Editor's Overview

THIS 30TH ISSUE OF THE *International Productivity Monitor* contains eight articles on a range of productivity issues: the challenges of measuring productivity in the digital economy; productivity trends and policies in Mexico; a comparison of Australian and Canadian productivity growth; productivity growth in U.S. agriculture; productivity in Canadian freight railways; global productivity growth; productivity convergence; and productivity strategies.

The emergence of disruptive technologies associated with digitalization raises the question of whether the conceptual basis and compilation methods of GDP are adequate to capture the output of the new forms and modes of production. In the lead article, **Nadim Ahmad** and **Paul Schreyer** from the OECD address these statistical challenges in a comprehensive manner. They discuss peer-to-peer services such as Uber and AirBnB, the blurring boundary between consumption and production, distinctions between consumer durables and investment, free and subsidized consumer products, cross-border flows of intellectual property and knowledge-based assets, measurement of e-commerce, and the measurement of prices and volumes for goods and services affected by digitization. They conclude that on balance the GDP accounting framework is up to the task posed by digitalization, but that practical measurement remains a challenge in such areas as the cross-border flows of intellectual property within firms and e-commerce transactions.

Mexico's productivity performance has been very poor in recent decades, with total economy multifactor productivity in 2014 8 per cent below its 1990 level. Given that productivity levels in Mexico are well below those in advanced countries, the potential for productivity convergence has not been realized. In the second article, **José Ernesto López Córdova** and **Juan Rebolledo Márquez Padilla** from the Ministry of Finance and Public Credit of Mexico provide a diagnosis of this performance and present the institutional framework the Government of Mexico has put in place to promote productivity. The authors stress the misallocation of both labour and capital as the main reasons for this situation, pointing to the large proportion of workers in low-productivity informal activities and the financially-underserved private sector.The pace of the reallocation of resources in the Mexican economy to high-productivity activities has been inadequate. The Government of Mexico recognizes this problem and has consequently placed productivity at the heart of its policy agenda. In addition to enacting productivity enhancing reforms, it has established an institutional framework to promote productivity, including the establishment of a National Productivity Commission with the power to make binding recommendations to government.

Canada and Australia have much in common, but one major difference in recent years has been their productivity performance. Between 1994 and 2013, business sector labour productivity in Australia grew 2.3 per cent per year, compared to 1.3 per cent in Canada. In the third article, **Evan Capeluck** from the Centre for the Study of Living Standards provides a detailed comparison of labour productivity performance in the two countries, with particular attention to the role of public policy in Australia's superior performance. He identifies five factors as contributing to Australia's faster productivity

growth: more rapid growth in capital intensity, a better macroeconomic environment, a stronger record on innovation, a somewhat greater market orientation in product market regulation, and a larger positive effect from inter-industry employment shifts. In terms of lessons from the Australian productivity experience, Capeluck highlights the need for Canada to pay greater attention to emerging markets as a source of export growth, to examine, and adopt where appropriate, the policies that Australia has implemented to boost BERD intensity to a level well above that of Canada, and to consider establishing an institution similar to the Australian Productivity Commission to address the nation's productivity woes.

Productivity growth varies greatly across sectors, with agriculture traditionally having enjoyed particularly impressive growth rates. In the fourth article, **Eldon Ball**, **Richard Nehring**, and **Sun Ling Wang** from the U.S. Department of Agriculture confirm this finding for the United States through a comprehensive analysis of the sources of growth in agriculture in that country. They estimate that total factor productivity grew in the sector at a 1.47 per cent average annual rate from 1948 to 2013, accounting for 97 per cent of output growth of 1.52 per cent. Declining employment in the sector meant that labour contributed -0.49 percentage points to output growth. Greater use of materials added 0.60 points to output growth while falling capital inputs contributed -0.06 points to output growth. The authors find that quality improvements had only minor effects on the growth rates of inputs over the period.

Economists increasingly recognize the insights that firm-level data can bring to productivity analysis. In the fifth article, **James Uguccioni** from the Centre for the Study of Living Standards uses company data to compare the productivity performance of Canada's two major railways, Canadian National (CN) and Canadian Pacific (CP). From 1986 to 2009, the last year firm-level data are available from Statistics Canada, output per worker advanced at a very robust 6.5 per cent average annual rate at CN and 4.8 per cent at CP. The higher growth at CN meant that its labour productivity level rose from 78 per cent of that of CP in 1986 to 113 per cent in 2009, with all the improvement taking place before 1999. The same story occurred for TFP, with CN enjoying a 4.4 per cent average annual increase versus 3.1 per cent at CP, boosting CN's relative MFP level from 83 pent cent of that of CP in 1986 to 111 per cent in 2009, again with all the improvement before 1999. Uguccioni attributes CN's stronger productivity performance relative to CP in the late 1980s and 1990s to the elimination of operating inefficiencies.

Economic growth is determined by growth in labour input and labour productivity. It is well known that falling birth rates are reducing, with a 15 year lag, the growth rate of the working age population and employment throughout the world. If past economic growth rates are to be maintained, then productivity growth must pick up. That is the premise of the report *Global Growth: Can Productivity Save the Day in an Aging World?* by the McKinsey Global Institute (MGI). In the sixth article in this issue **Andrew Sharpe** from the Centre for the Study of Living Standards provides a synthesis and critical assessment of this important report. He concurs that there is indeed potential for an acceleration of labour productivity growth in countries well below the technological or productivity frontier, as the MGI report effectively documents. But he argues that the likelihood of significantly faster productivity growth in advanced economies, as projected in the report, is low.

Continuing with the productivity catch-up theme, in the seventh article **Jonathan Haskel** of Imperial College London provides an assessment of the book *Productivity Convergence: The-*

ory and Evidence by Edward Wolff. Based on Maddison's data set, Haskel points out that in the year 1000 today's rich countries had on average a lower level of GDP per capita than the rest of the world (ratio of 0.93 between rich countries and rest of the world). By 1500 the rich countries had pulled ahead (1.30), with an even greater advance by 1820 (1.91). The Industrial Revolution then produced a massive increase in productivity and income divergence between the rich countries and the rest of the world, with the former achieving 6.92 times the per capita income of the latter by 1990. Rapid growth in populous China and India has led to some productivity and income convergence from 1990 to 2008 (5.19). Haskel notes that Wolff has identified strong and weak forces that contribute to convergence. Strong forces include technological catch-up, capital formation, education, R&D, and social institutions. Weak forces include trade, foreign direct investment, inequality, and natural resources.

Boosting economic growth, and especially productivity growth, has become a primary objective of public policy in Canada. Innovative policies need to be identified. In the final article, **Don Drummond** of Queen's University and the Centre for the Study of Living Standards evaluates the recently released book *Think Like an Enterprise: Why Nations Need Comprehensive Productivity Strategies* by Robert Atkinson, President of the Washington-based Information Technology and Innovation Foundation. Atkinson proposes a more active role for government. He recommends such measures as lowering the cost of capital, moral suasion to encourage firms to think more strategically, and greater government involvement to develop and disseminate new technologies and to facilitate interactions across firms and sectors. Drummond expresses some sympathy for this approach, but cautions that stringent tests for net social benefit are needed for new policy interventions.

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Are GDP and Productivity Measures Up to the Challenges of the Digital Economy?

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ABSTRACT

Recent years have seen a rapid emergence of disruptive technologies with new forms of intermediation, service provision and consumption, with digitalization being a common characteristic. These include new platforms that facilitate peer-to-peer transactions, such as AirBnB and Uber, new activities such as crowd sourcing, a growing category of the 'occasional self-employed' and prevalence of 'free' media services, funded by advertising and 'Big data'. Against a backdrop of slowing rates of measured productivity growth, this has raised questions about the conceptual basis of GDP, and whether current compilation methods are adequate. This article frames the discussion under an umbrella of the Digitalized Economy, covering also statistical challenges where digitalization is a complicating feature such as the measurement of international transactions and knowledge-based assets. It delineates between conceptual and compilation issues and highlights areas where further investigations are merited. The overall conclusion is that, on balance, the accounting framework for GDP looks to be up to the challenges posed by digitalization. Many practical measurement issues remain, however, in particular concerning price changes and where digitalization meets internationalization.

"The digital economy now permeates countless aspects of the world economy, impacting sectors as varied as banking, retail, energy, transportation, education, publishing, media or health. Information and Communication Technologies (ICTs) are transforming the ways social interactions and personal relationships are conducted, with fixed, mobile and broadcast networks converging, and devices and objects increasingly connected to form the Internet of Things." (OECD, 2015a:11)

THE DIGITAL ECONOMY[2] is everywhere and is continuously redefining and transforming the way we work and indeed live. But there are increasing concerns that, as ubiquitous as it is, it is in large part absent from our statistics. The advent of new digital innovations was expected to spark a new wave of productivity growth, similar to those seen in the past, e.g. as a result of electrification, and the ICT wave in the 1990s, but this has not yet materialised, raising a number of questions. Some of these relate to better understanding the role that these new technologies play in fostering productivity and economic growth, such as

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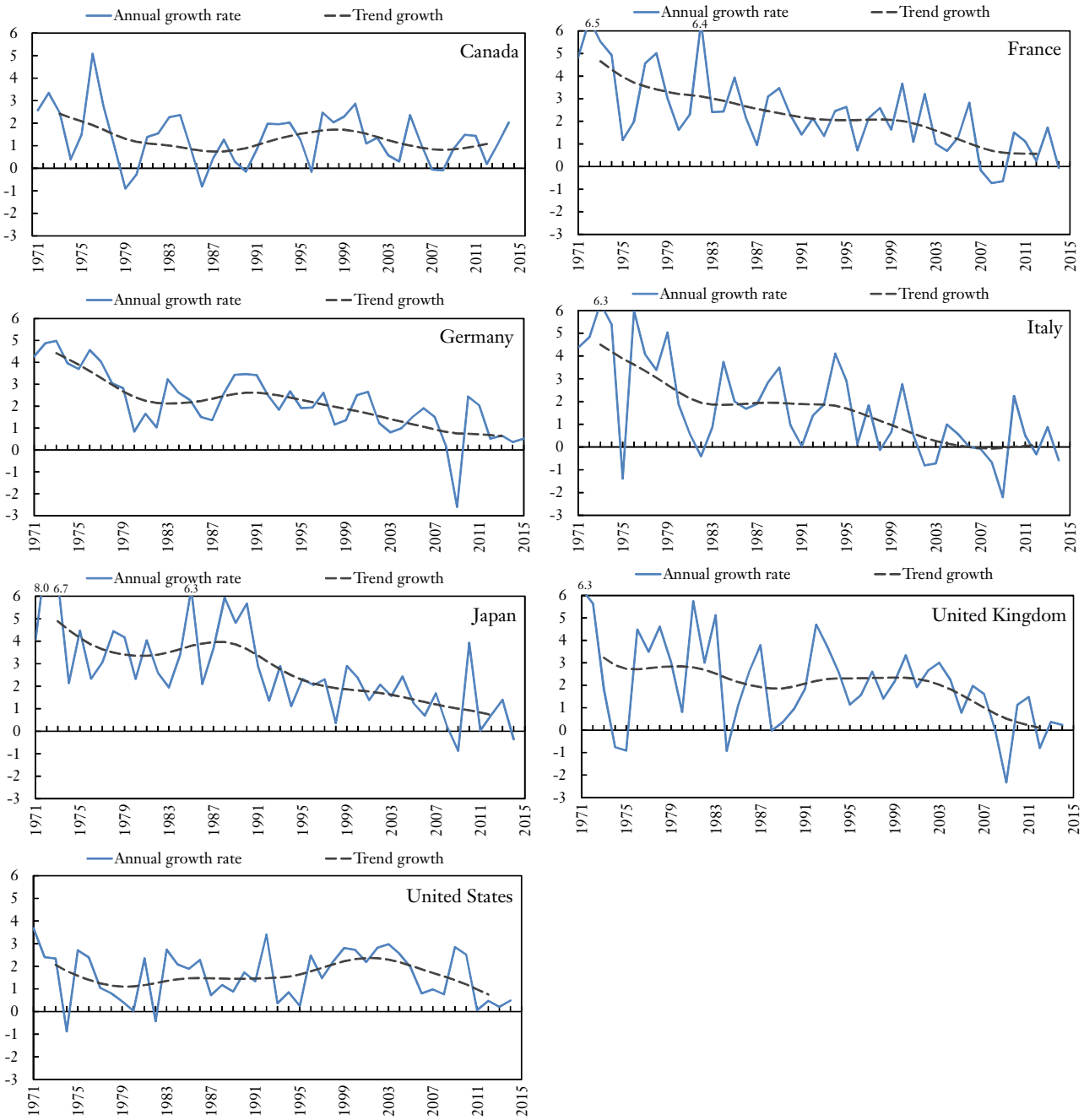
2 For the purpose at hand we use the terms 'digital economy' and 'digitalized economy' interchangeably.

Chart 1: Trend Labour Productivity Growth in G7 Countries

Total Economy, Percentage Change at Annual Rate



Note: Labour productivity is annual GDP per hour worker; trend estimates are derived using an HP-filter. See OECD (2016) Annex G for details.
Source: OECD (2016) *Compendium of Productivity Indicators*.

whether potential benefits are lagged, and the mechanisms and policy levers that can be pulled on to ensure that maximum benefits can be extracted. But many, and increasingly so, relate to measurement.

These concerns are of course understandable. The scale and pace of digitalization impacts not only the way in which businesses operate but also the way in which consumers engage with businesses and with each other. For businesses,

digitalization provides scope for improvements in production processes and access to new markets, but digitalization itself has also spawned many new businesses, and ways of doing business, whilst also providing significant scope for profit shifting across international borders. And digitalization has also impacted the role of the consumer, with households increasingly engaging in intermediation services that blur the divide between pure consumption and participative production.

This paper attempts to address the multitude of measurement issues raised by digitalization. Before beginning, however, it is useful to briefly frame the discussion in the context of the productivity slowdown that has to some extent precipitated the heightened spotlight on measurement.

The productivity slowdown observed in recent years has occurred at a time of rapid technological change, increasing participation of firms and countries in global value chains, and rising education levels in the labour force, all of which are generally associated with higher productivity growth. These seemingly contradictory facts have revived the debate on whether the productivity slowdown is a transitional phenomenon, longer-term condition, or indeed a function of mismeasurement. Whilst this puzzle remains true, it is important to note that the slowdown is not a recent phenomenon and indeed predates both the crisis and the current technological wave characterized by the digitalized economy (Chart 1). Of course this does not necessarily mean that mismeasurement is not an issue, rather it indicates that at best it cannot be singled out as the sole culprit (Byrne, Fernald and Reinsdorf, 2016). The remainder of this paper investigates the scope for mismeasurement looking individually at a range of transactions that characterize the digitalized economy.

New Forms of Intermediation of Peer-to-Peer Services

Although there is as yet no single definition of the digitalized economy there is at least a broad consensus that one of its manifestations is peer-to-peer (consumer-to-consumer) transactions facilitated by web-based intermediaries in the corporate sector. Perhaps the best known examples are Uber and AirBnB but others such as e-Bay have provided similar intermediation services for considerably longer.

Despite its novelty, giving rise to a new lexicon ('sharing economy', 'Uberisation', etc.), it is important to recognize that the underlying transactions that are the bread and butter of the sharing economy are in and of themselves not new. Households have long engaged in peer-to-peer transactions such as the provision of dwelling rental services, the provision of taxi services (often unlicensed), and the sale of second hand (and indeed new) goods (e.g. via garage sales and classified adverts). And GDP, at least conceptually, captures all of the related transactions and value-added created.

What is different about today's digitalized economy is the scale of these transactions. For instance, AirBnB now has a market capitalization close to that of Hilton Worldwide, and larger than that of other global hotel companies such as Marriott (Davidson, 2015). Such developments are driven by (1) the opportunities provided by web-based intermediaries to reduce entry barriers for households as service providers, increase market size, and minimize risks (both for the providers and the producers of the related services), and (2) the explosion in computing power and access to broadband that has facilitated consumer access.

> *"Between 2012 and 2013, smartphone adoption in OECD countries grew by 30 per cent, reaching a high of 73 per cent in Korea and an average of almost 50 per cent in 2013. Individuals use their smartphones*

for an increasing variety of activities with increasing intensity, including activities traditionally carried out on a computer, such as browsing the Internet, emailing or accessing a social network. More sophisticated activities, including online banking, mobile purchases and job search, are also experiencing fast growth. Many of these activities are carried out on dedicated mobile apps. Popular travel, mobility and retail apps have all made a recent appearance, pointing to the growing effect of digital services delivered via mobile apps on traditional sectors" (OECD 2015a:54).

The question therefore is not whether the conceptual accounting framework for GDP includes these transactions, but whether the compilation practices currently employed to measure peer-to-peer transactions, and which were designed to measure low-scale, relatively insignificant sums, are sufficiently robust to accurately measure them today.

Many of the characteristics of the 'sharing' economy, as described above, are common to informal economy transactions, i.e. transactions between unincorporated enterprises. But one aspect that differs concerns the role of the intermediary. The first question, therefore, is whether the current tools available to statistical offices can accurately capture the intermediation fees charged by the new digital intermediaries. To the extent that the intermediaries (at least those with not insignificant revenues) are registered in the national territory, and therefore in scope for traditional business surveys, the answer must be that their activity is likely to be captured in the accounts along with other registered entities. Where the entities are not registered in the national territory, so that the transactions between households and the intermediary are cross border, other complications (not unique to the sharing economy) may arise (as discussed below).

The more pertinent question therefore concerns the role of households as producers and in particular whether the current compilation methods adequately capture the underlying value-added produced, where this may be the case. Four generalized modes of peer-to-peer transactions, differentiated by the underlying activity of the sharing economy, are considered below. A fifth mode relating to business-to-business and business-to-consumer transactions is also considered.

Dwelling Services

The extent to which statistical information systems are able to accurately measure the scale of market transactions in dwelling services between households is difficult to say. Certainly in most countries the provision of such services is often accompanied by a requirement to register the related income for tax purposes. For long-term lettings, especially those facilitated by letting agencies, there is not likely to be a significant degree of under-recording, however this may not be the case for short-term occasional lettings. Prior to the advent of specialized (digital) intermediaries these infrequent lettings are likely to have been relatively small in scale and may not have been recorded exhaustively; indeed in some countries legislation permits tax-free letting services beneath a certain threshold. The advent of AirBnB has almost certainly increased the scale of these activities but there are two important factors to consider in assessing their impact on GDP.

The first and perhaps most important concerns the imputation already included in the national accounts for dwelling services (owner-occupied rent). These estimates assume that owner occupiers occupy their homes full-time, so, in theory, any unrecorded activity from short-term market lettings, such as those that typify AirBnB-type transactions, will at least in part be covered by the imputation for owner-

occupied rent. Some value of output will go amiss, however, as short-term rentals are likely to fetch a higher value than the longer-term rental values[3] that underlie the estimates for owner-occupied housing. These differences will reflect additional mark-ups including charges in return for the use of fixtures and fittings (e.g. furniture, Wi-Fi access) and associated labour input. More evidence is needed to gauge the importance of these mark-ups.

The second relates to the administrative nature of the intermediaries themselves and the scope they provide to improve measurement. As noted above, prior to the widespread use of registered intermediaries, the scale of infrequent short-term lettings is not likely to have been significant, but at the same time not likely to have been recorded, especially where the transactions did not involve an intermediary. But registration via intermediaries in and of itself is likely to increase the propensity for individuals to declare income to the tax authorities, especially in countries where VAT or a consumption tax is applied. AirBnB invoices, for example, include the name and address of the household engaged in letting services. Moreover the intermediaries themselves are also likely to have to declare their turnover, either directly for corporation tax, VAT and consumption tax[4] purposes or indirectly for occupancy or tourist tax purposes.[5]

It will be important for countries, and in particular those with data-sharing arrangements with the tax authorities, to make use of this source of information to develop estimates of any additional value of dwelling services that may arise in conjunction with new forms of transactions. At the same time, national accountants should be careful to avoid any double-counting of activity already included in imputed rent.

Business and Transportation Services

One important feature of the sharing economy is the role of intermediaries in bringing together unincorporated service providers (typically the self-employed) and households (consumers). The best known example is Uberpop but there are many other (and increasingly so) operators in this market, such as TaskRabbit that are helping to provide scalability and market access for the self-employed across a range of activities.

Again, the underlying activities in and of themselves are not new, and have been traditionally captured using the numerous approaches related to the informal and non-observed economy. Typically, for unincorporated units (e.g. those below administrative thresholds), this has meant using labour force surveys that capture the income of the self-employed and also secondary activities of employees. Often these estimates are augmented (validated) with expenditure estimates provided by household expenditure surveys used in supply-use tables. But where the activities involve an agreement between the two parties to engage in a cash transaction that avoids the payment of tax, notably VAT, it is unlikely that the activity will be recorded in GDP at all, short of explicit rule of thumb adjustments made to capture the activity. However, partly offsetting this, at least for productivity measures, is the likeli-

3 These are estimated as the equivalent of a longer-term rental of similar size and quality or by applying a user cost approach that captures the value of capital services. In addition the increased ease with which new digital intermediaries facilitate letting may have encouraged owners of unoccupied properties, held purely as investment vehicles and which may not have been captured in estimates of imputed-rent, to put these on the rental market, although this activity is not expected to be significant.

4 AirBnB charges VAT on its service fees for customers from the European Union, Switzerland, Norway, Iceland, and South Africa and Japanese consumption tax for customers from Japan.

5 For example AirBnB directly collects an occupancy tax in Amsterdam, San Francisco and Portland.

hood that the associated labour input will also be unrecorded.

The emergence of a wide host of intermediary service providers that link consumers to producers, coupled with increased and widespread broadband access, is likely to have significantly increased the scale of these activities by, typically, the 'occasionally self-employed'. This requires an examination of new approaches to measurement. Labour force surveys may continue to provide a useful vehicle for measuring these activities but they can only ever present an approximate approach and given the potential (and still uncertain) scale of these activities it may be necessary to identify complementary sources.

However, as was the case for dwelling services, although the intermediaries themselves may have increased the size of a long-standing measurement problem they may also provide a solution. This is because their turnover will reflect the underlying activities conducted, and additional administrative information may also be available relating to hours worked and sector of activity. It may be feasible to use data collected by intermediary service providers to improve the estimates of activities of unincorporated enterprises providing transportation services.

One additional complication presented by the growth in these activities concerns the nature of the underlying goods used to provide the services. The most important concerns motor vehicles used to provide occasional taxi-services, which raises issues concerning the delineation of consumer durables and gross fixed capital investment (dealt with below).

Distribution Services

A third important platform of the sharing economy relates to the intermediaries (such as e-Bay) bringing together buyers and sellers of goods (typically second hand but also new). Where these transactions concern unincorporated enterprises (below an administrative threshold) and households, in most countries, the standing assumption is that the distribution margin (in practice the value-added) is negligible or indeed zero. So, for example, if a household sells a second hand car via private listings to another household, the transaction will generate no recorded value-added by the household. If the activity relates to the buying and selling of a new good (and again for small scale activities) it is also unlikely that any value-added will be recorded.

Once again, the increased scale of transactions facilitated by digitalization may require a different approach to measurement. However, to some extent, there is a natural barrier of sorts to the size of the problem. For those unincorporated enterprises able to achieve scalability there is an increased likelihood of registering their activity for tax purposes, especially if they cross the VAT registration threshold and almost certainly if their customer base expands to corporations. For all other unincorporated enterprises, the assumption remains that transactions for each unit are not likely to be significant. The convention of not recording any value-added in these cases continues to appear reasonable.

This in practice produces the same results as transactions through intermediaries such as Freecycle (a non-profit institution linking households together to acquire, for free, second hand goods).

Financial Intermediation Services

Crowdfunding and the more narrowly defined peer-to-peer lending have emerged as not insignificant new sources of alternative financing in recent years. The latter refers specifically to intermediaries providing, in essence, liquidity transformation services, linking creditors and borrowers, while the former captures in addition broader forms of financing that typically reflect

equity-based stakes, or other explicit rewards, for creditors (again typically through an intermediary, and so share characteristics with venture capital vehicles).

Again, notwithstanding issues relating to cross-border trade, the value-added of the intermediaries, typically captured through explicit fees, will at least in theory be captured in GDP. It is important to note, however, that whilst these fees are a return for the liquidity transformation services provided by the P2P intermediaries, they are not the same thing as Financial Intermediation Services Indirectly Measured (FISIM), because (a) the transactions are explicit, with the gains (e.g. interest received relative to reference rates) from the intermediation services (after commission fees) accruing to the creditors (and often borrowers), and (b) the intermediaries are not classified as financial intermediaries with deposits and/or loans (the convention used in the 2008 SNA to determine the scope of financial intermediaries providing FISIM services). The conclusion from the above is that activities by P2P intermediaries are, in principle, fully accounted for in the 2008 SNA.

There is, however, another question related to the scope of FISIM and its limitation to banks that may require further deliberation as part of the 2008 SNA Research Agenda (United Nations, 2008). In practice creditors and borrowers use P2P transactions to seek higher returns (for creditors) and access to finance and often lower rates of borrowing compared to those the same borrowers would be offered by banks. This suggests that part of the FISIM activity provided by banks may, under P2P transactions, instead be provided by creditors (and potentially borrowers). In this case, households[6] would be engaging in a productive service by providing liquidity, transforming maturities and accepting risks.[7]

At the same time it has to be recognised that banks also provide a whole host of other services (convenience services such as offering safe deposits, the use of cash machines, accounting services, etc.) that are not provided by P2P intermediaries, and so FISIM services provided by banks would in any case be higher.

It is important to recall that this is not the first time the scope of FISIM has been under consideration. The recent Inter-Secretariat Working Group on the National Accounts (IWGNA)[8] Task Force on FISIM recognised that the scope of financial intermediaries providing FISIM services warranted further investigation, while the earlier OECD Financial Services Task Force also recognised the possibility that FISIM could in practice be provided in respect to other financial instruments and by non-financial institutions, but it also recognised that measuring the activity in a comparable way across countries, institutions and instruments would not be practicable, particularly in the context of equity, reflecting the difficulty in separating a FISIM component from holding gains and losses.

It is perhaps premature to call for a re-opening of discussions on the institutional boundary of FISIM but, as a first step, an improved understanding of the size of P2P lending across countries, at least relative to conventional lending, appears to be warranted even if current estimates suggest that numbers are still small. For example Price Waterhouse Coopers estimates P2P turnover (reflecting the commission and

6 Diewert (2014) considers also the financial services provided by non-financial firms.

7 By the same token, the activity of money lenders – highly relevant in developing economies – would be recognised as production.

8 The ISWGNA includes the statistical arms of the OECD, United Nations Statistics Division, Eurostat, the IMF and the World Bank.

not the underlying lending flows) in 2013 at $163 million in the United States.[9]

Other Intermediaries

Digital intermediaries are not of course only concerned with household-to-household transactions. Many intermediaries are engaged in linking producers to consumers, where at least one party is a corporation. Notwithstanding potential cross-border complications (discussed below), these, in isolation, present little conceptual or measurement difficulties. The appearance of new, web-based intermediaries in the corporate sector, merely results in a shift of intermediation revenues and value-added from traditional providers (such as a travel agent) to web-based providers (such as Booking.com), and as long as the institutions are recorded in administrative registers (as they would almost certainly be for large-scale players and those that engage in transactions with other corporations) their activities should be recorded in the national accounts. Note that the amounts involved here are the margins or service fees charged for the intermediation, not the value of the transacted service itself (such as the accommodation fees for hotel rooms or private accommodation rentals).

