or the *Quarterly Journal of Economics* or the *Journal of Political Economy* that actually use historical evidence.

JR: When people do get excited about this, the research is published in good journals. It just needs to be better institutionalized. Another problem is that there is this whole field of economic history that resists modernizing.

CR: How about graduate training? Do you have some complaints about our typical graduate programs in economics?

DA: At MIT there is a political economy field and general exam, and it's very popular. The bigger problem I have is that there is still the view that you should not do political economy because you won't be able to find a job.