Consumers as Producers: Blurring the Production Boundary

The pervasiveness of internet access by households has helped to blur the traditional borderlines between household production for market purposes, own account production, consumption, and leisure. Increasingly households are involved in intermediation that would previously have been the almost exclusive preserve of a dedicated intermediary. In other words, households are increasingly engaged in activities that would previously have been included in GDP.

Perhaps the best example is the use of internet search engines or travel websites to book flights and holidays, previously the preserve of a dedicated travel agent. But there are many other examples that merit consideration under this broad umbrella where market production blurs with non-market activity: self-check in at airports, self-service at supermarkets, cash withdrawal machines and on-line banking to name but a few.

These innovations have all helped to transform the way consumers engage with businesses and brought with them associated benefits but they also involve greater participation on the part of consumers, and indeed involvement in activities that used to be part of the production process.[10] Because the involvement of the consumer displaces traditional activity, the question is whether this increased 'displacing' participation should be included in GDP, one of the main arguments being that GDP would be higher, for example, when a travel agent acts as an intermediary to conduct the search compared to when the individual conducts the search his/herself.

By convention the simple answer is no, and so current estimates of GDP, as defined, are not affected by the inability to record these participatory activities. Moreover the issue relating to lower/higher GDP depending on whether the consumer conducts the activity or not is neither new nor without precedent. There has been a

9 Value-added in the U.S. Finance and Insurance industry is around 1.2 trillion USD, so the PWC estimate is the equivalent of about 0.14 per cent.

10 However it is important to recognise that prior to digitalization, consumers were not entirely detached from the production process, either. They would still have to look at the proposals for example made by the travel agent and wait in long queues to cash in cheques or withdraw money, so one could make an argument that in some cases digitalization has decreased the participation of consumers in the production process (at least in terms of time spent).

long standing critique that many services provided by households for their own consumption (cooking, cleaning, baby-sitting, shopping) could in theory be provided by a third-party and so should be included in the production boundary, if only to avoid introducing temporal and cross-country distortions that might arise when higher disposable income allows households to purchase these services rather than produce them themselves.

But these have not been included, partly on the grounds that they would create other distortions to GDP (through the inclusion of a significant non-market activity) that would render GDP almost meaningless as a measure of economic activity and a tool for policy making, and partly because of the valuation difficulties involved.[11,12] Indeed the national accounting framework provides scope for only one type of service produced on own-account for own-consumption in the production boundary (owner-occupied housing services). Instead the approach and response of the national accounts community has typically been to encourage the development of satellite accounts that capture these non-market household services as a tool to provide improved insights into material well-being and a complementary view of GDP.

Although the scale of 'digitalized' participation activities is likely to be significantly less than those for other non-market services outside the production boundary, the inclusion of estimates would remain distortive and would still require a subjective view on the price of the activity. Moreover their incorporation would certainly precipitate the inclusion of a whole range of non-market activities, such as those described above, but also many others such as assembly (e.g. furniture), decorating, or transportation.

That is not to say, however, that this resolves all of the problems (and one particular issue concerning the role of consumers in the provision of 'free' services is discussed below). The increased participation of consumers in activities suggests that there may have been quality changes in the final services provided, requiring a careful consideration of the implications on price measures and hence on volume estimates of GDP (also discussed below).

Consumer Durables and Investment

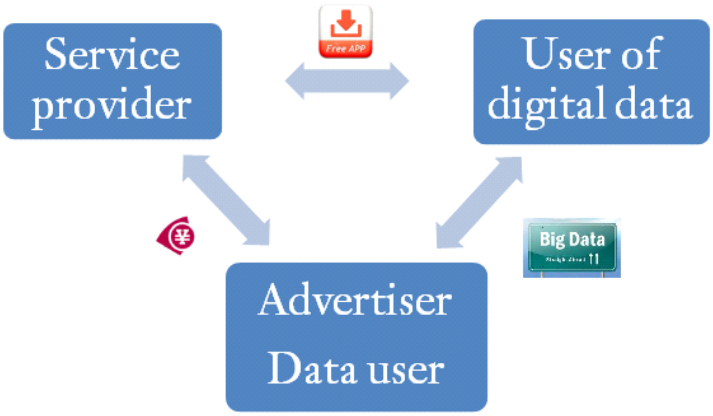
As noted above the sharing economy has seen an increased participation of unincorporated enterprises (households) in informal activities. This brings with it questions related to the delineation of dual use consumer durables and gross fixed capital formation.

The System of National Accounts does not provide prescriptive guidance on when durables should or should not be included as investment when they are used both for own-use and also in production by unincorporated enterprises. As such it is not clear whether current national compilation systems use the same qualifying criteria and, therefore, are necessarily able to capture increased investment that may have taken place from those individuals choosing to benefit from the increased market access provided by intermediaries such as Uber. A reclassification of consumer durables as investment does not affect GDP but has a direct bearing on measures of capital, and by implication, multifactor productivity. A better understanding of how countries make the relevant distinction and the source information used would clearly be welcome in order to assess the potential impact on productivity measures.

11 Note too that the valuation could be based on replacement or opportunity costs, which can lead to significant differences in the estimate.

12 See also Ahmad and Koh (2011) and Schreyer and Diewert (2014).

Figure 1: Free Products and Triangular Transactions



Free and Subsidized Consumer Products

Free digital products for consumers are frequently put forward as examples of output or consumer welfare that goes unnoticed in GDP figures. Such products include free apps for smartphones or tablets and free search capacity provided by websites such as Google. For instance, Brynjolfsson and McAffee (2014:108) argue that

> *"[…] There is a huge layer of the economy unseen in the official data, and for that matter, unaccounted for in the income statements and balance sheets of most companies. […] the trends in the official statistics not only underestimate our bounty, but in the second machine age they have also become increasingly misleading."*

To frame this discussion, it is important to note that the provision of free services by corporations to households is not a new phenomenon. Households have long been accustomed, for example, to receiving free media services (television and radio) financed implicitly via advertising. Indeed supermarkets often sell loss-leader products to attract customers and to build market share and banks often provide teaser rates and inducements to attract borrowers and lenders. The 2008 SNA Research Agenda (United Nations, 2008, Appendix 4.16) recognised that the provision of free products by corporations required further consideration:

> *"In the SNA, no final consumption is recorded for corporations because corporations are not considered to be final users of goods and services, except for capital products which, with the exception of valuables, are acquired for the purpose of production. However, large corporations often undertake sponsorship of cultural and sporting events. To date, the SNA regards the payments involved as a form of advertising but it could be argued that they are a form of individual consumption and could be treated as final consumption expenditure of corporations and social transfers in kind to households..."*

In this sense, digitalization has merely increased the scale of free or subsidised products and perhaps accelerated the need to proceed with this particular SNA Research Agenda item. But digitalization has brought with it another complexity, relating to the mode of financing. Whereas in the past the financing model was driven by advertising revenues or an attempt to create brand awareness, today's models are also increasingly financed by the acquisition of Big Data (on consumer preferences, characteristics and spending patterns). These two modes of 'finance' are considered in turn below.

Financing via Advertising

Financing via advertising involves a triangular set-up between the service provider, consumer and advertiser (Figure 1). The free (or subsidised) product is put at the disposition of the consumer and financed by advertising services for which there is an explicit transaction between the service provider and the advertising company. Assuming, for simplicity, that the services are provided for free, the sales generated by the service provider correspond to the value

of advertising services. Implicitly, therefore, the value of the free service provided to the consumer can be equated with the value of the corresponding advertising services.

Because there is no explicit payment by the consumer there is an argument that GDP is underestimated by the value of the free services received. Certainly GDP would be lower compared to the counterfactual, where advertising revenues are not used to subsidise the service. But this, to some extent overlooks the fact that, under the 'free' model, the consumer does indirectly pay through the higher prices paid for advertised products (as the firms paying for the advertising recoup their costs).[13] In which case, other things being equal, overall GDP would be equal in both cases; the only difference being different consumption patterns of consumers in the two cases.

The argument set out in the SNA Research Agenda[14] however points to the possibility of an alternative treatment that would increase GDP through (new) final consumption of corporations (with corresponding social transfers in kind increasing actual final consumption of households).

Nakamura and Soloveichik (2015) put forward a different (albeit similar) proposal (of particular interest because it provides estimates) that equates the time spent by households watching advertisements as an act of production, for which they are paid by the advertising firm, and in turn pay for the (previously free) services to the service provider. Consequentially, under this proposal, no explicit transaction would be recorded between the service provider and the firm paying for the advertising service, and both GDP and household consumption would be higher.

The authors impute a value of production by unincorporated household enterprises equal to the value of advertising receipts and use data on advertising expenditure for different media, along with an estimated price index, to gauge the quantitative impact of recording household production in this way on real GDP growth. Across about 80 countries, the imputed services consumed by households grew considerably faster (at 6.7 per cent per year) than overall GDP in

13 In earlier discussions on the scope of GDP, some (Kuznets (1948), Haberler and Hagen (1946) and Hicks (1948)) argued that government production should be treated as an intermediate product, as the value of services provided for free and financed by taxes was already reflected in the (higher) value of final products, and so their inclusion as general government final consumption led to double-counting. This view, as is now known, was not supported, the main argument (Gilbert et al. 1948) being that the collective services provided by government are not an element in businesses' cost and are consequently not reflected in the value of their output, unless one presumes an unrealistic identity between the services provided by government and the value of taxes that producers pay (see also Vanoli, 2005). The different treatment of free products provided by government and businesses was an important catalyst for the inclusion of the subject on the 2008 Research Agenda. But the analogy is limited. If, for example, government subsequently chose to charge households for individual services, all other things being equal, household final consumption would increase, offsetting the decrease in government final consumption, while gross value-added (GVA, GDP in basic prices) would be unaffected (but not necessarily GDP at market prices, which would depend on whether taxes on products, such as VAT, were in turn reduced). Similarly if media providers chose to charge consumers for their media services, rather than finance them indirectly via advertising, GVA would also remain unchanged. The media provider would continue to record the same level of value-added as would that of the firm that previously paid for advertising services (who would no longer be consuming intermediate services provided by the media company but whose gross output would in turn fall as the brand premium on output should also fall). This suggests that the recording of free products to households as consumption by government but not by businesses is not inconsistent. The same outcome would not, however, arise if the accounts already included an imputation for free media services. In this case overall value-added would be lower by the amount of the imputation. An interesting footnote, not central to the discussions at hand, is that GVA would not necessarily be unchanged were collective services provided by government charged for directly rather than financed via taxes if business were also made to incur some of these costs directly as intermediate consumption.

14 Another and similar accounting possibility is to impute a current transfer to households that they in turn use to purchase the media services.

real terms, although as they note, because of the relatively low share of advertising-supported entertainment in GDP the imputation has a negligible impact on GDP growth.

> "*However, advertising-supported entertainment accounts for less than 0.5 per cent of nominal GDP. Because advertising-supported entertainment is such a small share of the economy, its 4 per cent faster real growth rate only raises overall growth rates by 0.018 per cent per year" (Nakamura and Soloveichik, 2015:14).*

It is also interesting to observe that the nominal GDP share estimated by the authors has been remarkably stable over the last three decades, indicating that the exclusion of an imputation for advertisement-financed free services does not create a systematic downward bias in real GDP growth.

That being said, it is also important to recognise that the proposal is not without its own complications. The premise that households provide services to firms by participating in the production of advertising services perhaps stretches the third-party criterion of the accounting framework to its limits, as ultimately the effect is to engage in an activity that in the main increases their own propensity to consume the advertised products (and only indirectly has a third party effect if the households then engage in convincing others to buy the goods).

In addition it is useful to frame the proposal in the context of long-standing considerations relating to the possible inclusion of brands as produced assets in the accounting framework; proxied via expenditures on advertising. Whilst the Nakamura and Soloveichik proposal generates the same GDP as the option set out in the SNA Research Agenda proposal, this would not be the case if advertising expenditures were subsequently recorded as investment.[15]

Moreover, the Nakamura-Soloveichik proposal necessarily ignores the captive nature of households in this process of production and the fact that they have little control of the price charged for their services, which ultimately is determined by the service provider. But, under the proposal, the service provider is recorded as invisible in this process and is recorded only as providing services to households and not advertising services to other firms. This can lead to significant interpretative problems, not least for productivity. For example the model used by one service provider (say a television company) may be to show adverts every 15 minutes, for which it charges a lower price compared to another television company that shows the same programme only with adverts every hour (which is likely to attract more viewers and so a higher advertising price). In equilibrium, all other things being equal, the revenue for both firms would be the same but the hours 'worked' by one set of viewers would be considerably higher.

This, in turn, raises further complications pertaining to the actual valuation of the imputed flows of consumption, income and production.

15 Assuming that the SNA Research Agenda proposal as detailed on page 1 was accepted, GDP would be unaffected if advertising expenditures were subsequently treated as investment, as corporations' 'final consumption' would instead be recorded as investment. However if the Nakamura and Soloveichik proposal was accepted, GDP would be higher (again) if advertising expenditures were subsequently treated as investment, as the 'advertising services' provided by households and purchased by firms would then be recorded as investment by the firms purchasing these services, but the imputation for the free media services received by households (equivalent in value to the advertising services provided) would still be recorded as household final consumption. In other words if the value of the free services provided by media companies (and the value of services provided by households) was equal to X, the Nakamura and Soloveichik proposal would increase GDP by X. If in the future the SNA chose to recognise 'brands' as a produced asset (measured by the costs of production – namely advertising costs), GDP would rise again by X. So, relative to the 2008 SNA position, a combination of the Nakamura-Soloveichik proposal and recognition to treat brands as production capital would increase GDP by X+X.

The accounting proposals typically assume that the value of the 'free' products equals the observed value of advertising services. This is a matter of debate. Conceptually speaking, the valuation via advertisement is a producer valuation that may or may not correspond to a valuation by the consumer. When there are explicit transactions, theory suggests that the observed (equilibrium) price reflects both the marginal valuation of the consumer and the marginal cost of the producer. In the case at hand, nothing guarantees that this equality holds and one could indeed imagine a user value imputation different from the producer value. Apart from the rather complicated accounting arrangements necessary for such an approach, there is the important question of how to measure the unobserved user value. A shadow price would be required that reflects the consumer's marginal utility from spending an extra hour or minute producing the respective advertising services. This might be estimated through the opportunity cost of time spent, such as foregone earnings. There is an important literature on valuing leisure and household production that may provide guidance.[16]

Whatever the precise measurement of shadow prices, it is clear that consumer valuation should not attempt to measure total consumer welfare arising from the use of free digital products, just as the value of traditional market products is not a measure of consumer welfare.[17] Measures of the total value of consumer welfare such as consumer surplus are at odds with the conceptual basis of measuring GDP and income, let alone any welfare measure that goes beyond consumption and encompasses quality-of-life dimensions. There is no question about the importance of such measures and the OECD's work in this area[18] is but one example. However, measuring production and income is a different objective from measuring welfare. In addition, some elements of consumer welfare are automatically present when price indices that embrace a consumer perspective are used for measuring real GDP (see below).

Financing via Data...and Databases

The second avenue for the financing of free digital products is collecting and commercially exploiting the vast amounts of data generated by users of digital products. In many ways, this financing model resembles the advertising model: there is an implicit transaction between consumers (who provide data) and producers (who provide digital services for 'free' in return). A third party may or may not be involved. Economically speaking, the service provider finances its free services by building up a digital asset (volumes of data) that is subsequently used in the production of data services.

Although not explicitly spelled out in the SNA Research Agenda, which deals with advertising modes of finance, the model proposed there could also be applied here, resulting in GDP increasing. However (unlike the advertising model) the analogy is slightly more complicated here as there is no obvious proxy to establish the value of the services provided for free.

One approach could be to consider the new additional investment added to the database (owned by the service provider or a third party). But this is also problematic as, in practice, for reasons described below, the System of National Accounts only records, as investment, expenditures related to the digitalization of the data and not the inherent value of the data itself. Ultimately, it is the intrinsic value of the data that

16 For estimates in OECD countries see Ahmad and Koh (2011), Fraumeni (2008) and Landefeld, Fraumeni and Vojtech (2005). For a recent theoretical treatment, see Schreyer and Diewert (2014).

17 See Schreyer (2016) for a discussion of GDP and welfare.

18 For a discussion of OECD work on well-being, see OECD (2011a, 2013a, 2015b) and Boarini *et al.* (2015).

captures the exchange between the consumer and the producer. Moreover this presupposes that the whole is equal to the sum of the parts, in other words that the sum of individual pieces of data provided by households is equivalent to the totality of that data in a single dataset.

Where a third party is involved that pays the digital services provider to collect data on its behalf, it could be possible to use the associated payments it makes to the digital services provider to acquire the data as a suitable proxy but where no third party is involved this would again be problematic. An alternative approach, where no third party is involved, would be to estimate the increase in the market value of the database (including the embodied data and after adjusting for price effects and depreciation) and use this as the proxy. However, from a practical perspective this would be onerous as it would require an estimate for all digital services providers (as it would not be possible to determine a priori whether they collected data for their own intermediate use).

However even if it were possible to derive meaningful estimates there is a risk that, in imputing these values, the national accounts inadvertently opens the door to the capitalization of knowledge (and by extension human capital). It was, at least in part, to avoid this that the SNA recommends that only the costs of physical maintenance and construction of databases are included as produced capital, rather than the earnings potential of the data embedded in the database itself.

In all probability the market value of databases is likely to be significantly greater than a valuation according to the Perpetual Inventory Method (PIM), which values capital stocks using past investment (adjusted for depreciation and retirement). Indeed it is likely that it is only when databases are sold in their entirety (including the market value of the data embodied in them) that the full value of databases will be recorded in the accounts (as goodwill, i.e. not contributing to GDP).

Creating an analogy with the Nakamura and Soloveichik proposal presents additional problems as not all provisions of data by households (the corollary of consumers watching adverts) result in free goods or services being provided in exchange; supermarkets for example are increasingly engaged in the creation of Big Data without there being any explicit exchange (free or subsidised products) being made in return to consumers. The analogy therefore would lead to an imputed exchange being made for some provisions of data and none in others; in much the same way that consumers are exposed to advertising in a multitude of ways without there necessarily being an explicit exchange in return.

In summary, while it is clear that digitalization has increased the wedge between metrics of production and welfare, reinforcing the case for supplementing GDP and income with other indicators, it does not follow, particularly given the multitude of practical challenges presented and the conceptual considerations of capitalizing knowledge, that welfare measures should replace measures of production.

However, the arguments for an imputation should not necessarily be dismissed on the grounds that they are impractical nor because they open the door to capitalization of knowledge. The 2008 SNA Research Agenda already advocates further work to explore this issue, but its remit is unnecessarily limited to advertising modes of finance. The scope should be extended to consider data modes of financing and the consequential impacts any recommendations could have on the valuation of databases and knowledge more generally.

Free Assets Produced by Households

The provision of free services to consumers is not the only area where 'free' is in and of itself an

issue for the accounts. Conceptual difficulties also emerge when considering the creation of 'public goods' using labour provided for free, and where financing is typically only provided by donations (as opposed to paid services for the use of the goods, whether directly as fees or indirectly via other forms of financing e.g. advertising). Wikipedia and Linux are two well-known examples.

It is beyond contention that these have provided significant benefits for consumers and a case can be made that time spent on these activities includes an element of production but it is also clear that, within the current accounting framework at least, the services they provide as well as the work involved in their creation (correctly) do not enter into GDP.

This is not to say that they do not have value per se nor that they are excluded from the production boundary, as they clearly have value to users and can play an important role in the production process, but because production is free, by extension so too is the value of the assets.

Note that assets that have not been produced freely (at zero cost) but are available for free are included in the accounts and balance sheets.[19] For market producers, on the grounds that they create additional spillovers, such as brand awareness and increased likelihood of payment for premium services. For government, on the grounds that they deliver public benefits, with the value equivalent to the associated costs of production. Where the associated costs of production are zero therefore, as is largely the case with Wikipedia and Linux, it follows that these will not be included in the valuation of the final asset. In addition and perhaps most importantly, the very nature of the assets is that there is a collective 'global' ownership of the assets[20] meaning that it would not be possible, in any case, to record the assets on the balance sheets of any individual country.

That being said a better understanding of the economic benefits (and impact) through satellite accounts, in particular to households, but also to businesses (who may reduce recorded investment costs through the use of freely available software) would be welcome; not least to assess the potential consequences on estimates of multi-factor productivity that occur when paid for software is substituted by free software.

Cross-Border Flows of Intellectual Property and Knowledge-Based Assets

The 2008 SNA recognises five categories of intellectual property assets:

i. Research and development;

ii. Mineral exploration and evaluation;

iii. Computer software and databases;

iv. Entertainment, literary and artistic originals; and

v. Other IPPs.

With the exception of mineral exploration and evaluation, IPPs are subject to substantial international trade. As is clear from the OECD's work on base erosion profit shifting, intellectual property products have increased the ability of

19 The OECD Handbook on Deriving Capital Measures of Intellectual Property Products (OECD, 2009) says the following with regards to free intellectual property products: "Occasionally market producers make their originals available for free before the end of their physical and economic service life. But the fact that the IPPs are made freely available does not of itself exclude the IPPs from being recorded as assets. As long as the original producer still expects to obtain economic benefits from the IPP an asset remains." Other complications arise in conjunction with government owned assets for free use and are described there as well.

20 A comparison can be drawn with the SNA treatment of the atmosphere and the corresponding work of the OECD/Eurostat Task Force on the Treatment of Emission Permits in the National Accounts. Paragraph 46 says 'The decision not to consider the atmosphere as an asset in the 2008 SNA is consistent with the underlying philosophy of economic assets in the accounts. No value can meaningfully be placed on it in a national accounting sense, and crucially it is a common property resource that cannot be identified with a single owning entity, apart from at best, humanity in general'.

Table 1: Classification of Knowledge Based Assets

Computerized information (knowledge stored in programmes	Innovative property (research and development assets)	Economic competencies (human and organization capital)
Software*, databases*	Scientific R&D*, mineral exploration*, artistic originals*, financial product innovation, design, R&D in social sciences and humanities	Branding (advertising, marketing), training, organizational structure

* Contains assets currently capitalized in the official measure of investment.
Source: Corrado, Hulten and Sichel (2005).

firms to shift the registration (legal ownership) of their IPPs from one (high-tax) jurisdiction to another (low-tax), and as a consequence also shift the underlying value added created by these assets.

The international statistics community, starting with the OECD Task Force on R&D and subsequently UNECE Task Forces on Globalisation in the National Accounts and Global Production, have for a number of years strived to introduce clarity here, with a key focus on attempting to ensure alignment with the principles of economic ownership (i.e. who runs the risks and receives the rewards) but the current situation remains a work-in-progress with all Task Forces calling for further work to be conducted.

Unlike many of the issues raised above, the issue here is not necessarily that the related flows (payments and receipts) from the use of the assets are not recorded in the accounts – the issue is whether the flows necessarily align with national accounts concepts of economic ownership, rather than legal ownership.[21] One factor that has meant that current estimates are likely to default to legal ownership in practice reflects the fact that taxes are paid and recorded on the basis of legal ownership, and adjustments that relocate assets to the territory of the economic owner actually using them in production would result in further imputations of somewhat incongruous cross-border taxes.

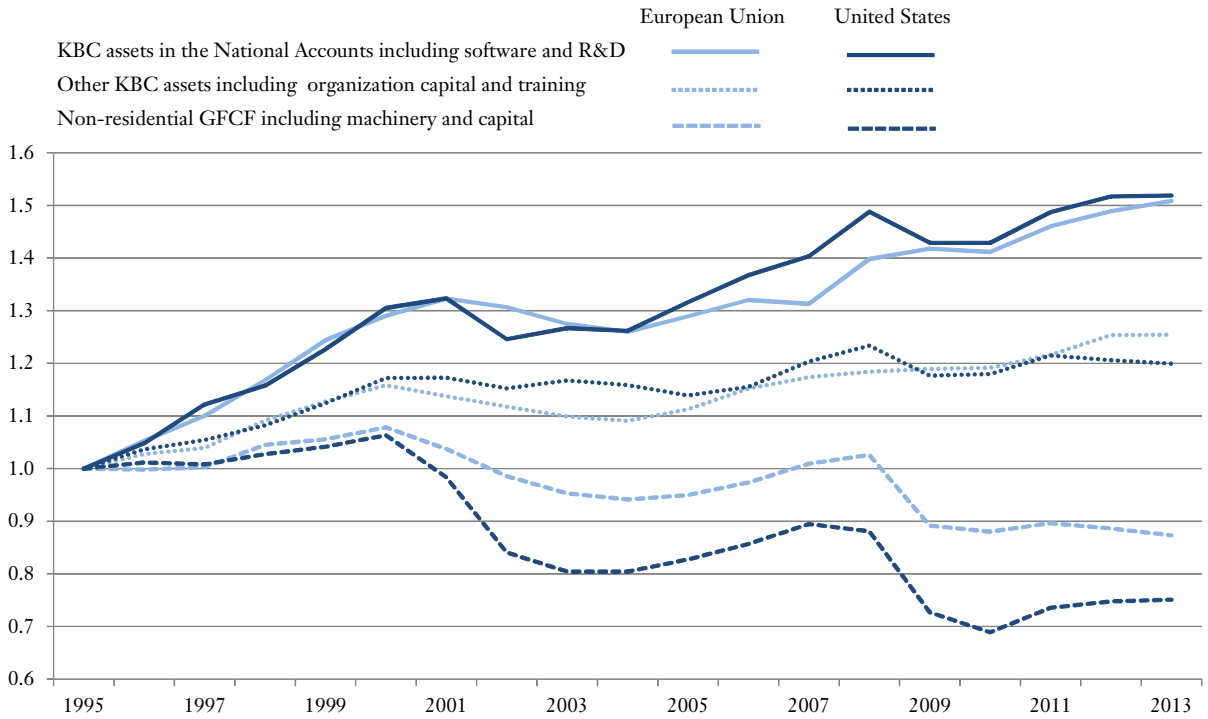
This means that current estimates, and comparability, of GDP across countries will be affected, although, to some extent, this is partly mitigated by balance of payments income flows (and so GNI) which will counter-balance these inconsistencies (although not in entirety nor necessarily in the same year, as profits can be 'parked' in the country where legal ownership of the IPP is established).

But this is not of course the only problematic outcome, productivity estimates may also be affected, and not only because value-added may be incorrectly allocated to any particular country but because the 'transferred' IPP generating the recorded value-added may not always be captured in cross-border international trade statistics. This may mean that the balance sheets (especially when estimated using PIM) in one country may be too high and in another too low. Further work is needed across countries to ensure that there is an underlying consistency between assets on the balance sheets, used for productivity analysis, and output. One important avenue for exploration would be through the development of accounts that break down national accounts estimates by activity (value added, expenditures and sales of IPP assets and services), and producing corresponding estimates of productivity, capital-labour shares, and primary income (payments and receipts) for the following three categories of firms: foreign affil-

21 The 2008 SNA (United Nations, 2008, paragraph 3.21) distinguishes between legal owner ('the institutional unit entitled in law […] to claim the benefits associated with the entities') and economic owner ('the institutional unit entitled to claim the benefits associated with the entities […] by virtue of accepting the associated risks'). Often, legal and economic owner coincide but not necessarily so.

Chart 2: Knowledge Intensity of Business Investment, Selected EU Economies and the United States, 1995-2013

Business Sector Investment by Type of Asset, Percentage of Gross Value Added, 1995=1.0



Source: OECD calculations based on INTAN-Invest data, www.intan-invest.net and OECD, *Structural Analysis (STAN) Database, http://oe.cd/stan,* June 2015. For added descriptions, see OECD (2015c) *Science, Technology and Innovation Scoreboard*.

iates, domestically owned firms with affiliates abroad, and other domestically owned firms.

This problem – a disconnect between capital stock estimates and recorded GDP, and hence productivity estimates - is exacerbated when the scope of digitalized assets is expanded, as many have argued. The most commonly used classification (of a broad scope of what has become known as knowledge-based assets) was developed by Corrado, Hulten and Sichel (2005). Table 1, which provides a description of those assets, shows that some of the assets are currently included in the 2008 SNA but many are not. Moreover, estimates suggest that the growth of knowledge-based assets (both those included in the SNA and those that are not) have typically, and significantly, outpaced growth in tangible assets (Chart 2).

However, where these estimates have been used in productivity analysis they typically assume that the knowledge based assets recorded in a given country are only used in production in that country (and often overlook the fact that the assets may in fact have been shifted offshore), but the assets themselves (even if they have not been shifted offshore), in particular brands owned by multinationals and organisational capital, can be used in practice to generate value added across a number of countries. This is likely to mean that productivity estimates will in turn be affected.

As was the case for assets already included in the SNA, reconciling the underlying asset with the flows of value added is non-trivial. Because of profit shifting (and parking of profits), investigations of intra-firm primary income flows will not necessarily provide the solution. In the

absence of profit shifting one could reallocate income flows related to the use of the underlying assets as value added generated in the territory of the parent company. This results in, all other things being equal, higher labour productivity figures in those countries with positive net receipts from knowledge based assets and lower labour productivity in those with negative net receipts.

The recommendations made above for intellectual property products apply equally to those knowledge based assets currently outside of the SNA asset boundary. But one immediate recommendation is for some caution in interpreting the productivity results that emerge from extending the asset boundary without adjusting for the cross-border use of the underlying assets.

E-commerce

The OECD's Guide to Measuring the Information Society (OECD, 2011b) defines e-commerce transactions as "the sale or purchase of goods or services, conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders." It is important to note, under this definition, that the goods or services are ordered by these methods, but the payment and the ultimate delivery of the goods or services do not have to be conducted online.

For transactions occurring within the economy and where at least one party is a registered enterprise, there is no particular reason to believe that e-commerce transactions present any greater difficulty for GDP measurement than transactions conducted using other modes. As noted above e-commerce transactions between households may present some difficulties but despite the growth in this activity in recent years it is only in rare circumstances (when in all likelihood the household will appear as a registered enterprise) that value added is likely to be underestimated, and so the problem is negligible, particularly when one factors in the balancing and validation process that supply-use tables embody.

Where problems may occur concerns cross border e-commerce of services, discussed in more detail below. Also, problems may exist for goods transactions. In many countries customs statistics only record imports of goods above a certain value. In theory therefore, and in the absence of complementary data sources, the assumption is that the supply-use balancing process is able to capture these 'missing' imports. But to what extent this is true is difficult to say. The OECD Statistics Directorate has recently begun an exercise to compare merchandise trade flows with comparable goods measures recorded in the national accounts, which should be able to provide some indication on whether these gaps have grown in recent years, as might be expected given the growth in cross-border e-commerce purchases. Nevertheless, work is on-going (see below) to explore additional data sources that may help capture these flows, chiefly through postal records and credit card transactions.

That being said, because most of the value of e-commerce goods transactions will be B2B and large scale, cross-border e-commerce goods transactions are not expected to create significant measurement errors in GDP.

It is difficult, however, to be as confident when it comes to cross-border e-commerce services transactions (such as streaming and downloading), as data is generally scarce (and where there is the added complication of illegal downloads).

UNCTAD, the Universal Postal Union, and the WTO have recently set up a Technical Group, including the OECD, to better measure e-commerce transactions, and it is hoped that this will deliver improvements in measurement and an indication of the scale of the current measurement problem.

Prices and Volumes

The sections above have all focused on the possible (mis)measurement effects of digitalization on current price measures of value added and GDP. But digitalization also creates significant challenges for prices, and hence volume-based measures of GDP and productivity. As was the case for current price measures, many of these challenges are not new, and are merely exacerbated by digitalization.

One challenge is customization that is enabled by digitalization. With products (in particular services but increasingly also goods) becoming more unique, price comparisons that control for quality differences become more complicated. The Eurostat-OECD Methodological Guide for Developing Producer Price Indices for Services (OECD 2014) provides detailed advice on this issue by product, highlighting a number of approaches that could be used for measuring price changes in specialized products (contract pricing, model pricing, component pricing, hedonic methods) but the fact remains that accurately measuring quality changes remains challenging. However, it is perhaps important to put the issue of 'customization' into its appropriate context when considering volume measures of GDP. Notwithstanding issues raised by the substitutability of products (see below), the objective is to measure price changes, not the price level of the product. Consequently, proxy estimates that employ comparable price changes over comparable (non-customized) products may limit the scope of potential errors on volume estimates.

A notable characteristic of digitalization relates to the multiplicity of 'pricing models'. The Bean Review (paragraph 3.15) observes:

> *"The pricing model for many internet and mobile services is one where a basic version is available for free with an enhanced version available to paying subscribers (the so-called 'freemium' model). Moreover, where a service is financed through a subscription, the subsequent use of the service is unlimited (i.e. there is a fixed cost for access but a zero marginal cost of use). This implies that the monetary transaction, even when recorded, fails to reflect the volume of digital product consumed; in effect, the price per unit is not observed."*

The implication here is that the volume of consumption may be under, or indeed over, stated. This is indeed the case if the unit of the service provided, and hence price measurement, is simply defined as 'one access to a digital service', regardless of the quantity of contents available and potentially downloadable by the subscriber. However, standard procedures of quality adjustment of price indices would in principle readily account for say a doubling of the offered contents in a streaming service by registering a corresponding drop in prices.

Moreover it is important to put the issue of product (quantity) paid for and product (quantity) consumed into some context because it is not new. The average consumer for example will often purchase goods (typically food) that they may not eventually consume, especially when supermarkets create incentives (e.g. three for the price of two). But it is clear that the accounts correctly record the purchases and not the actual consumption. The same can be said for digitalized products. In other words, whether a consumer downloads 10 movies rather than 5 from their unlimited subscription does not matter for GDP estimates (although this is another matter when considering consumer surplus).

As noted above an important feature of digitalization is in its creation of new business models. The Bean Review (2016:94) examines the case of accommodation services and conjectures that there may be a downward bias to volume measures:

> *"Gross value added from the accommodation services [provided by AirBnB] are*

currently deflated by the Services Producer Price Index (SPPI) and the Consumer Price Index (CPI). Both indices contain hotel prices but not Airbnb prices. Some analysis from 2013 suggests that renting an entire flat through Airbnb was 20 per cent cheaper than renting a hotel room, whereas renting a single room within an Airbnb host's home was almost 50 per cent cheaper. Moreover, an Airbnb rental is arguably superior to a hotel room due to the variety of choice, access to a kitchen, etc. Consequently, the failure to reflect the price of Airbnb rentals in the price deflator for accommodation services suggests that the value added generated by that sector may be underestimated, even assuming that Airbnb nominal expenditures are fully captured through surveys (which is a strong assumption)."

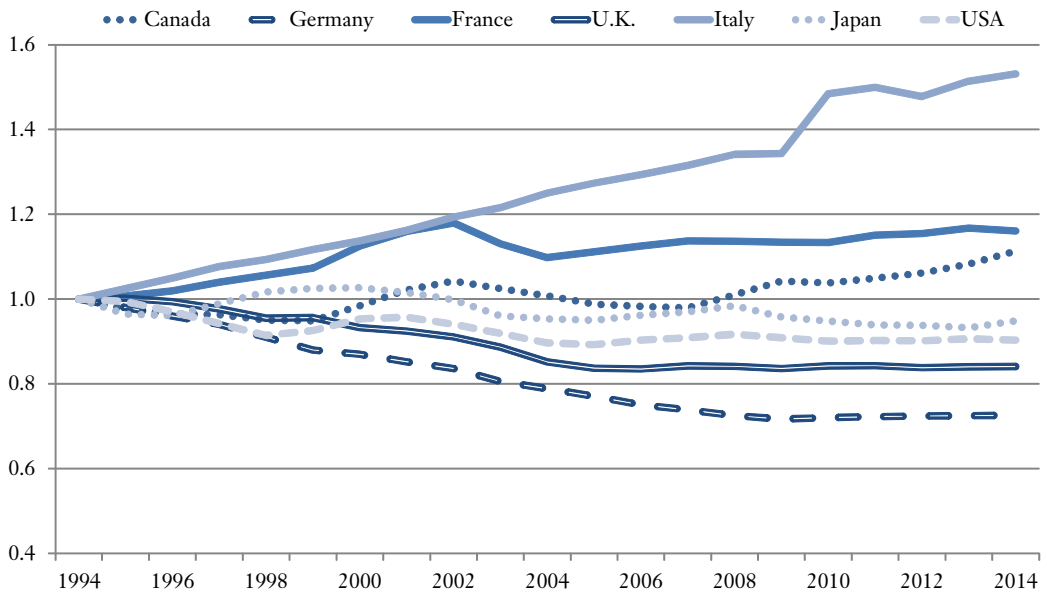
The underlying assumption made in the Bean Report is that AirBnB rooms are of higher quality than comparable hotel rooms. So the use of a price index that only refers to hotel rooms will fail to capture the switch to cheaper AirBnB rooms and underestimate the total volume of accommodation services. But the assumption of superior quality of AirBnB rooms is not without contention[22] nor is the presupposition that the two ways of providing accommodation services should be treated as a single product.[23]

Getting quality change and switching between products right may very well be the greatest challenge presented by digitalization as it is not, of course, limited to AirBnB nor indeed to new business models per se. The internet has had a democratizing effect that has reduced the space between buyers and producers, in the process piloting consumers towards cheaper suppliers and producers of goods and services, even within the same country. This reduces, other things being equal, recorded consumption for a given basket of products. But conventional price indices may not be able to capture this substitution effect, similar to the well-known outlet bias problem (assuming of course that quality is unchanged, which as highlighted above is not necessarily a given). Naturally, this may also have implications for the slowing productivity measures in the face of digitalization. Further investigations to determine how current price indices capture this potential bias, and indeed whether the substitution in and of itself should

22 Whether accommodation services provided through internet platforms are of superior quality is, at least, a point of discussion. Indeed, AirBnB provides a granular choice in terms of the location of accommodation services but whether, for a given location, the quality of accommodation is superior to the quality offered by a comparable commercial supplier is not clear. OECD (2014:178ff) provide an overview of the pricing methods for accommodation services. Price indices for accommodation services are rather complex and generally control for quality change in commercial provision of accommodation services. If commercial service quality trends upwards (as would be the case with rising room size or greater choice through food and beverage services; room service; banquet and catering services; telephone services; internet access; laundry services; parking facilities; etc.) this may not be representative of quality change in privately provided services and thus partly or entirely compensate for a possible downward bias from greater choice of locations.

23 The SNA (paragraph 15.66) states "differences in quality may be attributable to differences in the physical characteristics of the goods or services concerned and be easily recognized, but not all differences in quality are of this kind. Goods or services delivered in different locations, or at different times, such as seasonal fruits and vegetables, must be treated as different qualities even if they are otherwise physically identical. The conditions of sale, or circumstances or environment in which the goods or services are supplied or delivered can make an important contribution to differences in quality.... The same goods or services sold by different kinds of retailers, such as local shops, specialist shops, department stores or supermarkets may have to be treated as different qualities." Paragraph 15.67 states: "It is generally assumed in economic analysis that whenever a difference in price is found between two goods and services that appear to be physically identical there must be some other factor, such as location, timing or conditions of sale, that is introducing a difference in quality. Otherwise, it can be argued that the difference could not persist, as rational purchasers would always buy lower priced items and no sales would take place at higher prices."

Chart 3: Price Indices for Software Investment, Selected OECD Countries, 1994=1



Source: OECD Productivity Database, March 2016.

necessarily be captured as a price or a quality change, are necessary.

But these are not the only issues raised by digitalization. Long-standing challenges remain in some of the more mature problem areas, such as software for example, where the evidence points to significant differences across countries in measurement approaches.

Nor is this issue necessarily limited to software. Similar divergent movements might also be expected in other areas, such as ICT equipment[24] and research and development deflators. And other classic issues relating to quality versus price also remain in large part unresolved; notably the quality changes implied by increased consumer participation in intermediation activities, such as self-service supermarkets, all of which require further consideration.

However, as in other cases noted above, although digitalization has increased the size of the problem it may also be part of the solution. There is considerable scope to complement traditional methods of price measurement with new data sources and data-gathering techniques, including scanner data and web-scraping, which provide capacity to collect large samples of prices at high frequency – weekly or even daily. With a higher frequency of price collection, the turnover of models between periods of price collection is reduced, making it easier to match models[25] between consecutive periods, and so improve the ability to control for quality change. In addition this can help to reduce the size of of the well-known 'new goods bias' where prices of newly introduced models fall quickly in the period immediately following their introduction.

Hitherto, when prices are collected and resampled infrequently (every month, quarter or year), but the model change is rapid, additional methods of quality adjustment have had to be invoked, including often complex hedonic pricing methods.[26] The evidence suggests that more

24 See, for instance, Byrne and Corrado (2015).

25 Matching models is an established method to compare prices while controlling for quality change.

timely collection using digitalized sources can provide robust, and more efficient, alternatives.

A good example is Cavallo and Rigobon (2016:19) in reference to MIT's Billion Prices Project. The authors point out that "Online prices offer a simple solution to this [new goods] problem by providing a large number of uncensored price spells for all models on sale at any point in time. With this type of data, a simple index using overlapping qualities can closely approximate official indexes that use complex hedonic quality-adjustment methods." They demonstrate the capacity of high-frequency online price collection for dealing with quality change by showing monthly inflation rates for televisions in the U.S. market that closely approximate the results of the hedonic price index constructed by the U.S. Bureau of Labor Statistics.

Conclusions

On balance the accounting framework used for GDP looks to be up to the challenges posed by digitalization. Certainly from a conceptual perspective GDP does not look to be deficient. Indeed where conceptual issues do arise, these have been flagged up as actions within the 2008 SNA Research Agenda, or are of limited significance to overall GDP.

At the same time however it is also clear that in many areas, that affect both GDP and productivity, practical measurement remains a challenge – not least in the context of cross-border flows such as intra-firm flows of intellectual property and e-commerce transactions, where work is on-going.

In many of the areas where measurement is problematic, the underlying issue is not new. What is new is the scale of the problem. With new intermediaries and new modes of doing business increasing the size of more informal (sharing economy) transactions between households, conventional methods, which have hitherto provided rough estimates for these flows, may no longer be appropriate. However the very cause of the increased size of the problem (the new intermediaries) may also be a source of the solution, in that they provide potential access to new administrative data that records what were previously largely invisible (non-observed) transactions.

But this is not the case for all measurement challenges. The measurement of price change and in particular the distinction between quality and price change, which is both a practical and conceptual consideration, require increased and concerted efforts, not least because of the anecdotal and real evidence that points to widespread differences across countries. However, notwithstanding the conceptual challenges posed, by participative production for example, again, digitalization, and its scope to provide more frequent data collections, may itself provide part of the solution.

At the same time, it is clear (notably from the discussions on free services, the increasing participation of households in the production process, and prices) that digitalization brings further into focus the fact that GDP is a measure of production and not a measure of welfare or consumer surplus. This reinforces the need to complement GDP with other indicators that capture well-being.

Perhaps the most pertinent conclusion that can be drawn is the need for more evidence on current country practices in dealing with the issues raised above as well as empirical estimates of some of the phenomena at hand. This will allow researchers to gauge the size of current

26 See ILO et al. (2004). Boskin et al. (1996) brought the quality adjustment issue to the fore as the largest single element in the estimated bias of the U.S. CPI. A body of literature evolved in regards to the quality adjustment of high-tech products, aptly overviewed and assessed by Triplett (2006).

challenges and to develop more targeted best-practice recommendations.

As a follow up to this article the OECD will circulate a dedicated questionnaire shaped along the lines of the issues raised above as a first step in an overall strategy that could lead to more concrete practical guidance. This will also provide a vehicle to set out the groundwork for more elaborate discussions on some of the conceptual challenges raised, including considerations on whether, and if so how complementary measures (e.g. satellite accounts) could be developed that better identify the consumer surplus gained through digitalization.

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Productivity in Mexico: Trends, Drivers, and Institutional Framework

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ABSTRACT

Over the past three decades, economic growth in Mexico has been lackluster, with declining multifactor productivity as the main culprit. Mexico's growth malaise stems not only from existing barriers to the productivity of labour and capital, but also, to a large extent, from a misallocation of both inputs. This is epitomized by a large informal labour market and by a financially-underserved private sector. Factor misallocation has generated large productivity gaps between sectors and regions. In particular, a process of structural transformation that mobilizes resources toward high-productivity activities has unfolded slowly. To spur economic growth, the Mexican Government has placed productivity at the center of the policy agenda, not only by enacting a wide array of productivity-enhancing structural reforms, but also by establishing an institutional framework conducive to the design and implementation of public policies that address existing bottlenecks.

ONE OF THE CURRENT conundrums in the economic situation in Latin America is the apparent paradox posed by the lackluster economic growth in Mexico (McMillan, 2011 and Hanson, 2010). In particular, this lackluster growth has occured despite the fact that Mexico is a poster child for the implementation of economic policies that should in principle foster strong and stable economic growth in developing nations.

Since the early 1990s, the Mexican government has taken important steps to pursue a sound macroeconomic environment. In April 1994, the Mexican Central Bank became autonomous, with its main objective to preserve the purchasing power of the Mexican peso. Starting in 1995, the government implemented aggressive measures to reduce the public deficit. Among these measures were quarterly internal leverage controls, longer maturity profiles on loan instruments, and rules to guarantee a responsible management of public finances.

A gradual transition to a flexible exchange rate regime was supported by the autonomy of the

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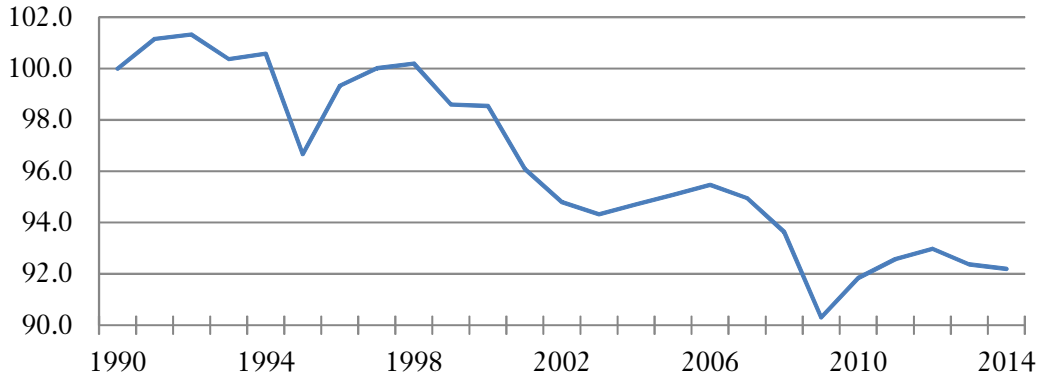
Chart 1: KLEMS Multifactor Productivity, Total Economy, Gross Output, Mexico, 1990-2014

1990=100



Source: National Geography and Statistics Institute of Mexico (INEGI).

Central Bank, an inflation targeting policy and transparency and accountability on the part of government bodies. Measures to promote economic stability were coupled with constitutional reforms to guarantee the rule of law, starting with the Supreme Court's independence.

The resulting macroeconomic stability has provided certainty to economic agents, reduced the cost of credit, and stimulated investment, especially after Mexico's entry into the North American Free Trade Agreement (NAFTA) in 1994.

By 2000, Mexico had become a democracy[2] and had opened its economy to free trade, eliminated numerous subsidies and privatized state enterprises that where generating distortions in the economy.[3] Sound fiscal policy reigned in public finances, an independent Central Bank guaranteed a solid and credible monetary policy,[4] and the Supreme Court oversaw the rule of law.

Despite these important steps, economic growth was insufficient: between 1980 and 2014, Mexico's real GDP grew at an annual average rate of only 2.4 per cent, only about half of the average growth observed in emerging and developing economies (4.6 per cent). The main reason for the mediocre economic growth performance over the last thirty years has been weak multifactor productivity (MFP) growth.[5]

Between 1990 and 2014, multifactor productivity (MFP) for the total economy in Mexico decreased by 7.8 per cent, the equivalent of an annual decrease of 0.3 per cent (Chart 1). Since

2 The PRI ruled in Mexico from 1929 to 2000, when the PAN won the Presidence. A gradual transition towards democracy had been on its way for years: in 1994 the major political parties negotiated an electoral reform, and in 1997 the PRI lost its majority in Congress.

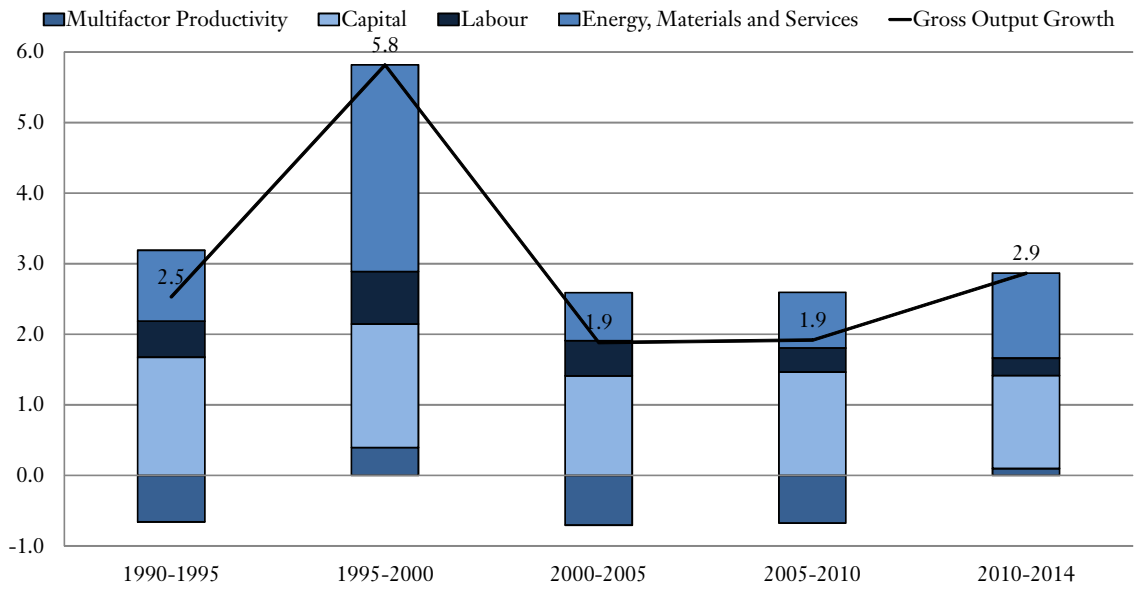
3 In some cases, however, privatization resulted in private monopolies, as in the case of the telecommunications sector.

4 The Central Bank's success in preserving the purchasing power of the peso is demonstrated by the three following facts: (1) in the 22-year period before its autonomy (1972-1994), the average annual inflation rate was 37.2 per cent, while in the 22-year period after its autonomy, the average inflation rate was 8.7 per cent; (2) in 1993, a year before it became autonomous, the annual inflation rate was 9.8 per cent, while in 2015, the annual inflation rate was 2.7 per cent; and (3) every single month since January 2015, the annual inflation rate has been within the Central Bank target of 3 per cent plus or minus 1 percentage point.

5 In terms of trends for the components of expenditure, private consumption (about 55 per cent of total demand) grew at an annual rate of about 2.5 per cent between 1980 and 2014, much less than exports (6.2 per cent). Total demand grew at an average annual growth rate of 2.9 per cent over the same period.

Chart 2: Multifactor Productivity, Capital, Labour and Intermediate Goods Contributions to Gross Output Growth, Total Economy, 1990-2014

Average Annual Percentage Point Contribution



Source: National Geography and Statistics Institute of Mexico (INEGI).

1995, the economic stabilization measures outlined above reduced the rate of decline in multifactor productivity, though not to the point of reversing the fall.

The objective of this article is to examine the policy and institutional responses of the Government of Mexico to the two decades of insufficient economic growth and lagging MFP. Hopefully, the Mexican experience will serve as an example to the other countries facing similar challenges. It is interesting to note that other studies, such as by the McKinsey Global Institute (2014), concur in their assessment of the main causes of lagging labour productivity in Mexico and the policies needed to address this situation.

What are then the causes behind the declining MFP levels in Mexico? What have been the consequences of factor misallocation? What are the public policy implications of large differences in productivity levels between sectors and regions of the economy?

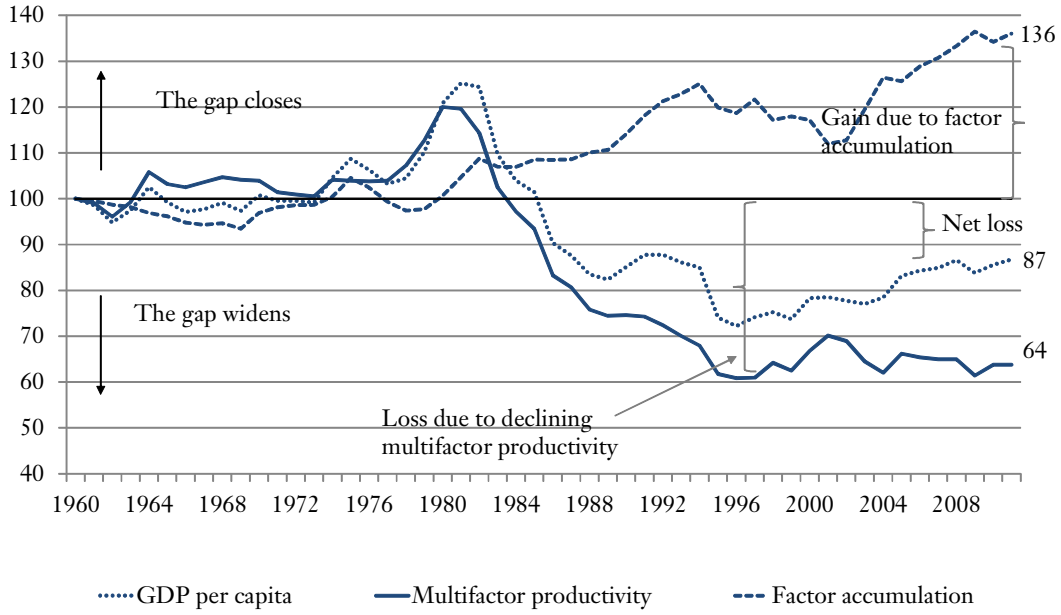
In the first major section of the article, we will focus on productivity trends, positing that factor misallocation is the main cause of the declining level of multifactor productivity since 1990. In section two, we examine the different realities of development at the regional and industry levels in Mexico. In section three we describe the productivity policy agenda of the Mexican government. Section four discusses the horizontal, vertical, and regional productivity strategies. Section five concludes.

Trends in Productivity Growth in Mexico

Multifactor Productivity

With the exception of the period between 1995 and 2000 and the period between 2010 and 2014, multifactor productivity has had a negative contribution to growth in Mexico since 1990, while factor accumulation, that is growth of all factors of production (labour, capital,

Chart 3: GDP Per Capita Gap: Mexico With Respect to the United States, 1960=100



Note: Factor accumulation includes the growth of physical capital intensity, human capital intensity, and the ratio of the labour force to the total population.

Source: Mexican Ministry of Finance and Public Credit from Daude and Fernández-Arias (2010), with data from Feenstra, Inklaar and Timmer (2013).

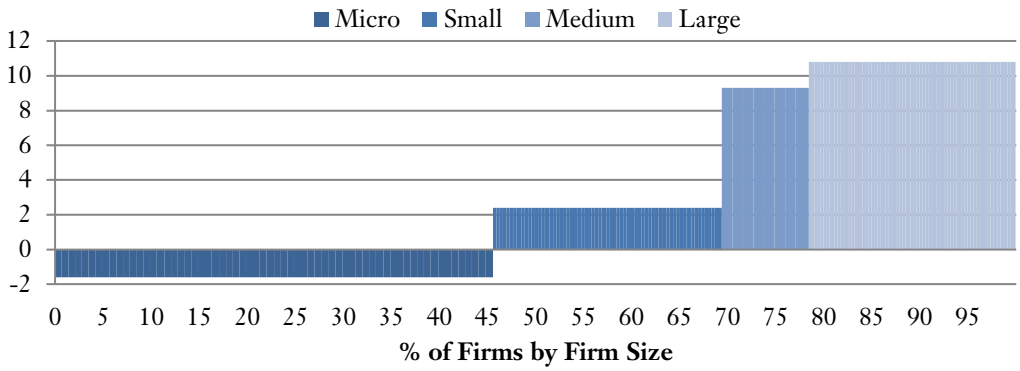
energy, raw materials, and services) has accounted for most of the economic growth registered in the period (Chart 2).[6] Over the past three decades, capital stock and labour input growth in Mexico have been faster than the United States, but the income gap between the two countries has widened (Chart 3). This gap is explained by declining multifactor productivity level in Mexico.

Even though Mexico has been affected by external shocks, such as the 2001 recession in the United States and the 2008-2009 global recession, the main causes of lagging MFP are internal. In particular, the disappointing productivity levels stem from a misallocation of productive resources, mainly labour and capital. Estimations show that aggregate MFP in Mexico would increase by 220 per cent if factors of production were allocated efficiently and all distortions were eliminated (Busso, Fazio, and Levy, 2012).

In Mexico, 6 out of 10 workers work in the informal sector (National Geography and Statistics Institute, 2005-2015). Barriers that impede the integration of workers into the formal economy include: low levels of educational attainment of the labour force; a mismatch between the skills demanded by the productive sector and workers' abilities; social security schemes that may reduce demand for workers in the formal sector; and a real or perceived mismatch between the costs and the benefits for a

6 The growth accounting approach used includes inputs of energy, raw materials, and services in addition to capital and labour. Specifically, gross output is defined as $f(x) = A(K, L, E, M, S)$. Hence, the growth accounting equation is expressed as $\Delta Y = \alpha\Delta K + \beta\Delta L + \gamma\Delta E + \varepsilon\Delta M + \theta\Delta S + \Delta A$. With capital (K), labour (L), energy (E), raw materials (M), and services (S). Each factor is weighted with its current price share in total gross output ($(\alpha, \beta, \gamma, \varepsilon, \theta)$). Being a residual measure, multifactor productivity growth is estimated as follows: $\Delta A = \Delta Y - \alpha\Delta K - \beta\Delta L - \gamma\Delta E - \varepsilon\Delta M - \theta\Delta S$.

Chart 4: Labour Productivity Growth by Firm Size, Annual Growth Rate, Per Cent, 2003-2008



Source: Ministry of Finance and Public Credit (2013) with data from OECD (2012).

firm to operate in the formal sector (taxes and costly regulations over access to credit and government programs).[7] Thus, the informal economy is absorbing resources that could be used more effectively in formal companies, which enjoy double the MFP of their informal sector counterparts. The entry of workers into the formal economy becomes even more pressing as the demographic dividend wanes (today the working-age population is around 65 per cent of total population).[8]

In addition to a patent misallocation of labour, capital is also not reaching the companies where it could be used most productively. Credit channeled through the financial sector represents 31.4 per cent of GDP in Mexico, well below the average for Latin America (53.3 per cent) and OECD member countries (145.4 per cent) (World Bank, 2015). The same goes for investment in the form of seed capital, business accelerators and entrepreneur funds. In Mexico, investment in these forms of private capital represents 0.06 per cent of GDP, less than one-third of the corresponding share in Chile or Brazil.[9]

Even though internal levels of credit to the private sector are still low, the Financial Reform[10] approved in January 2014 has had positive results in terms of both credit and savings figures. Between 2012 and 2015, internal credit to the private sector increased by almost five percentage points of GDP (from 25.7 per cent in 2012 to 30.6 per cent in 2015), while financial domestic savings increased from 55.8 per cent to 64.2 per cent of GDP.[11] According to data from the Ministry of Finance and Public Credit, interest rates for personal credits went down 8.5 percentage points and credit channeled through development banks increased 20.1 per cent in real terms (August 2014 versus August 2015). This evidence of a stronger financial system is encouraging, but there is still a long way to go

7 For discussion on this topic, see Levy (2008) and Arias *et al.* (2010).

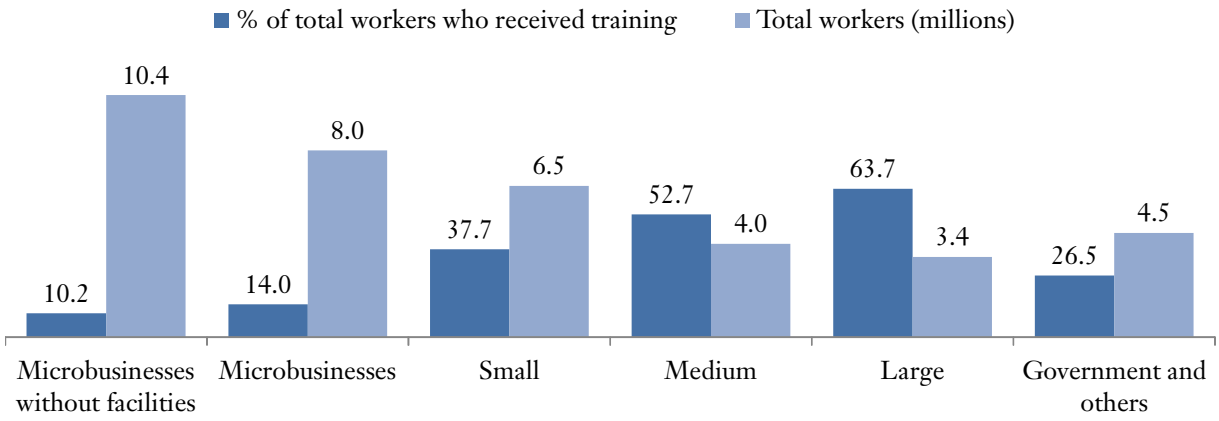
8 The "demographic dividend" refers to the window of opportunity for strong economic growth resulting from the rapid growth of the working-age population relative to the dependent population.

9 Mexican Ministry of Economics with data from Latin American Venture Capital Association and the Economic Commission for Latin America and the Caribbean (CEPAL).

10 The Reform entailed amendments to over 34 legal instruments and the enactment of the Law to Regulate Financial Groups.

11 Financial domestic savings should not be misconstrued as domestic savings.

Chart 5: Total Employment and the Share of Workers that Received Employer-Financed Training by Employer Category, Mexico, 2009



Source: Mexican Ministry of Finance and Public Credit with National Geography and Statistics Institute of Mexico (INEGI).

before the Mexican credit market can reach its full potential.

Labour Productivity

Overall, labour productivity growth has showed a positive trend, advancing 0.7 per cent per year between 2005 and 2014. But there has been considerable variation in labour productivity growth by firm size. During the 2003-2008 period, the productivity of the smallest companies in Mexico plunged 1.6 per cent per year. In contrast, medium and large enterprises showed an annual per cent growth of more than three times that of small production units (Chart 4).[12]

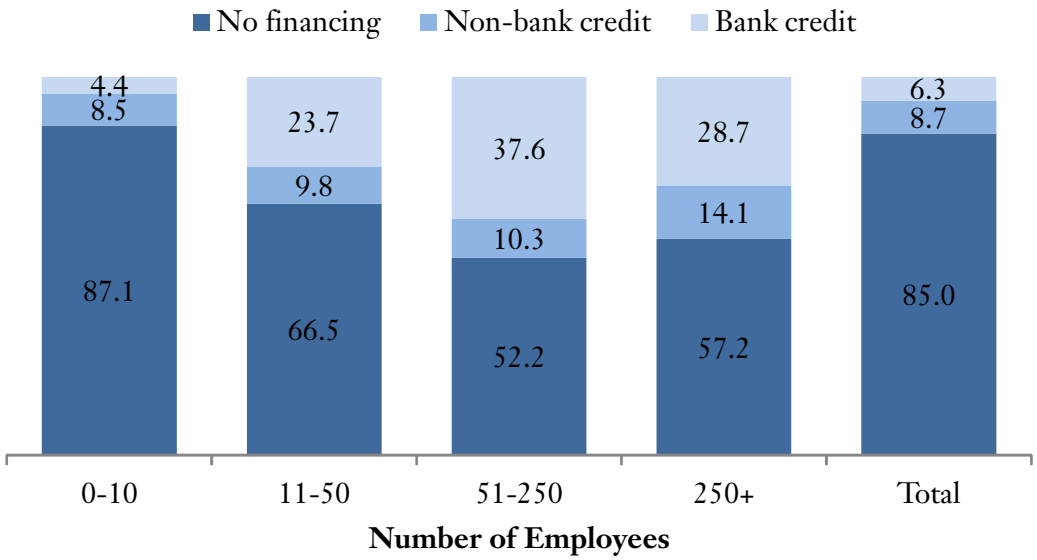
One of the causes behind weak labour productivity growth is a deficient school system that has failed to provide the quality education required by the labour market. According to the OECD, 51 per cent of Mexican students do not have the necessary knowledge and skills to perform well in a contemporary society, well above the OECD average of 22 per cent (OECD, 2010). Only 36 per cent of the working age population has a secondary school diploma (approximately 9 years of formal education), compared to 74 per cent for OECD countries.[13]

Only 40 per cent of the workers receive training funded by their employer with the incidence of workplace training rising with firm size (Chart 5) (IADB, 2014). The low quality of education and the low levels of educational attainment and workplace training directly affect the ability of workers to adopt new technologies and production methods and hinder their overall capacity to perform well in a knowledge-based society. Since evidence points to a positive relationship between the number of high performing students and the number of patent applications both across countries and across Mexican states, we should reinforce our educational system, so that it is capable of generating a critical number of high-skilled workers that can contribute to insert firms in the knowledge-based society. We need, thus, not only to increase the quality of education, but also the number of relevant fields of studies as well. Evi-

12 Firm size is determined through the weighted sum of the number of workers (10 per cent) and yearly profits (90 per cent).

13 In Mexico, secondary school ends after 9 years, unlike in Canada and the United States, where it ends after 12 years.

Chart 6: Credit Access for Manufacturing Companies by Firm Size (% of Total)



Source: Mexican Ministry of Finance and Public Credit based on information from the National Geography and Statistics Institute of Mexico (INEGI).

dence points to a positive relationship between relevant fields of study and the number of patent applications both across countries and across the Mexican states. Training should also reach those groups and sectors where it is more needed.

As we have seen, much of the growth that Mexico experienced has been based on rising labour supply. The demographic bonus, due to a sustained increase in working age population, has offset the decrease in multifactor productivity. However, as the demographic bonus fades by 2025, growth will necessarily rely more on labour productivity growth or on higher female labour force participation.

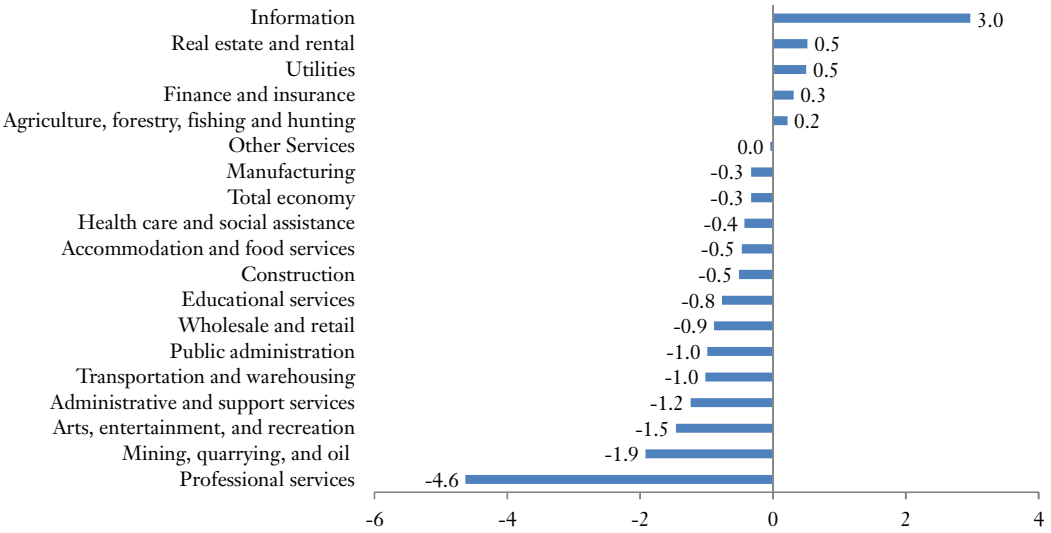
Capital Productivity

The availability of credit varies greatly by firm size. Credit goes primarily to large firms, while small and medium size enterprises suffer from an endemic lack of access to credit (Chart 6), especially when they most need it – during their first years of operation.

Low innovation activity within firms is another factor holding back capital productivity in Mexico. While advanced economy expenditure (both public and private) on R&D represents about 2 per cent of GDP, R&D expenditure in Mexico represented about 0.5 per cent of GDP in 2012. A goal of 1 per cent R&D expenditures as a per cent of GDP has been set for 2018. Furthermore, while in advanced economies about two-thirds of R&D expenditure is financed by the private sector and only one third is publicly funded, in Mexico, only one third of R&D expenditure is financed by the private sector and two-thirds is funded by the public sector. This is relevant because the private expenditure for R&D is more likely to have positive and significant impacts on productivity and is more likely to lead to patents. Thus, it is not surprising that patenting activity in Mexico is rather low: only 8.4 per cent of total patent applications in Mexico are by national individuals or firms. The rest are patents registered by foreigners.

The use of land for agricultural or urbanization purposes is also problematic. Nearly 70 per cent of arable land is comprised of small parcels

Chart 7: Multifactor Productivity by Sector, Annual Growth Rate, 1990-2014



Source: Mexican Ministry of Finance and Public Credit based on information from the National Geography and Statistics Institute of Mexico (INEGI).

(5 hectares or less) devoted to subsistence agriculture. These small parcels, in turn, produce 39 per cent of total agricultural production in the country. The inability of small producers to enjoy the benefits of economies of scale, to access better credit conditions, and to employ better cultivation techniques affects their overall productivity.

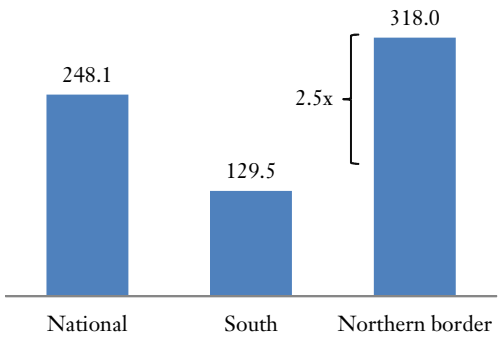
On the other hand, the process of urbanization in Mexico has been characterized by a disproportionate growth of the urban territory: while the urban population doubled over the last thirty years, urban territory grew six fold (Gobierno Federal, 2014). The unproductive use of urban territory which led to the expansion of low-income housing in the periphery of cities has had important negative consequences in terms of social cohesion, connectivity, and environmental impacts (Gobierno Federal, 2014).

Uneven Development: Sectoral and Regional

Latin America is home to 10 of the 15 most unequal countries in the world, including Mexico (United Nations Development Programme, 2016). The country's industrial base is comprised of global and national companies producing cars, parts for the aerospace industry, electronics, and other sophisticated equipment that requires state of the art technology for its production. Next to these highly developed industries lies a reality of subsistence agriculture, informal businesses and poverty. States such as Nuevo León are as productive as South Korea, while other states have productive capacities similar to Honduras (*The Economist*, 2015). Over 46.2 per cent of the population live in poverty and 33.4 per cent (8.5 million people) live in vulnerable conditions (Consejo Nacional para la Evaluación de la Política de Desarrollo Social, 2015).[14] These stark differences in living conditions and complexity of economic activities match the differences in terms of MFP of economic sectors and regions (Chart 7).

The least productive sectors (tourism, retail, and agriculture) represent nearly 51 per cent of the labour force, while the most productive sectors (manufacturing, professional and financial services, transport, and electricity, among others) only account for 28.2 per cent. This patent misallocation of labour and other factors of production calls for a structural change, i.e. the

Chart 8: Productivity Levels by Region in Constant Thousands Pesos Per Employed Person, Mexico, 2014



Note: Southern states include Guerrero, Chiapas and Oaxaca. Output excludes mining activities.

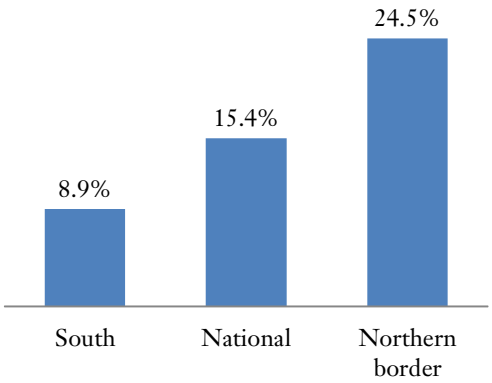
Source: Mexican Ministry of Finance and Public Credit based on information from the National Geography and Statistics Institute of Mexico (INEGI).

movement of productive resources to activities where they can be used more efficiently. Although the process of structural transformation that reallocates resources toward high-productivity activities has taken place, it has done so rather slowly.

There is also significant variation in regional labour productivity levels. This gap is particularly salient between the northern and southern states (Chart 8). In the south, fewer people are employed in manufacturing (Chart 9), while informality and poverty are higher. However, disparities in per capita output and productivity between the northern and southern states of Mexico have not always been persistent. A number of studies (e.g. Esquivel and Messmacher, 2002) have found that Mexico's measures of regional income and labour productivity inequality experienced a steady decrease between 1970 and 1985. This trend was reversed during the 1990s, when Mexico opened up its borders to trade and integrated with the North American market (Esquivel and Messmacher, 2002).

The widening gap in labour productivity levels between Mexico's north and south has been associated with better infrastructure and human capital in the former (Esquivel and Messmacher, 2002). These two factors were critical during Mexico's economic transformation in the 1990s, allowing businesses in the north to attract investment and industrialize faster, while the south remained trapped in a downward spiral of low productivity, low wages and erosion of human capital.

Chart 9: Manufacturing Employment as a Share of Total Employment by Region, Per Cent, 2015



Source: Mexican Ministry of Finance and Public Credit based on information from the National Geography and Statistics Institute of Mexico (INEGI).

14 The population that lives under income vulnerability and social vulnerability is defined differently from the population living under poverty. A person is considered to live under poverty conditions if she meets two requirements: (1) she has an income level lower than the well-being threshold (calculated as the income needed to afford basic food and non-food baskets of goods and services), and (2) she is deprived in at least one of six main social dimensions: educational attainment, access to health services, social security ot housing with adequate quality space, basic housing services and access to food. In contrast, the vulnerable population meets only one of the two aformentioned characteristics. 7.1 per cent of the population live under income vulnerability, which means that their income is below the well-being threshold (minimum income to cover nourishment and basic services) and 33.4 per cent of the population live under social vulnerability conditions, which means that while their income is above the well-being threshold, they do not have access to one or more basic services or proper nourishment.

Placing Productivity at the Centre of the Policy Agenda

A Comprehensive Agenda of Structural Reforms

Structural reforms have had positive impacts on the labour productivity, MFP and competitiveness of businesses. The current Administration (2012-2018) has pursued an ambitious reform agenda with three objectives: (i) to boost economic growth through labour and multifactor productivity; (ii) to guarantee the rule of law and the rights of the Mexican citizens; and (iii) to shield the roots of the democratic regime. In total, 11 reforms were approved by a coalition of the three main parties in power. Among the important reforms aimed at increasing productivity and improving the performance of markets, are those related to energy, fiscal issues, the financial sector, education, labour and competition policy.

The implementation of the reforms has already yielded positive results: the 2014 fiscal reform increased tax revenues by 4.6 per cent of GDP and decreased the government's dependence on oil revenues from 39.4 per cent to under 18 per cent of total revenues. Furthermore, since the reform was enacted, the number of taxpayers has increased by 10.2 million, and the informality rate has declined from 59.8 per cent in 2012 to 57.9 per cent in 2015. More competition in the telecommunications sector has resulted in lower telecom costs and more opportunities for investment in advanced technologies: the price of international long distance calls was been reduced by over 40 per cent and mobile rates by 34 per cent between June 2013 and March 2016. In addition, the reform has eliminated long distance charges for all calls within Mexico. The new legislation has spurred investment of over $8 billion USD by new entrants to the market, including a $7.4 billion USD investment from AT&T.

As to energy reform, gasoline and diesel prices have dropped 3 per cent, the first price decline in Mexico for this category since 1991. This is only the immediate impact: the energy reform allows private companies –domestic and foreign– to participate in both oil and electricity, at different stages of the production process. As a result of this major shift in energy policy, we estimate an impact on investment of $6.9 billion USD in the oil sector in the coming years, which – of course – would lower energy prices. This reform will also strengthen national value chains and help to develop a high productivity energy sector.

Institutional Framework to Place Productivity at the Centre of the Policy Agenda

Beginning with the establishment of the cross-cutting strategy "democratizing productivity" in the National Development Plan for the period 2013-2018, the federal government has implemented a series of measures to place productivity at the center of the policy agenda. This cross-cutting strategy required that every federal government program be designed with the aim of increasing productivity in a specific sector, region or population group. Parallel to this effort, the Economic Productivity Unit was established as part of the Ministry of Finance and Public Credit, to follow the evolution of productivity indicators and oversee the implementation of the federal government's productivity strategy. The macro perspective of the Ministry of Finance and Public Credit and its close connection to all other government agencies in budgetary matters made the creation of the Productivity Unit inside this Ministry a natural choice. The Unit was tasked with devising a plan to implement the Democratizing Productivity Strategy, setting the model for a public-private productivity association (the National Productivity Commission or Comité Nacional

de Productividad (CNP)), and reviewing the operation of relevant federal programs with impacts on both labour and multifactor productivity, among others.

First on the Productivity Unit's agenda was the creation in May 2013 of a public-private association to promote labour and multifactor productivity-enhancing policies, the National Productivity Commission. The CNP is an advisory body to the executive and the business sector in matters related to economic growth and productivity. The Commission is chaired by the Finance Minister and the President of Mexico has acted as Honorary President since May 2015. The Ministries of Economics, Labour, and Education are also members, as well as the National Council of Science and Technology, five business associations, five labour unions, four universities and two technical training institutions.

Second on the agenda was the implementation of the cross-cutting democratizing productivity strategy. The Special Program to Democratize Productivity, a product of thorough background research into the causes of the declining multifactor productivity levels in Mexico, was published in August 2013. The program focused on five specific objectives, 19 strategies and more than 100 tasks assigned to one or more of the 20 federal government agencies. The tasks ranged from actions aimed at increasing labour market flexibility and improving the rule of law and the regulatory framework for businesses.

The program also included six indicators with specific targets: (i) informality rate (share of informal workers in total employment); (ii) labour productivity; (iii) R&D as percentage of the GDP; (iv) days to start a business; (v) labour productivity in the south-southeastern region; and (vi) multifactor productivity. Some of these indicators are already showing improvements. For example, the informality rate, as previously mentioned, declined from 59.8 per cent in 2012 to 57.9 per cent in 2015. Investment in R&D increased from 0.49 per cent of GDP in 2012 to 0.55 per cent in 2015. Finally, labour productivity has increased 0.8 per cent per year between 2012 and 2015.

The productivity agenda in Mexico was further reinforced with key partnerships with the international community. On the initiative of the Finance Minister, Mexico hosted the OECD's Global Dialogue on the Future of Productivity in July 2015. At this event OECD member countries and experts from around the world shared their views on productivity and growth and agreed to create an OECD Productivity Network to foster collaboration on productivity research and policy issues. The 2016 OECD Conference of the Global Forum on Productivity, to be held in July in Lisbon, Portugal, will have as its core topic the role of structural reforms in enhancing productivity.

Two Key Innovations: The National Productivity Commission and the Productivity Competitiveness Law

There are varying examples of tripartite productivity-oriented institutions throughout the world.[15] None have had the composition and characteristics of the Mexican National Productivity Commission (CNP). Gary Banks (2015), former Chairman of the Australian Productivity Commission, listed the necessary features that a productivity-oriented institution should possess to be effective:

- the skills to produce technically sound research and implementable advice;
- a mandate to focus on the longer-term;

15 Examples of such institutions include the Australian Economic and Advisory Council, the Economic Council of Canada from 1961 to 1992 (Banks, 2015), and the Canadian Labour Market and Productivity Centre, in operation from 1986 to 2006.

- sufficient 'independence' to ensure that their work is not susceptible to undue influence by special interests; and
- operating procedures that subject all their work to public input and scrutiny.

One can make the case that the CNP has these features:

- the Economic Productivity Unit's role as the technical secretariat of the CNP ensures that all policy recommendations have technical support;
- thanks to the 2015 Productivity and Competitiveness Law, the CNP's initiatives are now part of the federal government's long-term planning process; and
- the CNP prioritizes consensus and, in the case that it does not exist, the agreements only will happen by majority vote. This makes its research, findings, and recommendations not susceptible to undue influence.
- in terms of transparency, and as in the case of all other bodies with governmental participation, the Commission's processes are subject to review by the Federal Audit Organization and open to public scrutiny.

To ensure the continuation of the productivity agenda in future administrations as well as the survival of the National Productivity Commission, the Congress passed the Productivity and Competitiveness Law in 2015. This instrument provides a solid institutional framework to promote productivity in the long term. The Law included provisions in three key aspects: 1) the establishment of a long-term industrial policy with a 20-year time frame and policies for specific regions and sectors of the economy; 2) the establishment of a statutory basis for the National Productivity Commission; and 3) the alignment of budget programs and investment projects with productivity goals.

Long-Term Development Policy

After more than 20 years of free market policies, the Productivity and Competitiveness Law provided for the implementation of long-term development policy, implemented through a special economic development plan. According to the Productivity and Competitiveness Law, the plan should include strategies at three levels: 1) cross-cutting strategies related to innovation, labour productivity, technical training, credit for SMEs, investment in infrastructure, and connectivity and regulatory improvement; 2) strategies aimed at developing specific, high-productivity, capital and knowledge-intensive sectors as well as strategies to transform low labour and multifactor productivity, labour-intensive economic sectors; and 3) regional strategies to promote clusters and boost the development of the most underdeveloped regions in the country. The plan should also include actions in the short, medium and long-term as well as performance indicators. Within the framework provided by this Law, the Ministry of Finance and Public Credit is responsible for the design of the special economic development plan with the support of the Ministry of Economy and the National Productivity Commission.

Enhanced Role of the National Productivity Commission

The Productivity and Competitiveness Law named the President of Mexico the Honorary Chair of the National Productivity Commission, giving the organization a higher profile. The Commission was further strengthened with the capacity to put forward recommendations on matters related to national development policy. The recommendations are binding for the federal government.

The Commission can also issue recommendations to state and municipal governments, State Productivity Commissions, and to the social and

private sectors. Although not of a binding nature, the Commission can sign agreements with each relevant institution and private and social organization to implement the recommendations. Each recommendation is accompanied by a "commitment matrix" that lists specific actions, implementation deadlines and performance indicators.

The authority to issue recommendations is of special importance for the implementation of horizontal, vertical and regional productivity strategies, developed by the CNP, as discussed below.

Horizontal, Vertical and Regional Productivity Strategies

The CNP's horizontal strategy pursues three main objectives, around which five working groups have been formed: 1) to increase the productivity of the labour force through skills and technical training and work incentives; 2) to increase the productivity of capital through support for SMEs and entrepreneurs in innovation and technology adoption; and 3) to improve the allocation of factors of production by increasing the formalization of the economy and the provision of credit to SMEs. To date the working groups have held more than 100 meetings. Each working group includes representatives of the relevant Commission's constituencies, as well as special guests, depending on the agenda. Most of the Commission's initiatives are developed by the working groups and then subjected to approval in plenary sessions.

One of the main projects in the Commission's agenda is the preparation of a Lifelong Skills Formation Strategy for Mexico. This project will be developed in collabouration with the OECD. The Lifelong Skills Formation Strategy will be a long-term plan focused on technical education and on-the-job training, and seeks to create a unified skills system, aligned with both the national development strategy and the CNP agenda. This ambitious project would not have been possible without the new framework provided by the Productivity and Competitiveness Law, that allows for long-term projects such as these to be embedded in the overall national development plan.

The plan also seeks to address the need for skilled labour in highly productive sectors based on labour market trends and other prospective instruments.[16] A small group was formed inside the Commission to oversee the project. The experience of inter-ministerial and public-private collaboration over the two-year existence of the CNP has proved very valuable in the conduct of intergovernmental efforts.

The vertical strategy aims to generate structural change in the economy, expanding the most productive sectors and transforming traditional sectors. The Commission began by selecting eight economic sectors based on qualitative and quantitative criteria, including complexity analysis. The sectors were grouped in three categories: 1) high labour and multifactor productivity sectors with high growth potential (auto parts, aerospace procurement, electrical and electronics, and the agro-industrial sector); 2) high employment and low productivity sectors (retail trade, tourism, and gastronomy); and 3) sectors with high growth opportunity due to economic reforms (energy).

Regional Agenda

The activities related to the eight sectors selected by the CNP represent more than 50 per cent of total production in 27 out of the 32 states

16 Other prospective instruments include labour market intelligence and school-business collaboration, which allow the identification of present and future skills needs at regional, sectoral and industry levels for the provision of relevant educational and training opportunities.

in Mexico. This guarantees a greater impact of the vertical strategy.

The regional agenda, on the other hand, is oriented towards the south-southeast region of the country. As mentioned earlier, there has been a historical divergence of labour productivity levels between northern and southern Mexico. In this regard, the CNP's task is to add a productivity component to the development plans for the Special Economic Zones (SEZs), which seek to attract investment and development to these zones.

The SEZs initiative includes fiscal and labour benefits, a special customs regime, infrastructure, and other special conditions on investment. The CNP will complement this strategy with human capital development initiatives, policies to promote technology transfer and credit programs directed to the areas of influence around each zone.

The Federal Law of Special Economic Zones, approved by Congress in April 2016 and enacted by President Peña Nieto in May 2016, seeks to close the regional gap in productivity by creating Special Economic Zones in the laggard regions of the country. Up to now, four Special Economic Zones have been announced: (i) Puerto Chiapas, in the state of Chiapas; (ii) Lazaro Cardenas Port and adjacent municipalities in the states of Guerrero and Michoacán; (iii) the Interoceanic Corridor in the Tehuantepec Isthmus, Salina Cruz in Oaxaca and Coatzacoalcos in Veracruz; and, (iv) a Special Economic Zone between Tabasco and Campeche, the states most severely affected by the downturn in the oil market. There are high expectations about the success of this initiative, but at least a couple of years will pass before results are visible.

Ensuring the Accountability and Alignment of Budget Programs with Productivity Goals

In 2014, the Economic Productivity Unit designed a productivity evaluation for 36 Budget Programs aligned with the objectives of the Special Program to Democratize Productivity. This evaluation resulted in the adjustment of the performance indicators, operation rules and other normative documents of the 36 programs to better address productivity objectives.

The Productivity and Competitiveness Law reinforced the productivity evaluation and extended it to all budget programs related to the objectives of the long-term development policy. From the enactment of the law, more than 88 programs, which represent 13.9 per cent of the budget for administrative units in 2016, have been evaluated and modified to increase their alignment with the productivity agenda.

Conclusion

Mexico's low economic growth stems from the misallocation of labour and capital, reflected in large labour and multifactor productivity gaps among sectors and regions. Beginning with a set of productivity-enhancing structural reforms, the Mexican Government has enacted a series of measures to place productivity at the center of the policy agenda. Not only is the goal of increasing productivity present in the government's plans and programs, but it is also at the core of an entire institutional framework. This institutional framework includes an administrative unit, the Productivity Unit in the Ministry of Finance and Public Credit, that oversees the implementation of the government's productivity strategy and a public-private organization – the National Productivity Commission – that brings together the public sector, workers, businesses and academia and has the authority to issue binding recommendations. The institutional framework is supported by a legal instru-

ment, the Productivity and Competitiveness Law, that provides for the implementation of a long-term economic development plan.

Even though the results of both the structural reforms and of the productivity-enhancing policies will only be fully visible in the long-term, there are already early signs that the actions are working well, as reflected by increased competition in several sectors and by lower costs of basic inputs.

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A Comparison of Productivity Developments in Canada and Australia: Lessons for Canada

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ABSTRACT

The objective of this report is to examine the impact of public policy on Australia's productivity performance and to discuss possible lessons for Canada from this experience. To do this, the report conducts a comprehensive analysis of the productivity performance of both countries, with particular interest in determining which underlying factors can explain Australia's superior productivity growth in recent years. In addition, the report discusses the literature on the effects of public policy on Australian productivity performance since the 1990s.

AUSTRALIA AND CANADA share much in common. The countries have similar institutions based on their historical ties to the United Kingdom, enjoy high standards of living, have large natural resource sectors, accept large numbers of immigrants, and have experienced similar labour market performance. But one area where the two countries have diverged in recent years is productivity performance. Indeed, Australia has significantly outperformed Canada, with labour productivity growing at an average annual rate of 2.33 per cent in Australia since 1994 compared to only 1.31 per cent in Canada.

The objective of the article is to examine the impact of public policy on Australia's productivity performance and to discuss possible lessons for Canada from this experience. To do this, the article conducts a comprehensive analysis of the productivity performance of both countries, with particular interest in determining which underlying factors can explain Australia's superior productivity growth in recent years. It also discusses the literature on the effect of public policy on Australian productivity performance since the 1990s.

The article is organized as follows. The first section presents data on labour productivity growth in Canada and Australia at the aggregate and industry level.[2] The second section examines the drivers of labour productivity growth in Australia and Canada, with an emphasis on growth accounting and industry decomposition

1 Evan Capeluck was an economist at the Centre for the Study of Living Standards (CSLS) at the time of writing. The author would like to thank Andrew Sharpe and Alexander Murray from the CSLS, Bert Waslander, and Shiji Zhao from the Australian Productivity Commission for their comments and contributions. The author would also like to thank Matthew Calver, Jasmin Thomas, Erika Rodrigues, Nico Palesch, and Alexander Benjamin Rand for their contributions. Finally, the author would also like to thank Industry Canada for funding and Jim Stanford for comments received in his role as discussant on the paper at the 49th Canadian Economics Association Annual Meeting, May 29-May 31, 2015 at Ryerson University in Toronto, Ontario. This article is an abridged version of Capeluck (2016). Email: evancapeluck@gmail.com.

2 While this article focuses on labour productivity, Capeluck (2016) also compares Canada and Australia's capital and multifactor productivity performance at the aggregate and industry level. Australia's multifactor productivity growth exceeded that of Canada over the 1994-2013 period.

Table 1: Labour Productivity Growth and Related Measures, Compound Annual Growth Rates, Per Cent, Canada and Australia, 1994-2013

Period	Canada			Australia		
	Labour productivity	Real value added	Hours worked	Labour productivity	Real value added	Hours worked
1994-2013	1.31	2.77	1.45	2.33	3.52	1.17
1994-2000	2.16	4.80	2.57	2.95	4.23	1.24
2000-2013	0.92	1.85	0.93	2.04	3.20	1.14
2000-2008	0.88	2.19	1.30	1.79	3.47	1.65
2008-2013	0.97	1.32	0.34	2.44	2.78	0.33

Note: The estimates for Canada are for the business sector. The estimates for Australia are for the market sector.

Source: CSLS calculations based on Statistics Canada and ABS data. ABS: 5260.0.55.002. Statistics Canada: 383-0021

exercises. The impact of other factors not captured in these exercises that have been identified in the literature as contributing to productivity growth will also be discussed. The third section looks at the contribution of public policy to Australia's superior productivity performance. Finally, the fourth section summarizes the main findings and discusses the relevance and implications of the public policies adopted in Australia for Canada.

Productivity Trends

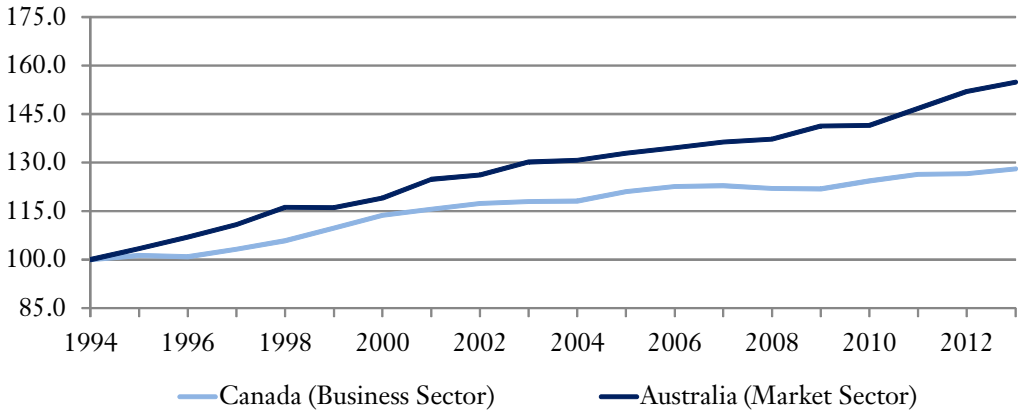
Aggregate Level

In Canada, business sector labour productivity increased at an annual rate of 1.31 per cent between 1994 and 2013, well below the growth rate exhibited by Australia (2.33 per cent) (Table 1). Australia exhibited stronger growth in total economy labour productivity than Canada in every sub-period between 1994 and 2013. For example, total economy labour productivity was 0.79 percentage point stronger in 1994-2000 and 1.12 percentage point stronger in 2000-2013. The higher growth in business sector labour productivity in Australia was attributable to both stronger real value added growth and weaker growth in total hours worked.

Both countries exhibited a significant slowdown in labour productivity growth between 1994-2000 and 2000-2013. In Australia, business sector labour productivity growth was down 0.91 percentage points from 1994-2000 to 2000-2013. The labour productivity slowdown was much more stark in Canada, with a decline of 1.25 percentage points. Labour productivity declined in both countries between these two periods because the slowdown in real value added growth was much larger than the decline in hours worked growth.

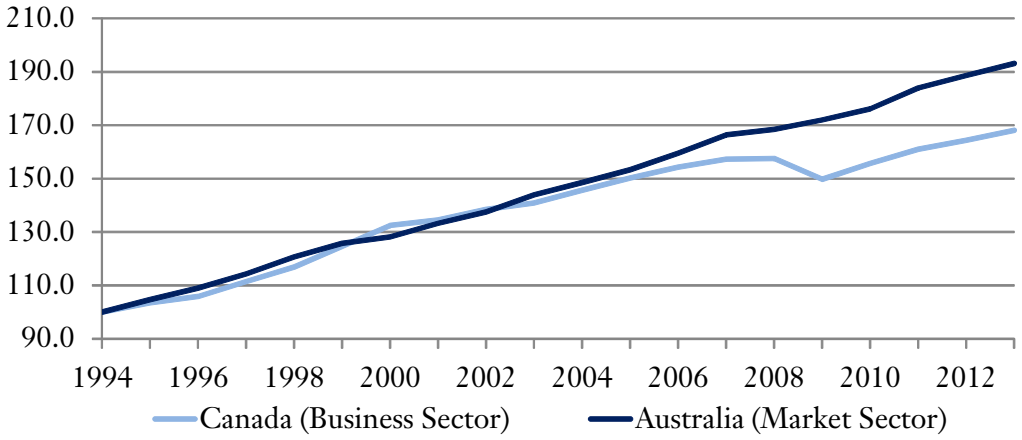
Australia outperformed Canada over the entire 1994-2013 period in terms of business sector labour productivity growth (Chart 1). In 2013, business sector labour productivity was 54.9 per cent above its 1994 level in Australia and 28.0 per cent above its 1994 level in Canada.

Chart 1: Index of Labour Productivity, Canada and Australia, 1994-2013



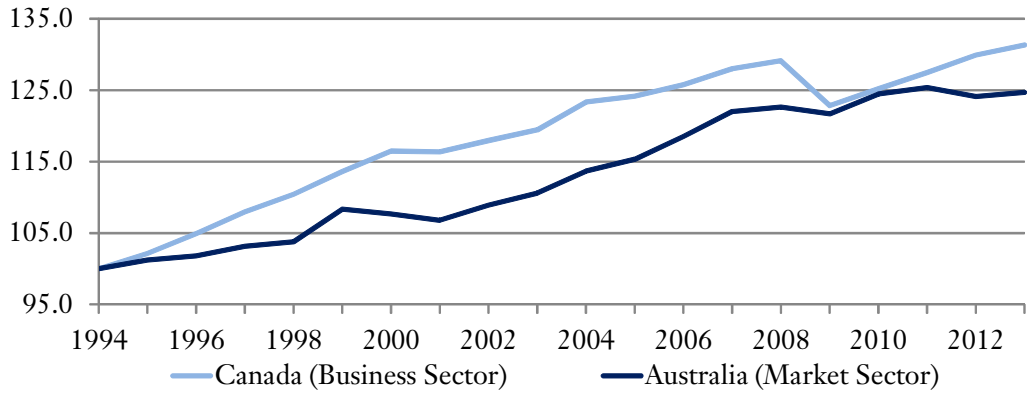
Source: CSLS calculations based on StatCan and ABS data. ABS: 5260.0.55.002 and 5204.015. StatCan: 383-0021.

Chart 2: Index of Real Value Added, Canada and Australia, 1994-2013



Source: CSLS calculations based on StatCan and ABS data. ABS: 5260.0.55.002 and 5204.015. StatCan: 383-0021

Chart 3: Index of Hours Worked, Canada and Australia, 1994-2013



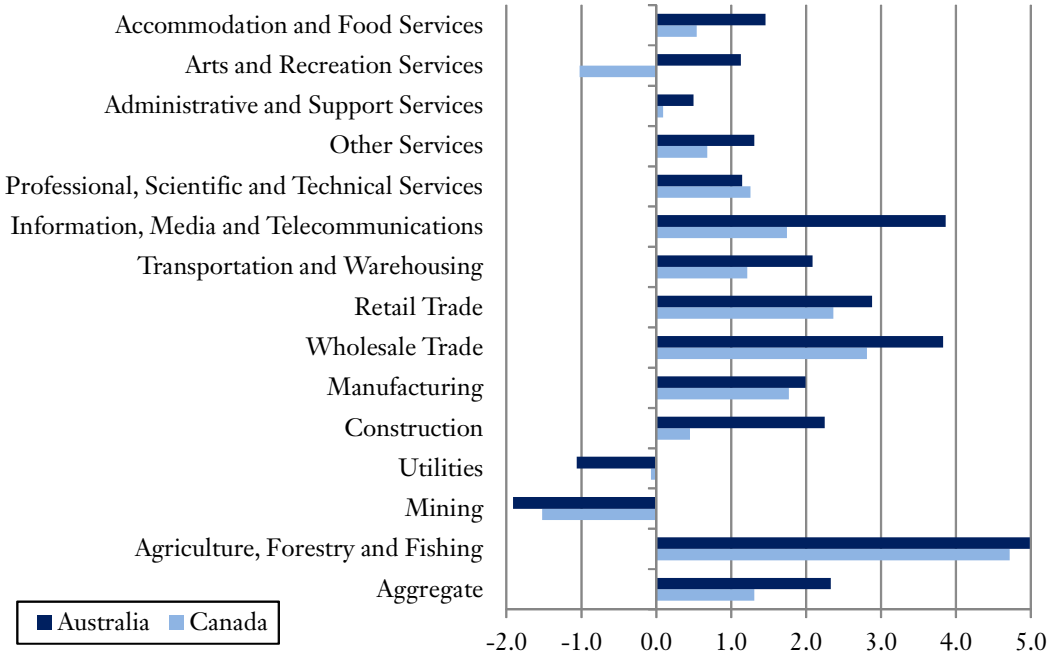
Source: CSLS calculations based on StatCan and ABS data. ABS: 5260.0.55.002 and 5204.015. StatCan: 383-0021

The weaker business sector labour productivity growth exhibited by Canada over much of the 1994-2013 period was driven by higher hours worked growth as opposed to lower real value added growth (Chart 2 and Chart 3). Canada's business sector kept pace with its Australian counterpart in terms of real value added growth from 1994 to 2006, while it surpassed its Australian counterpart in terms of growth in total hours worked. Following 2006, growth in both real value added and total hours worked slowed significantly in Canada relative to Australia, largely attributable to the 2008-09 recession.

Industry Level

Between 1994 and 2013, Australia outperformed Canada in terms of labour productivity growth in every industry except for utilities, mining, and professional and technical services (Chart 4). Some of the most striking cases were: arts and recreation services, where Australia saw labour productivity growth that was 2.15 percentage points higher than Canada; information media and telecommunications (2.12 percentage points); and construction (1.80 percentage points). In the aggregate, Australia exhibited labour productivity growth that was 1.02 percentage points higher than what was seen in Canada.

Chart 4: Labour Productivity Growth, Business/Market Sector Industries, Compound Annual Growth Rates, Per Cent, Canada and Australia, 1994-2013



Note: "Aggregate" refers to the business sector for Canada and the market sector for Australia.
Source: CSLS calculations based on Statistics Canada and ABS data. ABS: 5260.0.55.002. Statistics Canada: 383-0021.

In both countries, agriculture, forestry and fishing exhibited the strongest labour productivity performance, followed by wholesale trade and retail trade. In contrast, labour productivity growth was negative in mining and, to a lesser extent, in utilities in both countries.

The overall quality of the natural resource base can have an important effect on productivity. *Ceteris paribus*, easily accessible and high-quality natural resources will lead to lower costs and higher productivity than hard-to-reach and low-quality natural resources (Topp and Kulys, 2014; Sharpe and Waslander, 2014).[3] This could explain the negative labour productivity growth exhibited by mining and oil and gas extraction in both economies in 1994-2013. Gordon (2013) provides another possible explanation for weak MFP growth in resource-extraction industries called the "time-to-build" bias. Since there is often a gap of several years between when investment in an extraction facility begins and when production commences, there will be a period where investment is increasing with no corresponding increase in output. This would show up as negative MFP growth.

International Comparison

An international comparison of labour productivity growth rates in 2000-2014 across OECD countries suggests that the gap between Canada and Australia is due to both an weak performance in Canada and an strong performance in Australia. In fact, Australia exhibited labour productivity growth of 1.46 per cent per year in this period, 0.22 percentage point above the OECD average (1.24 per cent per year). Austra-

3 Gordon (2013) refers to this as the "low-hanging fruit" bias. Firms have an inventive to "start with the high-quality, low-cost plays and, when these are exhausted, move on to deposits that are of lower quality and are more costly." As firms move on to lower quality deposits, firms will need to employ an increasing amount of capital to produce a given level of output. This would show up as negative MFP growth.

Table 2: Sources of Labour Productivity Growth, Business/Market Sector, Compound Annual Growth Rates, Percentage Points, Canada and Australia, 1994-2013

Period	Canada				Australia			
	LP	MFP	CI	LC	LP	MFP	CI	LC
1994-2013	1.31	0.07	0.94	0.29	2.33	0.37	1.66	0.29
1994-2000	2.16	0.87	0.91	0.37	2.96	1.28	1.34	0.31
2000-2013	0.92	-0.29	0.95	0.26	2.04	-0.05	1.81	0.27
2000-2008	0.88	-0.50	1.11	0.27	1.79	-0.10	1.63	0.26
2008-2013	0.97	0.03	0.71	0.23	2.44	0.03	2.10	0.30

Note: "LP" stands for labour productivity. "CI" stands for capital intensity. "LC" stands for labour composition. The estimates for Canada are for the business sector. The estimates for Australia are for the market sector.
Source: CSLS calculations based on Statistics Canada and ABS data. ABS: 5260.0.55.002. Statistics Canada: 383-0021.

lia ranked 15th among the 37 countries included in the comparison. In contrast, labour productivity increased at an annual rate of 0.96 per cent in Canada, 0.29 percentage point below the OECD average. Canada ranked 26th among the 37 countries included in the comparison.

Explaining Divergent Productivity Trends

Growth Accounting

A good starting point for any discussion on the dynamics of productivity growth is the standard neo-classical growth accounting model. According to the framework, contributions to labour productivity growth can be broken down into three factors: 1) capital services intensity growth; 2) labour composition growth (or human capital development); and 3) multifactor productivity (MFP) growth.[4] They are often referred to as the sources of labour productivity growth. It is important to keep in mind, however, that they are (in general) only proximate causes of growth, and can be affected by several underlying factors.

Between 1994 and 2013, labour productivity growth in Canada and in Australia was driven by capital intensity, representing over 70 per cent of growth in each country (Table 2). However, the next largest contributor to labour productivity in Australia was MFP (15.8 per cent), while it was labour composition in Canada (22.4 per cent). It is important to note that the disparity in the contribution of capital intensity between Canada and Australia was quite large, at 0.72 percentage points, accounting for 71.1 per cent of the overall gap in labour productivity growth between the two countries. The remaining 28.8 per cent of the overall gap was due to higher MFP growth in Australia compared to Canada, while Canada's higher labour composition growth contributed a negligibly to the overall gap.

When broken down into sub-periods, Australia shows higher values for each component in almost every breakdown. The only exceptions are labour composition in the period 1994-2000 and 2000-2008, as well as MFP growth in 2008-2013. A larger contribution from capital intensity growth was consistently the main driver of the stronger labour productivity growth rate of Australia across the sub-periods.

Industry Decomposition

Aggregate labour productivity growth reflects the productivity performance of each constituent part as well as changes in the composition of the economy. The aggregate labour productivity level is (approximately) the weighted average of sectoral labour productivity levels, with the

4 See Capeluck (2016) for a detailed discussion of these factors.

Table 3: Decomposition of Aggregate Labour Productivity Growth, Canada and Australia, 1994-2013

	Canada				Australia			
	Aggregate	WSE	RLE	RGE	Aggregate	WSE	RLE	RGE
Percentage Point Contribution to Aggregate Labour Productivity Growth								
1994-2013	1.31	1.25	0.28	-0.22	2.33	1.94	0.76	-0.37
1994-2000	2.16	2.33	-0.10	-0.07	2.95	3.29	-0.10	-0.23
2000-2013	0.92	0.78	0.34	-0.21	2.04	1.46	1.37	-0.78
Percentage Contribution to Aggregate Labour Productivity Growth								
1994-2013	100.0	95.1	21.5	-16.5	100.0	83.2	32.5	-15.8
1994-2000	100.0	107.5	-4.4	-3.1	100.0	111.2	-3.5	-7.7
2000-2013	100.0	85.4	37.4	-22.8	100.0	71.5	67.0	-38.5

Note: "WSE" stands for "within-sector effect." "RLE" stands for "reallocation level effect." "RGE" stands for "reallocation growth effect." "Aggregate" refers to the business sector for Canada and the market sector for Australia.

Source: CSLS calculations based on Statistics Canada and ABS data. Statistics Canada: 383-0029 and 383-0021. ABS: 5204.005, 6291.0.55.003 and 5260.0.55.002.

weights being equal to each sector's labour input share.

Using the framework developed by Sharpe and Thomson (2010), we can determine the industry contributions to aggregate labour productivity growth in Canada and Australia.[5] In the framework, the absolute change in aggregate real labour productivity between two periods is (approximately) equal to the sum of the three components:

- the within-sector effect (WSE) measures the contribution to aggregate productivity growth due solely to the productivity increase experienced by individual sectors;
- the reallocation level effect (RLE) captures the contribution to aggregate labour productivity growth from labour movements from sectors with below-average labour productivity levels to sectors with above-average labour productivity levels; and
- the reallocation growth effect (RGE) captures the contribution to aggregate labour productivity growth from labour movements from sectors with below-average labour productivity growth to sectors with above-average labour productivity growth.

Table 4: Decomposition of Absolute Difference in Aggregate Labour Productivity Growth Between Australia and Canada, 1994-2013

	Aggregate	WSE	RLE	RGE
Absolute Difference in Growth Rates (Percentage Points)				
1994-2013	1.02	0.69	0.48	-0.15
1994-2000	0.79	0.96	-0.01	-0.16
2000-2013	1.12	0.67	1.02	-0.58
Share of Absolute Difference (Per Cent)				
1994-2013	100.0	68.0	46.8	-14.8
1994-2000	100.0	121.2	-0.8	-20.4
2000-2013	100.0	60.1	91.2	-51.3

Note: "WSE" stands for "within-sector effect." "RLE" stands for "reallocation level effect." "RGE" stands for "reallocation growth effect." "Aggregate" refers to the business sector for Canada and the market sector for Australia.

Source: CSLS calculations based on Statistics Canada and ABS data. Statistics Canada: 383-0029 and 383-0021. ABS: 5204.005, 6291.0.55.003 and 5260.0.55.002.

We will now present industry contributions to aggregate labour productivity growth broken down into the above-noted effects in Canada and Australia for 1994-2013. This period is broken down into two sub-periods: 1994-2000 and 2000-2013.

Within-sector effects contributed the most to aggregate labour productivity growth in both countries in 1994-2013 (Table 3). In 1994-2000, within-sector effects accounted for all of the

5 Refer to Capeluck (2016) for a detailed discussion of the decomposition framework.

Table 5: Industry Contributions to Aggregate Labour Productivity Growth, Canada, 1994-2013

	Aggregate	WSE	RLE	RGE
Percentage Point Contribution to Aggregate Labour Productivity Growth				
Business sector	1.31	1.25	0.28	-0.22
Agriculture, forestry, fishing and hunting	0.20	0.17	0.08	-0.04
Mining and oil and gas extraction	-0.01	-0.16	0.23	-0.07
Utilities	-0.01	0.00	0.00	0.00
Construction	0.01	0.04	0.00	-0.03
Manufacturing	0.33	0.37	-0.01	-0.04
Wholesale trade	0.19	0.19	0.00	0.00
Retail trade	0.18	0.17	0.01	0.00
Transportation and warehousing	0.06	0.07	0.00	0.00
Information and cultural industries	0.08	0.06	0.01	0.00
Finance, insurance, real estate and rental and leasing	0.25	0.23	0.01	0.01
Professional, scientific and technical services	0.05	0.07	-0.01	0.00
Administrative and support, waste management and remediation services	-0.05	0.00	-0.03	-0.03
Arts, entertainment and recreation	-0.02	-0.01	-0.01	-0.01
Accommodation and food services	0.02	0.02	0.00	0.00
Other private services	0.03	0.04	-0.01	0.00
Percentage Contribution to the Business Sector Total				
Business sector	100.0	100.0	100.0	100.0
Agriculture, forestry, fishing and hunting	15.6	13.3	29.1	19.9
Mining and oil and gas extraction	-0.6	-13.2	82.2	34.3
Utilities	-0.4	-0.2	-1.2	-0.1
Construction	0.5	3.0	-1.1	12.9
Manufacturing	24.8	29.8	-2.8	17.3
Wholesale trade	14.6	15.5	0.4	1.2
Retail trade	13.5	13.3	3.9	-0.3
Transportation and warehousing	5.0	5.3	-0.4	0.2
Information and cultural industries	5.9	5.1	3.1	-2.3
Finance, insurance, real estate and rental and leasing	19.2	18.7	4.6	-2.3
Professional, scientific and technical services	3.7	5.3	-4.4	2.2
Administrative and support, waste management and remediation services	-4.0	0.2	-10.2	11.9
Arts, entertainment and recreation	-1.8	-0.7	-2.1	4.1
Accommodation and food services	1.5	1.4	0.8	-0.4
Other private services	2.5	3.2	-1.8	1.4

Note: "WSE" stands for "within-sector effect." "RLE" stands for "reallocation level effect." "RGE" stands for "reallocation growth effect." "Aggregate" refers to the business sector for Canada and the market sector for Australia.

Source: CSLS calculations based on Statistics Canada and ABS data. Statistics Canada: 383-0029 and 383-0021. ABS: 5204.005, 6291.0.55.003 and 5260.0.55.002.

aggregate labour productivity growth, contributing 2.33 percentage points (or 107.5 per cent) in Canada and 3.29 percentage points (or 111.2 per cent) in Australia. The reallocation effects negatively contributed to aggregate labour productivity growth in both countries in 1994-2000.

In contrast, while within-sector effects remained the main driver of aggregate productivity growth in 2000-2013, the contribution of the reallocation effects were quite large. In 2000-2013, the contributions of within-sector effects to the aggregate labour productivity were notably lower, at 0.78 percentage point (or 85.4 per cent) in Canada and 1.46 percentage points (or 71.5 per cent) in Australia. The reallocation effects contributed 0.13 percentage points (or 14.6 per cent) in Canada and 0.58 percentage

Table 6: Industry Contributions to Aggregate Labour Productivity Growth, Australia, 1994-2013

	Aggregate	WSE	RLE	RGE
Percentage Point Contribution to Aggregate Labour Productivity Growth				
Market sector	2.33	1.94	0.76	-0.37
Agriculture, forestry and fishing	0.27	0.22	0.07	-0.02
Mining	0.16	-0.13	0.56	-0.26
Electricity, gas, water and waste services	-0.02	-0.05	0.05	-0.02
Construction	0.16	0.20	-0.02	-0.01
Manufacturing	0.40	0.32	0.04	0.04
Wholesale trade	0.25	0.27	0.01	-0.03
Retail trade	0.20	0.19	0.01	0.00
Transport, postal and warehousing	0.14	0.14	0.00	0.00
Information, media and telecommunications	0.15	0.17	-0.01	-0.02
Financial and insurance services	0.40	0.37	0.01	0.01
Rental, hiring and real estate services	0.04	0.02	0.02	-0.01
Professional, scientific and technical services	0.04	0.08	0.00	-0.05
Administrative and support services	0.02	0.02	0.01	-0.01
Arts and recreation services	0.00	0.01	0.00	-0.01
Accommodation and food services	0.06	0.06	0.00	0.00
Other services	0.06	0.04	0.01	0.01
Percentage Contribution to the MarketSector Total				
Market sector	100.0	100.0	100.0	100.0
Agriculture, forestry and fishing	11.7	11.5	8.8	4.6
Mining	7.1	-6.8	73.8	71.8
Electricity, gas, water and waste services	-1.0	-2.6	6.1	5.7
Construction	7.0	10.1	-2.5	3.7
Manufacturing	17.0	16.4	4.7	-11.6
Wholesale trade	10.7	14.0	1.1	8.5
Retail trade	8.7	9.7	1.3	-1.1
Transport, postal and warehousing	5.9	7.2	0.0	0.4
Information, media and telecommunications	6.5	9.0	-0.8	4.8
Financial and insurance services	17.1	19.3	1.4	-4.0
Rental, hiring and real estate services	1.6	1.2	2.9	1.8
Professional, scientific and technical services	1.6	4.2	0.6	13.1
Administrative and support services	0.9	1.1	1.7	3.2
Arts and recreation services	0.1	0.6	-0.5	1.6
Accommodation and food services	2.8	3.0	0.5	-0.9
Other services	2.4	2.2	0.9	-1.7

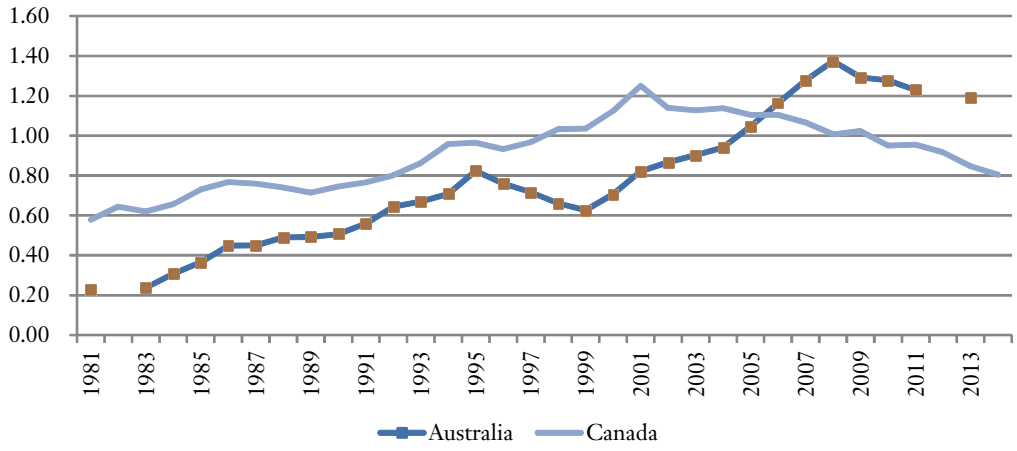
Note: "WSE" stands for "within-sector effect." "RLE" stands for "reallocation level effect." "RGE" stands for "reallocation growth effect." "Aggregate" refers to the business sector for Canada and the market sector for Australia.

Source: CSLS calculations based on Statistics Canada and ABS data. Statistics Canada: 383-0029 and 383-0021. ABS: 5204.005, 6291.0.55.003 and 5260.0.55.002.

points (or 28.5 per cent) in Australia. However, this masks the fact that reallocation growth effects negatively contributed to aggregate labour productivity growth in both countries, which was more than compensated for by a strong positive contribution from reallocation level effects.

Table 4 decomposes the absolute difference in aggregate labour productivity growth between Australia and Canada for 1994-2000 and 2000-2013. In 1994-2000, aggregate labour productivity growth in Australia was 0.79 percentage points higher than in Canada. The larger contribution from within-sector effects in Australia

Chart 5: BERD as a Per Cent of GDP, Canada and Australia, 1986-2010



Source: CSLS calculations based on OECD data.

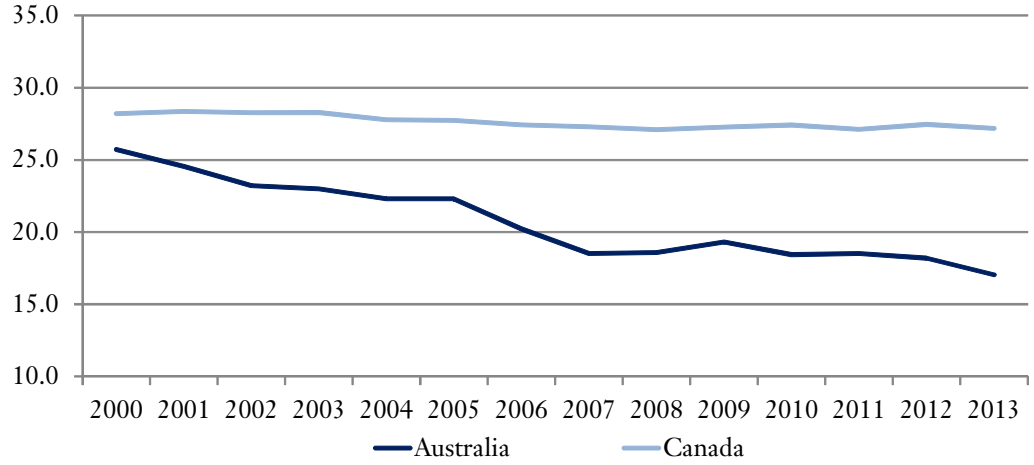
compared to Canada accounted for the entire gap in aggregate labour productivity growth between these countries in 1994-2000, at 0.96 percentage points (or 121.2 per cent). The reallocation effects negatively contributed to the gap.

The gap in aggregate labour productivity growth was even higher in 2000-2013, at 1.12 percentage points. The difference in within-sector effects between Australia and Canada only accounted for 0.67 percentage points (or 60.1 per cent) of the gap in aggregate labour productivity growth between these countries in 2000-2013. This implies that the reallocation effects accounted for 0.45 percentage points (or 39.9 per cent) to the overall gap in this period. In particular, Australia experienced a significantly larger contribution from the reallocation level effects than Canada in 2000-2013 (with a gap of 1.02 percentage points), which was more than enough to compensate for the fact that the reallocation growth effects were more of a drag on aggregate labour productivity in Australia compared to Canada.

Table 5 and Table 6 provide a detailed breakdown of industry contributions to aggregate labour productivity in Canada and Australia for the 1994-2013 period. Finance, insurance, real estate and renting and leasing contributed 0.19 percentage point (or 23.5 per cent) to the overall 1.02 percentage point gap in labour productivity growth between Australia and Canada in 1994-2013. This was wholly related to a stronger within-sector effect in Australia compared to Canada. Mining and oil and gas extraction ranked second, accounting for 0.17 percentage points (or 16.9 per cent) of this gap. In particular, mining and oil and gas extraction contributed 0.16 percentage points to labour productivity growth in Australia, while it contributed -0.01 percentage points in Canada. This was entirely due to a larger contribution of reallocation effects related to mining in Australia, which accounted for 0.14 percentage point (or 13.6 per cent) of the gap in aggregate labour productivity growth. Construction made the third largest contribution to the overall gap with 0.16 percentage point (or 15.4 per cent).

Even though mining and oil and gas extraction exhibited strongly negative labour productivity growth in both countries, its contribution to aggregate labour productivity growth was negative 0.01 percentage points in Canada and 0.16 percentage points in Australia, as the real-

Chart 6: Trade Union Density, Per Cent, 2000-2013



Note: According to the OECD, "trade union density corresponds to the ratio of wage and salary earners that are trade union members, divided by the total number of wage and salary earners."
Source: CSLS calculations based on OECD data.

location level effect was large enough to offset negative values for the within-sector effect and the reallocation growth effect in both economies. The larger contribution of mining and oil and gas extraction to aggregate labour productivity growth in Australia is entirely due to the fact that Australia experienced a much greater increase in the share of mining and oil and gas extraction in total hours worked than Canada.

Differences in the structure of the mining and oil and gas extraction industry may partially explain why Australia experienced a much larger increase in the industry's share of total hours worked. For instance, in 2013, coal and iron mining together accounted for 58.3 per cent of the industry's real output in Australia compared to 2.8 per cent in Canada. In addition, oil and gas extraction accounted for 73.3 per cent of real output in the industry in Canada, well above the equivalent share in Australia (21.4 per cent).

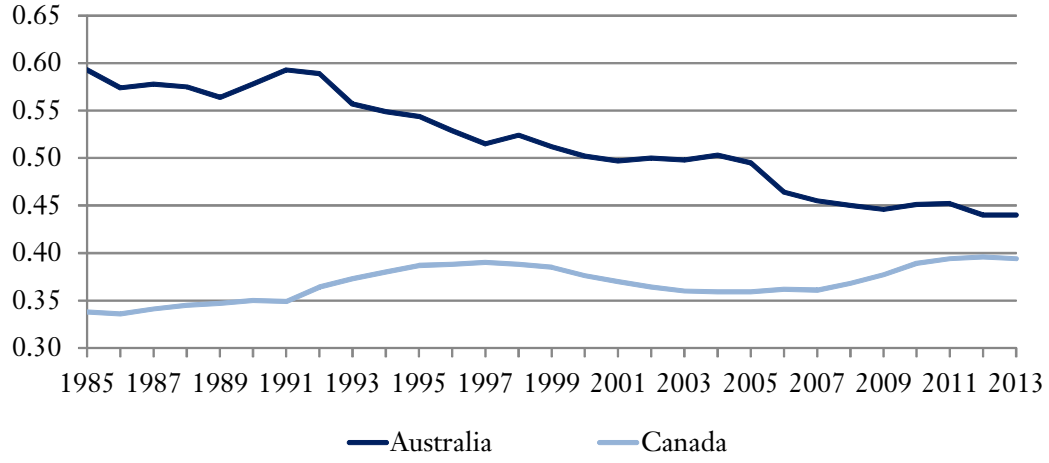
Productivity Drivers

Aside from the proximate explanations related to growth accounting and inter-industry shifts, there are several deeper explanations for the divergence in labour productivity between Australia and Canada in 1994-2013. Indeed, the gap in labour productivity growth between Australia and Canada reflects a gap between these countries in many of the drivers of labour productivity growth.

Innovation

Although it is difficult to measure the amount of technological diffusion and development occurring in an economy, R&D expenditure acts as a (somewhat) reliable indicator. We are particularly interested in business expenditure on R&D (BERD) as a percentage of GDP because BERD is the largest component of R&D expenditure and because BERD is closely linked with productivity in the business sector (which is the focus of this article). BERD as a share of GDP was higher than in Canada than in Australia between 1981 and 2005 (Chart 5). After 2005, Canada's BERD as a share of GDP continued the decline it began in 2001, while Australia's BERD as a per cent of GDP continued the rise it had begun in 1999. Australia's BERD as a share of GDP only began to trend downward in 2008, seven years after Canada's BERD as a per cent of GDP started its downward movement. More-

Chart 7: Minimum Wage Relative to Mean Wage of Full Time Workers, Canada and Australia, Ratio, 1985-2013



Source: CSLS calculations based on OECD data.

over, Australia's share of BERD in GDP increased 426 per cent between 1986 and 2013, compared to only a much smaller increase in Canada (46 per cent). Australia's large increase actually pushed its BERD share of GDP higher than that of Canada in 2006. Relative to other OECD countries in 2011, Australia's share of BERD in GDP ranked thirteenth out of thirty-two, while Canada's ranked twenty-first.

Labour Market Regulation

Employment Protection Legislation

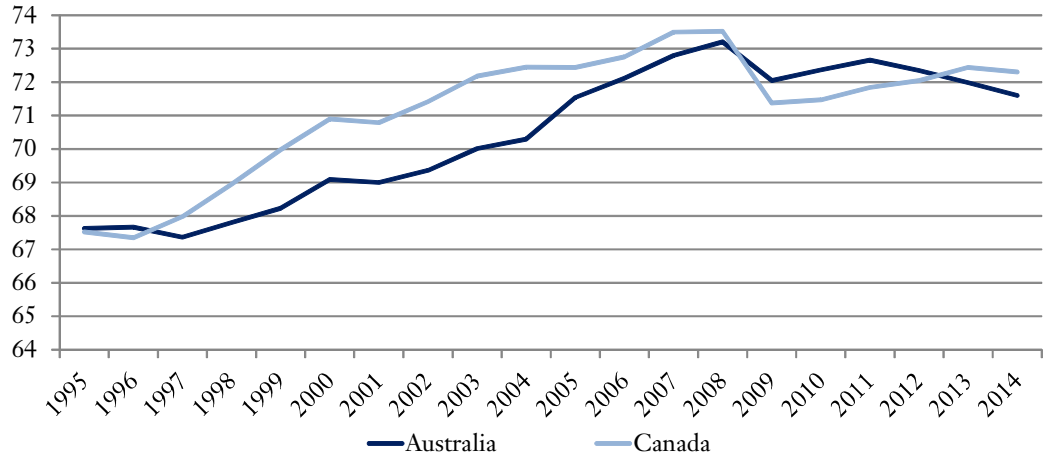
As measured by the OECD, employment protection legislation in Canada and Australia results in roughly the same level of protection for individual workers and the collective. Both countries rank within the top 10 OECD countries measured in the category of legislation designed for the protection of permanent workers against individual and collective dismissal, which can involve procedural inconveniences, notice periods, severance pay, and the difficulty of dismissal for individual workers and delays, costs or notification procedures required for collective dismissal.

Unionization

Trade union density, which corresponds to the share of wage and salary earners that are trade union members (whenever possible adjusted for non-active and self-employed members), has seen two very different paths be taken in Canada and Australia (Chart 6). While Canada's trade union density has remained essentially unchanged since 2000 (28.2 per cent in 2000 compared to 27.1 per cent in 2013), Australia's has seen a marked decline from levels comparable to Canada's in 2000 (25.7 per cent) to levels significantly below Canada's in 2013 (17.0 per cent).

Despite their lower rates of unionization, Australia has a unique "awards" system that imposes collective agreement-like minimum wages and other conditions on certain occupations and industries. Australia's unique awards system and its higher minimum wage suggest that its labour market is more regulated, in total, than Canada's despite lower rates of union membership. While trade union membership is quite low in Australia, a significant share of employees had their wages determined by collective agreements and the awards system. In

Chart 8: Employment Rates, Canada and Australia, Per Cent, 1995-2014



Source: CSLS calculations based on OECD data.

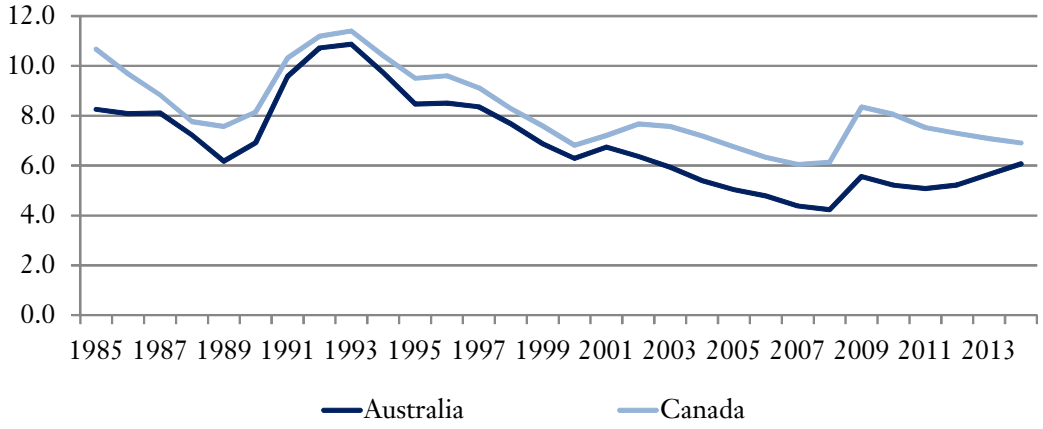
2010, 43 per cent of employees had their wages set by collective agreements, while 15 per cent had their pay set by 'awards only.'[6]

Minimum Wages

Increasing minimum wages can increase labour productivity through three main channels.

First, by increasing minimum wages, there is a substitution effect between capital and labour. Employers will choose to employ capital instead of labour at the minimum wage. Second, by increasing minimum wages, the average quality of labour can be increased through the composition effect. In particular, when minimum wages increase, low-skilled labour flows out of the labour market, thereby increasing the skill composition of the employed. Third, by increasing minimum wages, x-inefficiency is decreased. X-inefficiency is the difference between the efficient business behaviour implied by economic theory and the business behaviour that is

Chart 9: Unemployment Rates, Canada and Australia, Per Cent, 1985-2014



Source: CSLS calculations based on OECD data.

6 See Capeluck (2016) for discussion of Australia's national employment regulations.

observed in practice. When minimum wages increase, x-inefficiency will decrease because a business will begin to employ its previously unused capacity or shed excess capacity.

Australia's minimum wage relative to the mean wage of full-time workers was higher than Canada's for every year between 1985 and 2013 (Chart 7). In 1985, Australia's relative was 0.59, while Canada's relative was 0.34, resulting in a gap between Canada and Australia of 0.25. By 2013, Australia's relative had decreased to 0.44, while Canada's relative had increased to 0.39, resulting in a much smaller gap of 0.05. The majority (75 per cent) of the change in the gap was driven by the decrease in Australia's relative.

As seen before, minimum wages may have had an effect on capital deepening, since Australia's pace of capital deepening was much faster than Canada's pace of capital deepening between 1994 and 2013.

Increasing minimum wages, as discussed above, can lead to a substitution effect and a composition effect, both of which may reduce the employment rate below what could prevail with a lower minimum wage. In Australia, minimum wages are higher than in Canada. These higher minimum wages may have had an effect on the gap between Australia and Canada's employment rates between 1995 and 2008, but the impact appears to be minimal (Chart 8). The largest gaps between Canada's employment rate and Australia's employment rate were seen in the early-2000s, but these gaps were at most only 2.2 percentage points.

The resulting substitution and composition effects from an increase in the minimum wage may also increase the unemployment rate above what would prevail with a lower minimum wage. In Australia, since minimum wages are higher than in Canada, we might expect unemployment rates to be adversely affected, but contrary to expectations, unemployment rates in Australia were consistently lower than those in Canada between 1985 and 2014 (Chart 9).

Table 7: Product Market Regulation Indicator and Sub-Indices, Canada and Australia, 2013 (0 to 6)

	1998	2003	2008	2013
Product market regulation				
Australia	1.72	1.34	1.46	1.29
Canada	1.91	1.64	1.53	1.42
State control				
Australia	2.28	1.59	2.21	1.99
Canada	2.15	2.08	1.96	1.92
Barriers to entrepreneurship				
Australia	1.94	1.76	1.65	1.69
Canada	1.82	1.44	1.36	1.34
Barriers to trade and investment				
Australia	0.95	0.67	0.53	0.19
Canada	1.75	1.40	1.27	1.01

Source: CSLS calculations based on OECD data.

Product Market Regulation

In 2013, product market regulations appear to be more restrictive in Canada than in Australia, although this is highly subject to the weights applied to state control, barriers to entrepreneurship, and barriers to trade and investment. With equal weighting, Canada's product market regulations receive a score of 1.42 out of 6, which is slightly stricter than Australia's product market regulations score of 1.29 out of 6, where 0 is the least restrictive and 6 is the most restrictive (Table 7).

Canada's stricter regulatory policy is entirely driven by barriers to trade and investment, where Canada receives a score of 1.01 while Australia receives a score of 0.19. Australia and Canada have similar levels of state control (1.99 and 1.92, respectively) and Australia's barriers to entrepreneurship are stricter than Canada's (1.69 versus 1.34).

When compared to Australia over the past fifteen years, Canada had stricter product market regulation in each year examined; however, Canada's score out of 6 has been falling, indicating that product market regulation is becoming

less restrictive over the years. When comparing Australia and Canada, the greatest difference in product market regulation, according to the OECD indicator, was seen in 2003, while the smallest difference occurred in 2008. Relative to other OECD countries in 2013, Canada ranked seventeenth out of thirty-three, while Australia ranked eighth.

Macroeconomic Environment

Economists and policy makers have traditionally analyzed labour productivity through supply-side variables such as investment, innovation and human capital. Most have neglected the direct effects from the demand side. Without sufficient demand, productivity cannot grow even with strong supply-side variables. In addition, an economic crisis linked to inadequate demand can have negative effects on the supply-side potential of the economy through reduced investment and R&D (Summers, 2014). It is important to examine whether different demand conditions can explain the gap in labour productivity growth between Canada and Australia because of the heavy reliance of both economies on exports – an important source of aggregate demand and hence productivity growth.

The slowdown in output growth in both Australia and Canada between 1994-2000 and 2000-2013 was related to the decline in international export growth. While export growth was quite similar in both countries in 1994-2000, it was significantly stronger in Australia than in Canada in 2000-2013. This may explain the increase in gap in labour productivity growth between 1994-2000 and 2000-2013. While Australia's exports increased 2.9 per cent per year in 2000-2013, Canada's exports grew merely 0.24 per cent per year.

The divergence between the two countries in terms of export performance was largely related to geography: Australia's exports benefited from its proximity to China which grew rapidly throughout this period, while Canadian exports were afflicted by weak growth in domestic demand in its neighbour and closest trading partner, the United States, both before and especially following the 2008 global financial crisis. China's share of Australian exports rose from 4.2 per cent in 1995 to 23.5 per cent, while China's share of Canadian exports only rose from 1.3 per cent in 1995 to 4.4 per cent in 2009.

As previously mentioned, weaker demand conditions in Canada compared to Australia led to an increase in the gap in output growth from 1994-2000 to 2000-2013, and this development was associated with an increase in the gap in labour productivity growth. This is not a mere correlation, but rather a causal relationship, with slower output growth leading to slower productivity growth.

The proposition that labour productivity growth is a function of output growth is known as "Verdoorn's law," named after a Dutch economist who originally formulated the relationship in the 1950s. His empirical results showed that there was a strong positive association between output growth and labour productivity growth. Kaldor (1966) also posited such a relationship, showing that a 1 per cent increase in output led to an increase in labour productivity of approximately 0.5 per cent.

The statistical relationship between output growth and labour productivity growth could in principle run in either direction. It is indeed possible that a change in supply-side conditions, such as a technological shock, could raise or lower potential productivity growth and thereby increase or decrease actual output and labour productivity growth. However, the empirical evidence presented in this report provides limited support to such a supply-side productivity effect in the short- to medium-term.

A more likely scenario is one that runs from changes in demand conditions to changes in

Table 8: Summary of Drivers and their Potential Impact on the Gap in Labour Productivity Growth

Driver	Impact	Reasoning
Capital intensity	Significant	Capital intensity grew 1.66 per cent per year in Australia in 1994-2013 compared to 0.94 per cent per year in Canada, accounting for 71 per cent of the gap in labour productivity growth. Australia had higher investment in structures, M&E and ICT. This likely increased productivity through supply-side channels and reflected the better macroeconomic environment in Australia.
Human capital	Insignificant	In 1994-2013, the contribution of changes in labour composition to labour productivity growth was the same in both countries, at 0.29 per cent per year. Therefore, it is unlikely that differences in human capital accumulation contributed to the gap.
Innovation	Unlikely	We did not find significant evidence that differences in innovation can explain the labour productivity gap. While BERD intensity was higher in Canada than in Australia over much of the period, growth in BERD has been much more rapid in Australia than in Canada, particularly since 2000.
Inter-industry shifts	Significant	Inter-industry shifts explain a significant portion of gap in labour productivity growth. In fact, they accounted for 32 per cent of the gap in 1994-2013. Most importantly, Australia reallocated more labour to mining, which alone accounted for 17 per cent of the gap.
Quality of the stock of natural resources	Unlikely	Both countries exhibited negative labour productivity growth in mining driven by significant declines in MFP. This likely reflected increased difficulty in extracting natural resources in both countries. However, we found no evidence that differences in the quality of the natural resource stock have significantly contributed to the gap.
Macroeconomic environment	Likely	Stronger export growth may explain Australia's stronger productivity performance in 2000-2013. Exports grew 2.94 per cent per year in Australia in 2000-2013, compared to 0.24 per cent per year in Canada. A better macroeconomic environment associated with solid export growth improves labour productivity growth as suggested by Verdoorn's law. In contrast, both countries exhibited similar growth in exports in 1994-2000.
Microeconomic environment	Likely	According to the OECD, Australia has lower product market regulation and fewer barriers to trade and investment than Canada. This may, in part, explain the stronger labour productivity growth of Australia. However, Canada has slightly less labour market regulation (overall) than Australia.

labour productivity. A number of explanations have been advanced to explain why weak demand growth could have negative effects on labour productivity growth. These explanations include less spreading of overhead costs and fewer static and dynamic economies of scale. Weak demand is also bad for profits, which reduces both investment and R&D, key drivers of productivity growth. The situation reverses itself when demand is strong.

As Spiro (2013) sums it up nicely, even with strong supply-side variables such as human capital or better capital equipment in an economy, the potential of these variables cannot be realized if there is insufficient demand. The highly-educated workforce will seek employment in low-productivity sectors, such as retail or food services, because the demand is not there to create high-productivity jobs. Capital equipment will sit idle because there is no need to produce large amounts of output. In addition, businesses that do not sell enough output cannot justify investing in more, newer and better capital. The lack of ability to deploy human capital and physical capital into high-productivity sectors diminishes the cost competitiveness of an economy. This loss of cost competitiveness relative to other economies can further reduce output growth, which reduces labour productivity growth even more, thereby creating a vicious cycle.

Rao and Li (2013) further the argument made by Spiro that a slowdown in demand can negatively affect the accumulation of physical and human capital, causing a slowdown in productivity growth. This slowdown leads to a loss of cost competitiveness, reducing demand and exacerbating the decrease of capital accumulation; thus, creating a vicious cycle. In addition, Rao and Li used panel data to show "93 per cent

of the fall in average labour productivity growth in Canada between the periods of 1981 to 2000 and 2000 to 2012 can be attributed to the drop in real GDP growth." In addition, they showed the fall in internal and external demand impacts key labour productivity growth drivers such as R&D spending and M&E investments.

Key Points

This section has focused on investigating the possible reasons behind the gap in labour productivity between Australia and Canada in 1994-2013. Based on the evidence provided throughout this section, the gap in labour productivity growth between Australia and Canada is reflected by a gap between these countries in many of the drivers of labour productivity growth.

With respect to the supply-side drivers of labour productivity growth, Australia outperformed Canada in terms of capital intensity growth, growth in BERD intensity, product market regulation, and barriers to trade and investment. A simple growth accounting exercise showed that capital deepening accounted for 71 per cent of the gap in labour productivity growth in this period. The remainder was accounted for by MFP. Australia surpassed Canada in terms of investment intensity and investment growth for structures, M&E and ICT.

Australia also exhibited more rapid growth in BERD, although its BERD intensity was still lower than Canada's over much of the observed period. More notably, Australia has significantly less product market regulation than Canada according to the OECD, as well as fewer barriers to trade and investment. This may, in part, explain the stronger labour productivity growth of Australia. Many economists attribute Australia's rapid productivity growth in the late-1990s to deregulation and the reduction of barriers to trade and investment.

In contrast, we found no evidence that differences in human capital accumulation contributed to the labour productivity growth gap. The growth accounting exercise found that the contribution of changes in labour composition to labour productivity growth was the same in both countries in 1994-2013, at 0.29 per cent per year. Therefore, it is unlikely that differences in human capital accumulation contributed to the gap.

There is little evidence that differences in labour market regulation contributed to the gap in labour productivity growth. While the intensity of union membership was quite steady in Canada over the observed period, it steadily declined in Australia. Although unionization has been on the decline in Australia, the share of the population covered by collective agreements has increased, and industry- and occupation-specific minimum wages and terms of employment are determined in Australia's unique "awards" system. Furthermore, according to the OECD Canada has slightly less labour market regulation (overall) than Australia.

In the previous section, we found that inter-industry shifts explain a significant portion of gap in labour productivity growth. In fact, they accounted for 32 per cent of the gap in 1994-2013. Most importantly, Australia reallocated more labour to mining, which alone accounted for 17 per cent of the gap. This occurred because the mining sector's share of total hours worked increased much more in Australia than in Canada.

The labour productivity gap in recent years seems to have been driven by the macroeconomic environment. With respect to the demand-side drivers of the gap in labour productivity growth, stronger export growth likely explains part of Australia's stronger productivity performance in 2000-2013. Exports grew 2.94 per cent per year in Australia in 2000-2013, compared to 0.24 per cent per year in Canada. A

better macroeconomic environment associated with solid export growth improves labour productivity growth, as suggested by Verdoorn's law. In contrast, both countries exhibited similar growth in exports in 1994-2000.

Lower unemployment rates, as well as other changes that point to an increase in labour market tightness, can have a positive impact on labour productivity growth through labour scarcity. This can spur additional investment in labour-saving capital. It is unclear whether this factor has contributed to the gap in labour productivity growth. Despite the lower unemployment rate experienced by Australia, alternative indicators (e.g., the incidence of discouraged searchers and involuntary part-time workers) suggest that Australia's labour market was actually less tight than Canada's during this period. There is also a risk that methodological differences between Statistics Canada and the ABS limit comparisons of these indicators.

Theoretically, an increase in the minimum wage should have a similar effect on labour productivity growth to an increase in labour market tightness. Australia's minimum wage was higher than Canada's throughout the observed period. However, the minimum wage has fallen relative to mean and median wages over time in Australia, while it has increased relative to mean and median wages in Canada. It is therefore unlikely that Australia's higher minimum wage contributed to their superior labour productivity performance.

The Impact of Public Policy on Australian Productivity Growth

Productivity Boom in the 1990s: The Role of Microeconomic Reforms

Australia exhibited weak productivity growth before the 1990s, especially compared to Japan, the United States and other advanced economies in Europe (Parham, 2002). In response, successive Australian governments implemented a series of reforms to rectify the situation from the mid-1980s to the late 1990s. A great deal of research has been conducted on the impact of these reforms on productivity growth in Australia. In particular, it is widely believed that they explain the surge in productivity in the mid- to late-1990s. According to the standard narrative, which is frequently maintained by the Productivity Commission and other researchers, much of the improved productivity performance came from an unlocking of the supply-side potential of the Australian economy related to these reforms.

The reforms were wide-ranging and ambitious. They have had both macro and micro dimensions, although the focus of the literature is largely on the role of microeconomic reforms. More specifically, the reforms included the introduction of financial deregulation, privatization of government enterprises, the introduction of enterprise-level wage bargaining and individual employment contracts, reduced tariffs, tax reform, a dramatic shift in macroeconomic policy, and a new competition policy.

In theory, microeconomic reforms should improve productivity performance through three key mechanisms: 1) by making the economy more flexible so that scarce resources are directed to more productive uses; 2) by improving the efficiency of the economy through greater international and domestic competition; and 3) by making the business culture more focused on pursuing opportunities to expand in both foreign and domestic markets.

Broadly speaking, there are two sorts of evidence of the impact of microeconomic reforms on productivity performance: 1) aggregate-level evidence, which attempts to quantify the impact of these reforms on the productivity performance of the total economy; and 2) industry-level evidence, which tries to estimate the effect

of microeconomic reforms on the productivity performance of specific industries. We first discuss the aggregate-level evidence, and then turn our attention to industry-level evidence.

Much of the evidence on the effects of microeconomic reforms in Australia applied general equilibrium models to simulate the effects of these reforms. However, these studies are quite old and were often conducted before the implementation of reforms in order to forecast their impact.

More recent studies have focused on the role of microeconomic reform in the acceleration in productivity growth in the late 1990s. The Productivity Commission (1999) argued that the acceleration in productivity growth was driven by the impact of microeconomic reforms. Many other authors have also found evidence of a positive link between microeconomic reform and the productivity upsurge at the aggregate level (Salgado, 2000; Dowrick, 2000; OECD, 2000; Wooden, 2000).

However, aggregate-level evidence of the role of microeconomic reform in Australia's 1990s productivity surge has largely relied on descriptive analysis based on trends at the aggregate level, paying attention to the time trends in productivity and their relation to significant policy changes. There are significant weaknesses with this approach. It does not provide direct evidence of a link between microeconomic reform and productivity growth.

In addition to analyzing the effect of microeconomic reform on productivity at the aggregate level, the Productivity Commission (1999) has conducted a series of detailed case studies at the industry level to look for further evidence of a relationship between reform and the productivity acceleration. In principle, a more disaggregated industry-level analysis makes it easier to examine relationships between productivity growth and the timing of reforms, as it allows researchers to account for the fact that different reforms were implemented in different industries at different times (Productivity Commission, 1999). Furthermore, given the diversity of experiences by industry (with certain industries like wholesale trade, construction, finance and insurance, and transport and storage accounting for much of the 1990s productivity upsurge), the increase in productivity growth may be more appropriately thought of as an industry-based story (or even a firm-based story) instead of an aggregate-level story.

The Productivity Commission's (1999) analysis of specific reforms and the experiences of individual firms and industries have also provided strong evidence of an association between productivity-friendly policy changes and productivity gains in some, but not all, instances. In particular, the Productivity Commission conducted case studies for three manufacturing industries and two government-sponsored enterprises. They identified microeconomic reform as a major factor affecting the productivity performance in all three manufacturing industries. Similarly, microeconomic reforms were also found to be the key determinant of an improvement in productivity growth in the two government-sponsored enterprises.

Although much of the industry-level evidence presented does potentially provide more direct evidence on the impact of reform, and overcomes some of the difficulties inherent in aggregate-level analysis, it also has its weaknesses. In particular, researchers need to know the counterfactual to effectively assess the impact of policy changes.

It is difficult to draw lessons from Australia's 1990s productivity surge for Canada. Although many studies indicate that the productivity reforms were good for productivity, we simply do not know if they only had a one-off effect or if they led to a sustained increased in Australia's productivity growth rate. In addition, there are good reasons to doubt the standard narrative –

the one supported by the Productivity Commission – that microeconomic reform was responsible for the 1990s productivity surge, particularly given that much of the evidence of this causal relationship is largely circumstantial.

Furthermore, the evidence of the impact of reforms on Australia's 1990s productivity surge generally does not distinguish between separate policies but looks at the effect of reforms as a whole. Thus, it is difficult to draw lessons for Canada, as we simply do not know which exact policies had the largest impact on productivity growth in Australia. In theory, it is possible that a few of the policy changes had a large, positive effect on productivity, while others had a negligible (or maybe even negative) effect on productivity.

The Role of the Productivity Commission

The Productivity Commission is the arm's length research and advisory body of the Australian government. Its principal role is to inform policymaking on a wide range of economic, social and environmental matters, and to advise the government on policy reforms which are in the long-term interest of Australians. As suggested by its name, a major focus of the Commission is to deepen understanding of productivity in general and Australia's productivity performance in particular, and to find ways to enhance Australia's productivity performance.

The Productivity Commission and its predecessors have been intimately involved in most of the significant reforms adopted in Australia in the past four decades. Notably, the Commission played an important role in the promotion and adoption of microeconomic reforms from the mid-1980s to the late 1990s.

Australia exhibited weak productivity growth in the 1960s, 1970s and 1980s, especially compared to Japan, the United States and other advanced economies in Europe (Parham, 2002). The growing sense of crisis roused public support for successive governments to undertake structural reforms to boost productivity growth and ameliorate other economic ailments. As a result, a series of comprehensive reforms were introduced from the mid-1980s to the late 1990s.

The Productivity Commission and its predecessors were involved in this process of reform. In particular, it played an advisory and research role. For example, it estimated the impact of microeconomic reforms such as the Hilmer report reforms prior to their implementation (Industry Commission, 1995) and after the fact in order to evaluate their effect (Productivity Commission, 1999).

The Commission has assisted reform in numerous ways. Firstly, its well-researched advice on structural reform has provided Government with impartial information that is focused on the long term welfare of the community. As noted, although governments have a large supply of information and advice, much of it may not allow for an unbiased assessment due to its self-serving or narrowly-focused nature.

Second, the Commission's analysis and recommendations to the government are advantageous since they have been created with extensive public input and feedback on a draft report. This implies that they are likely to consider all relevant details and are therefore likely to be reliable.

Third, the processes of the Commission, such as public submissions, hearings, drafts, and final reports, allow governments the chance to estimate the reactions of the community and interest groups to various approaches to policy. This is important since it has the ability to reduce the likelihood of unexpected responses which can lead to policy reversals.

Fourth, the Commission's reports can be used by governments when making the case for policy

changes, or in avoiding the pressure to initiate policy measures that may be costly.

Finally, the Commission's public inquiry processes and reporting can raise awareness of the costs of existing policies and the benefits from productivity-enhancing reforms. While this does not necessarily imply that the broader public would decide to support a given reform, it can help to galvanize or at least inform those individuals who would benefit most from the reform. The small interests who would lose the most from productivity-enhancing policy changes are likely to put up strong opposition to said changes. Even if these changes are good for the broader community, the public may not be fully aware of the benefits coming from these changes and, in turn, may not support them. By informing the broader public on the costs and benefits of certain policies, the Commission has improved the dialogue on many key issues.

Summary and Policy Recommendations

The objective of this article has been to explain why Australia outperformed Canada in terms of productivity growth over the last two decades, and to see if there are any lessons for Canada from Australia's performance. We identified five factors, a number of them interrelated, that appear to explain Australia's superior productivity performance: 1) stronger growth in capital intensity; 2) a better macroeconomic environment and (foreign) demand conditions; 3) a stronger record on innovation; 4) (somewhat) more market-oriented product market regulations; and 5) a larger positive effect of inter-industry shifts.

We also looked for lessons from Australia's 1990s productivity surge for Canada. While the productivity surge coincided with a series of microeconomic reforms, much of the evidence of a causal relationship is largely circumstantial. Furthermore, the evidence generally does not distinguish between separate policies but looks at the effect of reforms as a whole. Thus, it is difficult to draw lessons for Canada, as we simply do not know which exact policies had the largest impact on productivity growth in Australia.

Since Canada pursued many of the same policy reforms as Australia in the 1980s and 1990s, such as trade liberalization, the loosening of labour and product market regulations and the adoption of a new monetary policy framework, it is unclear where Canadian policymakers should draw lessons from the Australian experience. One plausible area for further deregulation is the product market, as OECD data suggests that product market regulations are significantly more restrictive in Canada. The supply management system for dairy and poultry products is one clear example of where Australia has loosened product market regulations further than Canada.

The analysis in this report does give rise to a few potential lessons for Canada. These are as follows:

- Australia has greatly benefited from impressive export growth to the huge and fast growing Chinese market. Canada's main market, on the other hand, is the slow growing United States. Given the importance of demand growth for both output and productivity advance, Canada should focus greater attention on emerging markets where there is significant potential for growth in exports.
- Australia has been very successful in increasing its BERD intensity, Canada not so much. Given the great similarities between the two countries, Canada should closely examine the specific public policies that Australia has implemented to boost BERD intensity to determine if any could be adopted in this country.
- Australia has been aggressive in reducing product market regulation, Canada less so. Canada is in the middle of the pack among OECD countries in terms of product regulation, and

therefore has room to move to a less restrictive policy regime. The greatest potential for productivity gains in the product market regulation area for Canada is the gradual phasing out of marketing boards, especially for dairy products. The Australian experience offers much insight in this regard.

• Canada lacks a governmental organization that focuses on productivity issues, the role played by the Productivity Commission in Australia. Given the positive implications for government revenues of even small increases in productivity, the costs of such an organization would be very small relative to the benefits. The federal government should establish an organization that would play a similar role to the Australian Productivity Commission in championing the productivity issue.

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Productivity Growth in U.S. Agriculture: 1948-2013

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ABSTRACT

It is widely reported that productivity growth is the main contributor to output growth in U.S. agriculture. This article provides estimates of output growth over the postwar period and decomposes that growth into the contributions of input growth and productivity growth. The analysis is based on recently revised production accounts for agriculture. Our findings are fully consistent with those reported in the literature. Productivity growth dominates input growth as a source of output growth in the sector.

THE RISE IN AGRICULTURAL productivity has long been chronicled as the single most important source of output growth in the U.S. farm sector.[2] Though their methods differ in important ways, the major sectoral productivity studies by Kendrick and Grossman (1980), Jorgenson, Gollop, and Fraumeni (1987), Jorgenson (1990), and Jorgenson and Gollop (1992) share this common conclusion. In a more recent study, Jorgenson, Ho, and Stiroh (2005) find that productivity growth over the 1977-2000 period accounted for nearly 80 per cent of output growth in agriculture. This compares with only 19 per cent for the economy as a whole (Bureau of Labor Statistics, U.S. Department of Labor). Moreover, the rate of productivity growth over this period in agriculture (1.9 per cent) was nearly 3 times the corresponding rate in the non-farm economy (0.69 per cent).

The U.S. Department of Agriculture (USDA) has been monitoring the industry's productivity performance for decades. In fact, the USDA in 1960 was the first agency to introduce multifactor productivity measurement into the Federal statistical program. Today, having incorporated recommendations made by an American Agricultural Economics Association taskforce (USDA, 1980) and by a second more recent panel (Shumway *et al*., 2014), the department's Economic Research Service (ERS) bases its official productivity statistics on a sophisticated system of production accounts.[3] The USDA model of productivity growth is based on the translog transformation frontier. It relates the growth

1 The authors work for the Economic Research Service of the U.S. Department of Agriculture. The views expressed are those of the author(s) and should not be attributed to ERS or USDA. The authors would like to thank three anonymous references for useful comments. Emails: eball@ers.usda.gov; rnehring@ers.usda.gov; slwang@ers.usda.gov.

2 The term "productivity" used in this article refers to the increase in output growth not accounted for by input growth, also known as total factor productivity or multifactor productivity.

3 The more recent review was motivated by Office of Management and Budget (OMB) guidelines for ensuring the quality and integrity of information disseminated by Federal agencies (OMB, 2011).

rates of multiple outputs to the cost-share weighted growth rates of labour, capital, and intermediate inputs.

The applied USDA model is quite detailed. The changing demographic character of the agricultural labour force is used to construct a quality-adjusted index of labour input. Similarly, much asset-specific detail underlies the measure of capital input. The index of capital input is formed by aggregating over the various capital assets using cost-share weights based on asset-specific rental prices. The contributions of feed and seed, chemicals, energy, and purchased services to output growth are captured in the index of intermediate inputs. An important innovation is the use of hedonic price indexes in constructing measures of fertilizer and pesticides consumption. The result is a USDA time series of total factor productivity (TFP) indexes now spanning the 1948-2013 period.

This article provides a complete discussion of the steps taken to construct the revised system of accounts and measures of productivity. We then compare the contributions of input growth and productivity growth to output growth in the farm sector. The important role of productivity growth in agriculture becomes immediately apparent.

We also examine the importance of changing input quality as a source of output growth. The observation, first made by Griliches (1964) some fifty years ago, that improved labour quality of the agricultural labour force is an important determinant of the sector's output growth is confirmed in this analysis.

The article's major conclusion is that productivity growth has been the principal source of output growth in agriculture over the postwar period. Averaging nearly 1.5 per cent per year, growth in productivity accounted for more than 95 per cent of the growth in output.

Changes in input quality have made significant contributions to input growth and, therefore, output growth. The net effect of quality change in all three inputs (i.e., labour, capital, and intermediate inputs) was a 0.12 per cent per year contribution to output growth. In fact, quality change was the sole reason for any positive contribution arising through growth in aggregate input.

Production Accounts

The USDA's Economic Research Service (ERS) has constructed accounts for the farm sector consistent with a gross output model of production (Ball, 1985; Ball *et al.*, 1997, 1999). Output is defined as gross production leaving the farm, as opposed to real value added. Inputs are not limited to labour and capital but include intermediate inputs. Intermediate goods produced and consumed within the farm sector are self-cancelling transactions and, therefore, do not enter either output or input accounts.

The ERS defines the farm sector the same way as does the National Income and Product Accounts (NIPA). This means that minor goods and services (i.e. secondary outputs) produced in the agricultural sector that are primary to other industries were included in the primary industry's output. For example, machine services performed by farmers, a secondary output for farms, were excluded from agriculture and included in agricultural services.

In this article, however, we take the existence of certain (inseparable) secondary activities into account when measuring the productive activity of the sector. These activities are defined as activities whose costs cannot be separately observed from those of the primary agricultural activity (as defined by the System of National Accounts (United Nations, 1993)). Examples include machine services for hire, custom feeding of livestock, farm forestry, and recreational activities involving the means of production. The output of the sector thus results from two kinds of activities: agricultural activities,

whether primary or secondary, and non-agricultural (or secondary) activities of farms.

Output

The development of a measure of output begins with disaggregated data on prices and quantities of agricultural goods. For each category of output, the quantity includes the quantities sold off the farm (including unredeemed Commodity Credit Corporation loans), additions to inventory, and quantities consumed in farm households during the calendar year. The corresponding price reflects the value of that output to the producer, as subsidies are added and indirect taxes are subtracted from market values.[4] The measure of output also includes goods and services of non-agricultural (or secondary) activities when these activities cannot be distinguished from the primary agricultural activity. Tornqvist (or translog) indexes of output are formed by aggregating over agricultural goods output and the output of goods and services of inseparable secondary activities using revenue-share weights based on shadow prices.

Intermediate Input

Intermediate input consists of goods used in production during the calendar year, whether from beginning inventories or purchased from outside the farm sector.[5] Measures of intermediate inputs are formed as translog indexes over a set of goods and services. Price and quantity data corresponding to purchases of feed and seed are available from the USDA and directly enter the calculation of intermediate goods.[6] Data on current dollar consumption of petroleum fuels, natural gas, and electricity in agriculture are also available.[7] Prices for individual petroleum fuels are taken from annual issues of A*gricultural Prices* (U.S. Department of Agriculture). The *Monthly Energy Review* (Energy Information Administration, U.S. Department of Energy) is the source for natural gas and electricity prices. The corresponding quantity measure for each energy source is calculated implicitly as the ratio of expenditures and price. Fertilizers and pesticides also are important intermediate inputs, but their data require adjustment since these inputs have undergone significant changes in input quality over the study period. Since input price and quantity series used in a study of productivity must be denominated in constant-efficiency units, price indexes for fertilizers and pesticides are constructed using hedonic regression techniques.

A price index for fertilizers is estimated by regressing the prices of single nutrient and multi-grade fertilizer materials on the proportion of nutrients contained in the materials; prices of pesticides are regressed on differences in physical characteristics such as toxicity, persistence in the environment, and leaching potential.[8]

The corresponding quantity indexes for fertilizers and pesticides are formed implicitly by taking the ratio of the value of each aggregate to the corresponding hedonic price index. Finally, price and implicit quantity indexes are constructed for purchased services, such as contract labour services, purchased machine services, and maintenance and repairs.[9] Available data consist of nominal expenditures. To decompose expen-

4 Prices received by farmers, as reported in USDA's Agricultural Prices, include an allowance for net Commodity Credit Corporation loans and purchases by the government under the marketing loan program valued at the average loan rate. However, direct payments under the federal commodity programs are not reflected in the data.

5 We assume that intermediate goods produced and consumed within the farm (e.g. grain for livestock feeding) are from beginning stocks. Therefore, the measure of output is equated with gross production.

6 Purchases of livestock are recorded as additions to the stock of "goods in progress" and not as intermediate input. Similarly, cash receipts are net of livestock purchases.

7 Expenditures for motor fuels are net of excise tax rebates.

ditures for contract labour services into price and quantity components, we estimate a hedonic wage function where hourly earnings are expressed as a function of demographic characteristics including sex, age, education, and experience, as well as legal status and type of employment (hired versus contract labourers).[10] Purchased machine services are a close substitute for own capital input.[11] Therefore, we construct the implicit quantity of machine services as the ratio of expenditures to an index of rental prices of agricultural machinery (i.e. farm tractors; agricultural machinery excluding tractors). Translog indexes of intermediate input are constructed by weighting the growth rates of each category of intermediate inputs described above by their value share in the overall value of intermediate inputs.

Labour Input

Current USDA labour accounts for the farm sector incorporate the demographic cross-classifications of the agricultural labour force developed by Jorgenson, Gollop, and Fraumeni (1987) (Ball *et al.*, 1997). Matrices of hours worked and compensation per hour are developed for labourers cross-classified by sex, age, education, and employment class (employee versus self-employed and unpaid family workers).

This is accomplished using the RAS procedure popularized by Jorgenson, Gollop, and Fraumeni (1987:72-76) by combining the farm sector matrices initially produced in that study with demographic information taken from the Census of Population (Bureau of the Census, U.S. Department of Commerce). The result is a set of annual hours worked and hourly compensation matrices with cells cross-classified by sex, employment class, age, and education, and with each matrix controlled to the USDA hours and compensation totals, respectively.

Translog indexes of labour input are constructed for the 1948-2013 period using the demographically cross-classified hours and compensation data. Under the translog approach, labour hours having larger marginal productivity (wages) are given higher weights in forming the index of labour input than are hours having lower marginal productivities. Doing so

8 A hedonic price function expresses the price of a good or service as a function of the quantities of the characteristics it embodies. Therefore, the hedonic price function for pesticides may be written as $w_p = W(X,D)$, where w_p is pesticide price, X is a vector of characteristics or quality variables, and D is a vector of variables to be defined. The characteristics included in the regression are the application rate, chronic score, half-life, absorption, water solubility and vapour pressure. The application rate measures the chemical's potency. Hazardous characteristics are measured by chronic toxicity scores, and persistence is measured by the pesticide's half-life. The chronic toxicity index is the inverse of the water quality threshold (which measures the concentration in parts per billion) and serves as an indicator for environmental risk. The lower the index, the lower is the potential environmental risk for the chemical. The persistence indicator is defined by the share of pesticides with a half-life less than 60 days (the lower the indicator, the less persistent the pesticide is) and by the degree to which the pesticide binds to soil particles (sorption coefficient, Koc). The leaching potential is measured by water solubility (the amount in milligrams of pesticides that would dissolve in one liter of water, mg/L) and vapour pressure (how readily a chemical will evaporate) measured in millimeters of mercury (mm Hg). Other variables (denoted by D) are included in the hedonic regression, and their selection depends on the objectives of the study. If the main objective of the study is to obtain price indexes adjusted for quality, as in our case, the only variables that should be included in D are time dummy variables, which will capture all price effects other than quality. After allowing for differences in the levels of the characteristics, the part of the price difference not accounted for by the included characteristics will be reflected in the time dummy coefficients.

9 Premiums less subsidies for publically-provided disaster insurance are included in the cost of purchased services, while indemnities are included in the value of output (Shumway et al., 2014).

10 See Wang *et al.* (2013) for further discussion.

11 Purchased machine services exhibit a counter-cyclical pattern, suggesting substitution of purchased machine services for own capital input (Ball, Schimmelpfennig, and Wang, 2013).

explicitly adjusts the time series of labour input for changes in quality of labour hours as originally defined by Jorgenson and Griliches (1967). As a result, the price and quantity series for labour input are measured in constant-quality units.[12]

Capital Input

This study requires time series measures of capital input and capital rental prices. Construction of these series begins with estimating the capital stock and rental price for each component of capital input. For depreciable assets, the perpetual inventory method is used to develop capital stocks from data on investment. For land and inventories, capital stocks are measured as implicit quantities derived from balance sheet data. Implicit rental prices for each asset type are based on the correspondence between the purchase price of the asset and the discounted value of future service flows derived from that asset.

Capital Stock of Depreciable Assets

The perpetual inventory method cumulates investment data measured in constant prices into a measure of capital stock. Data on investment in current prices are obtained from the ERS Resource and Rural Economy Division.[13] The Bureau of Labor Statistics Producer Price Indexes for passenger cars, motor trucks, wheel-type farm tractors, and agricultural machinery excluding tractors are employed as investment deflators. For structures, the implicit price deflator is taken from the U.S. national income and product accounts.

Under the perpetual inventory method, the capital stock at the end of each period, say K_t, is measured as the sum of past investments, each weighted by its relative efficiency, say d_τ:

$$(1)\quad K_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau}$$

In equation (1), we normalize initial efficiency d_0 at unity and assume that relative efficiency declines so that:

$$(2)\quad d_0 = 1,\ d_\tau - d_{\tau-1} \le 0,\ \tau = 0, 1\ldots, T$$

We also assume that every capital good is eventually retired or scrapped so that relative efficiency declines to zero:

$$(3)\quad \lim_{\tau\to\infty} d_\tau = 0$$

The decline in efficiency of capital goods gives rise to needs for replacement investment to maintain the productive capacity of the capital stock. The proportion of a given investment to be replaced at age τ, say m_τ, is equal to the decline in efficiency from age $\tau-1$ to age τ:

$$(4)\quad m_\tau = -(d_\tau - d_{\tau-1}),\ \tau = 1, \ldots, T$$

These proportions represent mortality rates for capital goods of different ages. Replacement requirements, say R_t, are a weighted sum of past investments:

$$(5)\quad R_t = \sum_{\tau=1}^{\infty} m_\tau I_{t-\tau},$$

where the weights are the mortality rates.

Taking the first difference of expression (1) and substituting (4) and (5), we can write:

$$(6)\quad K_t - K_{t-1} = I_t - \sum_{\tau=1}^{\infty} (d_\tau - d_{\tau-1}) I_{t-\tau}$$
$$= I_t - \sum_{\tau=1}^{\infty} m_\tau I_{t-\tau}$$

12 See Jorgenson and Gollop (1992) for a discussion of the theoretical basis for adjusting labour input for compositional shifts in the labour force.

13 The series on investment in farm structures includes capital outlay on housing provided employees. Accordingly, housing service flows are viewed as a component of output.

$$= I_t - R_t$$

The change in capital stock in any period is equal to the acquisition of investment goods less replacement requirements.

To estimate replacement, we must introduce an explicit description of the decline in efficiency. This function, d, may be expressed in terms of two parameters, the service life of the asset, say L, and a curvature or decay parameter, say β. Initially, we will hold the value of L constant and evaluate the efficiency function for various values of β. One possible form for the efficiency function is given by:

$$(7)\quad d_\tau = \frac{(L-\tau)}{(L-\beta\tau)},\ 0 \le \tau \le L,\ d_\tau = 0,\ \tau \ge L$$

This function is a form of a rectangular hyperbola that provides a general model incorporating several types of depreciation as special cases.

The value of β is restricted only to values less than or equal to one. Values greater than one yield results outside the bounds established by the restrictions on d. For values of β greater than zero, the function d approaches zero at an increasing rate. For values less than zero, d approaches zero at a decreasing rate.

Little empirical evidence is available to suggest a precise value for β. However, two studies (Penson, Hughes, and Nelson, 1977; Romain, Penson, and Lambert, 1987) provide evidence that the decline in efficiency occurs more rapidly in the later years of service, corresponding to a value of β in the zero-one interval. For purposes of this study, it is assumed that the efficiency of a structure declines slowly over most of its service life until a point is reached where the cost of repairs exceeds the increased service flows derived from the repairs, at which point the structure is allowed to deteriorate rapidly ($\beta = 0.75$). The decay parameter for durable equipment ($\beta = 0.50$) assumes that the decline in efficiency is more uniformly distributed over the asset's service life.

Consider now the efficiency function that holds β constant and allows L to vary. The concept of variable lives is related to the concept of investment used in this study where investment is composed of different types of capital goods. Each of the different types of capital goods is a homogeneous group of assets in which the actual service life L is a random variable reflecting quality differences, maintenance schedules, or simply chance variation. For each type of capital good there exists some mean service life $\overline{L}$ around which there is a distribution of the actual service lives of the assets in the group. In order to determine the actual capital available for production, the actual service lives and the relative frequency of assets with these service lives must be determined. It is assumed that this distribution may be accurately depicted by the standard normal distribution.

One property of the normal distribution is related to the infinite nature of the distribution. Without adjustment, the distribution would yield cases where assets were discarded prior to their purchase or assets with unrealistically long service lives. In order to eliminate these extremes, some adjustment is warranted. This adjustment involves truncation of the normal at some point before and after $\overline{L}$. The values of the normal are then adjusted upward within the allowed range of service lives.

In this study, we truncate the distribution at points two standard deviations before and after the mean.[14] Two standard deviations are assumed to be 0.98 times the mean service life. This dispersion parameter was chosen to conform to the observation that assets are occasionally found that are considerably older than the mean service life and that a few assets are acci-

14 Mean service lives correspond to 85 per cent of the U.S. Department of the Treasury's *Bulletin F* lives.

dentally damaged when new. Once the frequency of a service life L is known,[15] the decay function for that particular service life is calculated using the assumed value of β. This step is repeated for all possible service lives. An aggregate efficiency function is then constructed as a weighted sum of the individual efficiency functions using as weights the frequency of occurrence. This function not only reflects changes in efficiency but also the discard distribution around the mean service life of the asset.

Capital Stock of Land

To obtain a constant-quality stock of land, we compile data on acres of land in farms and average value (excluding buildings) per acre for each county in each state using information gleaned from the Census of Agriculture. Data for years intermediate to the censuses are obtained by interpolation.[16] The Census definition of land in farms includes all grazing land (including reservation grazing land, land in grazing associations, and land leased for grazing) except public lands leased for grazing on a per-head basis.[17] From total land in farms, we exclude the land area in roads and house lots and miscellaneous areas such as marches, open swamps, and bare rock areas.[18]

The Census of Agriculture reports data on the value of farm real estate (i.e. land and structures); it does not provide data on land values separately. Historically, the value of farm real estate was partitioned into its components using information from the Agricultural Economics and Land Ownership Survey (AELOS). However, AELOS was last conducted in 1999. More recently, we have relied on the annual Agricultural Resource Management Survey (ARMS) to derive estimates of the value of land from data on the value of farm real estate.

Inventories

Beginning inventories of crops and livestock are treated as capital inputs.[19] The number of animals on farms is available from annual surveys, as are the stocks of grains and oilseeds (National Agricultural Statistics Service, USDA).[20] December average prices, available from *Agricultural Prices*, are used to value commodities held in inventory.

Capital Rental Prices

An important innovation in measuring capital input is the rental price of capital originated by Jorgenson (1963, 1973). However, this rental price is based on the particular assumption that the pattern of capacity depreciation is characterized by a decaying geometric series. The remaining task is to generalize the representa-

15 Very little data exist on the form of the distribution around the mean service life. The only study available was conducted by Winfrey (1935) detailing the actual service lives of a group of assets. Winfrey's S-3 distribution had a bell-shaped appearance somewhat akin to the normal distribution. No rigorous tests were performed to determine if the distribution was, in fact, a normal distribution, but based on this admittedly sparse evidence it is assumed that there exists a normal distribution about the mean life of a particular type of asset. This assumption is used mostly for convenience since tables of values for the normal distribution are readily available.

16 Interpolation involves fitting a cubic spline curve to the observed values. A cubic spline is a segmented function consisting of third-degree (cubic) polynomial functions joined together so that the entire curve and its first and second derivatives are continuous.

17 Service flows from public lands are estimated from grazing fees paid (Bureau of Land Management and Forest Service) and are included in intermediate input.

18 Land enrolled in the Conservation Reserve Program (CRP) is a component of capital stock, while conservation services are considered a component of output.

19 Net additions to inventory during the calendar year are included in the measure of output.

20 The estimates are of stocks in all positions. To obtain estimates of producer-owned stocks, we subtract quantities of commodities held by commercial (i.e., non-farm) entities, as well as commodities used as collateral for Commodity Credit Corporation loans.

tion of the rental price to allow for any pattern of capacity depreciation.

To accomplish this task, we draw on the literature on investment demand (Arrow, 1964; Coen, 1975; Penson, Hughes, and Nelson, 1977; Romain, Penson, and Lambert, 1987). Assume that firms buy and sell assets so as to maximize the present value of the firm.

Let w_k denote the price the firm must pay for a new unit of capital, p the price the firm receives for each unit of output, and r the real discount rate. An increase in the capital stock, K, by one unit will increase output in each period by $\partial y/\partial K$, the marginal product of capital. Gross revenue in each period will rise by $p(\partial y/\partial K)$, but net revenue will rise by only $p(\partial y/\partial K) - w(\partial R_t/\partial K)$, where $\partial R_t/\partial K$ is the increase in the replacement in period t required to maintain the capital stock at the new level. Firms should add to the capital stock if the present value of the new revenue generated by an additional unit of capital exceeds the purchase price of the asset. This can be stated algebraically as:

$$(8)\quad \sum_{t=1}^{\infty}\left(p\frac{\partial y}{\partial K} - w_k\frac{\partial R_t}{\partial K}\right)(1+r)^{-t} > w_k$$

To maximize net present value, firms will continue to add to capital stock until this equation holds as an equality. This requires that:[21]

$$(9)\quad p\frac{\partial y}{\partial K} = rw_k + r\sum_{t=1}^{\infty} w_k\frac{\partial R_t}{\partial K}(1+r)^{-t} = c$$

The expression for c is the implicit rental price of capital corresponding to the mortality distribution, m. The rental price consists of two components. The first term, rw_k, represents the opportunity cost associated with the initial investment. The second term, $r\sum_{t=1}^{\infty} w_k\frac{\partial R_t}{\partial K}(1+r)^{-t}$, is the present value of the cost of all future replacements required to maintain the productive capacity of the capital stock, multiplied by the discount rate, r.

Expression (9) can be simplified as follows. Let F denote the present value of the stream of capacity depreciation on one unit of capital according to the mortality distribution, m.

$$(10)\quad F = \sum_{\tau=1}^{\infty} m_\tau(1+r)^{-\tau}$$

It can be shown that:

$$(11)\quad \sum_{t=1}^{\infty}\frac{\partial R_t}{\partial K}(1+r)^{-\tau} = \sum_{t=1}^{\infty} F^t = \frac{F}{(1-F)}$$

so that:

$$(12)\quad c = \frac{rw_k}{(1-F)}$$ [22]

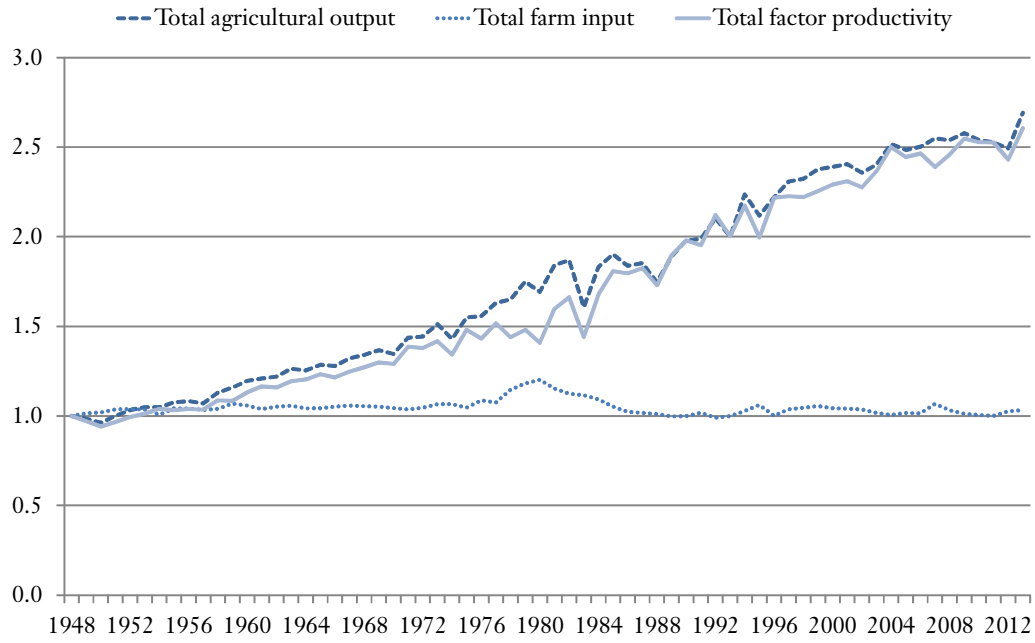
The real rate of return, r, in equation (12) is calculated as the nominal yeild on investment grade corporate bonds,[23] less the rate of asset price inflation (i.e. capital gain).[24] An *ex ante* real rate is obtained by expressing inflation as an ARIMA process.[25] Implicit rental prices are

21 If $r>0$, then $\sum_{t=1}^{\infty}(1+r)^{-t} = \frac{1}{1-\left(\frac{1}{1+r}\right)} - 1 = \frac{1}{r}$. Substituting this result in (8) and rearranging yeilds (9).

22 For the special case where $d_\tau = \delta(1-\delta)^{\tau-1}$, which was assumed by Jorgenson (1963, 1973), $F = \sum_{\tau=1}^{\infty}\delta(1-\delta)^{\tau-1}(1+r)^{-\tau} = \delta/(r+\delta)$ and $c = w_k(r+\delta)$, which is the expression for the rental price commonly found in the literature.

23 The nominal rate is taken to be the average yield on Moody's AAA bonds over all maturities (Federal Reserve Board).

Chart 1: Trends in Output, Farm Input, and Productivity in U.S. Agriculture, 1948=1, 1948-2013



Source: USDA's Economic Research Service.

then calculated for each (depreciable) asset type using the expected real rate of return.[26]

The user cost of inventories is obtained using equation (12), assuming zero decay. The cost of land service flows is derived using the accounting identity where the value of total product is equal to the total factor outlay.

Translog quantity indexes of capital input are estimated by aggregating over the various capital assets using cost-share weights based on asset-specific rental prices. Rental prices for capital input are generated implicitly as the ratio of the total value of capital service flows to the translog quantity index. As is the case for labour

24 Use of asset-specific capital gains when calculating real rates of return was recommended by Shumway et al. (2014). Previously, the USDA used a broad measure of inflation, the implicit deflator for gross domestic product, to calculate the real rate of return, arguing that expected real rates of return should be equal across all assets (Ball et al., 1997; 1999).

25 Price inflation is expressed as an AR(1) process. We use this specification after examining the correlation coefficients for autocorrelation, partial and inverse autocorrelation, and performing the unit root and while noise tests.

26 A more common approach to measuring the user cost of capital is to use an ex post rate of return (Jorgenson and Griliches, 1967; Christensen and Jorgenson, 1969; Jorgenson, Gollop and Fraumeni, 1987). This unknown rate of return can be found by using the condition that the sum of returns across all assets equals observed total profit (alternatively, gross operating surplus). However, many have expressed concern with the ex post approach (Schreyer, Bignon, and Dupont, 2003). They note that investment decisions must be made in advance of having all the relevant information. Firms employ some notion of the required rate of return when deciding how much to invest, and this required rate may differ from the realized rate. Moreover, they must base their decisions on expected, not actual, capital gains and losses. Using the ex post measure would imply either that all expectations are realized or that the quantities of capital can be instantaneously adjusted to the desired level after all uncertainties have been resolved. Neither assumption appears plausible a priori. It is for this reason that we adopt the ex ante approach when measuring user costs.

Table 1: Sources of Growth: U.S. Farm Sector (Average Annual Contribution to Growth Rates, Percentage Points)

	1948-2013	1948-1953	1953-1957	1957-1960	1960-1966	1966-1969	1969-1973	1973-1979	1979-1981	1981-1990	1990-2000	2000-2007	2007-2013
Output growth (%)	1.52	0.96	0.49	3.72	1.11	2.24	2.51	2.44	2.58	0.79	1.89	0.92	0.91
Sources of growth													
Labour	-0.49	-0.83	-1.11	-0.88	-0.86	-0.65	-0.41	-0.19	-0.23	-0.45	-0.21	-0.40	-0.18
Capital	-0.06	0.57	-0.02	0.00	0.04	0.16	-0.10	0.23	0.11	-0.78	-0.20	-0.06	0.13
Materials	0.60	0.95	1.11	1.63	0.73	0.49	0.84	1.67	-1.08	-0.37	0.84	0.78	-0.49
Total Factor Productivity	1.47	0.27	0.52	2.96	1.19	2.24	2.18	0.73	3.78	2.39	1.46	0.60	1.45
Source decomposition													
Labour													
Hours	-0.61	-1.06	-1.24	-0.92	-1.14	-0.95	-0.46	-0.21	-0.20	-0.52	-0.41	-0.45	-0.24
Quality	0.12	0.23	0.12	0.04	0.28	0.30	0.05	0.01	-0.03	0.07	0.19	0.05	0.07
Capital													
Stocks	-0.08	0.27	-0.15	-0.12	0.01	-0.15	-0.25	0.20	-0.09	-0.35	-0.09	-0.12	-0.07
Quality	0.02	0.30	0.12	0.13	0.04	0.32	0.15	0.03	0.20	-0.42	-0.11	0.06	0.20
Materials													
Quantity	0.62	1.04	0.92	1.71	0.71	0.37	0.87	1.97	-1.55	-0.31	0.84	0.79	-0.44
Quality	-0.02	-0.09	0.19	-0.08	0.02	0.12	-0.03	-0.29	0.47	-0.06	0.00	-0.01	-0.05

Source: USDA's Economic Research Service

input, the resulting measure of capital input is adjusted for changes in asset quality.

Productivity Growth

Input growth typically has been the dominant source of output growth for the aggregate economy and for each of its producing sectors. Jorgenson, Gollop, and Fraumeni (1987) find this to be the case for the aggregate economy for every sub-period over the period 1948-79. Denison (1979) draws a similar conclusion for all but one sub-period, covering the longer period 1929-76. In their sectoral analysis, Jorgenson, Gollop, and Fraumeni (1987) find that output growth relies most heavily on input growth in 42 of 47 private business sectors over the 1948-79 period, and in a more aggregated study (Jorgenson and Gollop, 1992) that extends through 1985, in 8 of 9 sectors. Finally, Jorgenson, Ho, and Stiroh (2005) provide estimates of the sources of output growth for 44 sectors of the U.S. economy for the period 1977-2000. Input growth completely dominates in 36 of these sectors.

Agriculture turns out to be one of the few exceptions, as can be seen in Chart 1. Productivity growth dominates input growth. This is confirmed in the top panel of Table 1 which reports the source decomposition of output growth in the farm sector over the full 1948-2013 period and twelve peak-to-peak sub-periods.[27] Applying the translog model, output growth equals the sum of contributions of labour, capital, and materials input and productivity growth. The contribution of each input equals the product of the input's growth rate and its respective share in total cost.

The singularly important role of productivity growth in agriculture is made all the more remarkable by the dramatic contraction in

27 The sub-periods are not chosen arbitrarily but are measured from cyclical peak to peak in aggregate economic activity. Since the data reported for each sub-period are average annual growth rates, the unequal lengths of the sub-periods do not affect the comparisons across sub-periods. This convention and these sub-periods have been adopted by the major productivity studies. See, for example, Jorgenson, Gollop, and Fraumeni (1987).

labour input in the sector, a pattern that persists through every sub-period.[28] Over the full 1948-2013 period, labour input declined at an average annual rate of 2.2 per cent, a rate unmatched by any of the 50 non-farm sectors evaluated by Jorgenson, Gollop, and Fraumeni (1987). When weighted by its 0.22 share in production costs, the contraction in labour input contributes an average -0.49 percentage points per year to output growth.

Capital input (including land and inventories) in the sector exhibits a different history. Its contribution to output growth alternates between positive and negative over the 1948-2013 period. On average, however, capital, like labour, contracts over the full period. Its negative growth contributes an annual -0.06 percentage points to output growth.

The negative contributions of both labour and capital are particularly striking given the positive contributions offered through improvements in both labour and capital quality, the reallocation of labour hours and capital stocks to higher marginal productivity uses. As revealed in Table 1, farms have higher-quality labour. This primarily is due to a more educated farm labour force.[29] Increased labour quality made a positive contribution to output in 11 of 12 sub-periods, averaging 0.12 percentage points per year over the full 1948-2013 period. Quality improvements in capital added another 0.02 percentage points, yet neither improved labour nor capital quality was sufficient to offset the contractions in the corresponding input. Increased labour quality offsets less than 20 per cent of the decline in raw labour hours; improvements in capital quality offset about 25 per cent of the decline in capital stocks.

Material input's contribution, as reported in Table 1, was positive in 10 of the 12 sub-periods and averaged a substantial positive rate equal to 0.60 per cent per year. Though large, this positive contribution just offsets the negative contributions from labour and capital. The net contribution of all three inputs was only 0.05 percentage points per year, leaving responsibility for positive growth in farm sector output largely to productivity growth in all but the 1973-79 and 2000-07 sub-periods.

Examining Table 1 makes clear that the 1973-79 period was an outlier. Output, labour, and capital growth rates did not deviate much from trend. Material input, however, exhibited significant positive growth at a rate far in excess of the incremental growth in output, accounting single handedly for the measured decline in the rate of productivity growth. This anomaly appears to be due to rapid growth in export demand during the period which resulted in the increased consumption of intermediate goods as well as a significant withdrawal of goods from inventory. Both led to a reduction in productivity growth. First, while additional intermediate inputs generated additional output, the incremental growth in materials input exceeded the incremental growth in output. Second, one-for-one transfers of final goods from inventory to market embed zero productivity growth.

The early 2000s saw the emergence of biofuels as a source of demand for grains and oilseeds.

28 Annual data on the price and implicit quantity of labour, capital, and materials inputs are available at http://www.ers.usda.gov/datafiles/Agricultural_Productivity_in_the_US/National_Tables/table01.xlsx

29 As discussed earlier, labour hours are cross-classified by sex, age, education, and employment class. Analysis of the changing composition of hours over the 1948-2013 period reveals that, among the four sources, education was the only dimension making a positive contribution to labour quality. As overall labour hours declined, demographic shifts in the sex, age, and class of employment composition of hours worked left higher proportions of hours worked in cells representing lower marginal productivity sex, age, and class cohorts. In contrast, the decline in hours worked was coincident with an increase in the proportion of more highly educated workers. This was sufficient to offset the negative effects of changes in sex, age, and class composition of hours and result in the persistent pattern of improving labour quality.

Corn used in ethanol production in 2007 accounted for roughly one-quarter of total demand. The land area planted to corn increased some 15 million acres (or roughly 20 per cent) between 2006 and 2007, resulting in the cultivation of more marginal lands. Despite significant year-over-year increases in fertilizer and pesticides consumption, yields per acre were largely unchanged.

In spite of these anomalous sub-periods, productivity growth was truly extraordinary over the 1948-2013 period. As indicated in Table 1, it averaged 1.47 per cent per year. Cumulated over the full sixty-five year period, this average annual rate (compounded annually) implies that farm sector productivity in 2013 was 160 per cent above its 1948 level. Given the cumulative 3.3 per cent increase in total input between 1948 and 2013, productivity growth caused agricultural output to grow significantly in every subperiod so that by 2013 farm output was 170 per cent above its level in 1948.

Summary and Conclusions

This article compares the contributions of input growth and productivity growth to output growth in postwar U.S. agriculture. We also examine the importance of changing input quality as a source of output growth.

The contribution of each input to output growth is measured as the product of the input's growth rate and its respective share in total cost. Over the postwar period, labour input in agriculture declined at an average annual rate of 2.2 per cent. When weighted by its 0.22 share in production costs, the contraction in labour input contributed an average -0.49 percentage points per year to output growth.

Capital input increased dramatically during the immediate postwar period, reflecting rapid mechanization of agriculture. Service flows from durable equipment increased at a 9 per cent annual rate from 1948 to 1953. But the average growth rate over the full 1948-2013 period was slightly less than 1 per cent per year. Land input declined at a 0.46 per cent average annual rate. Over the full 1948-2014 period, however, capital input declined 0.18 per cent per year. Its negative growth contributed an annual -0.06 percentage points to output growth.

Unlike labour and capital, growth in intermediate inputs made a positive contribution to output growth, averaging 0.60 percentage points per year. Though large, this positive contribution just offsets the negative contributions from labour and capital. The net contribution of all three inputs was only 0.05 percentage points per year, leaving responsibility for positive growth in farm sector output almost entirely (96.7 per cent) to productivity growth.

Changes in input quality have made significant contributions to input growth and, therefore, output growth. The net effect of quality change in all three inputs (i.e. labour, capital, and materials) was a 0.12 per cent per year contribution to output growth.

Although small in size, the contributions through input quality are quite significant. The 0.12 per cent contribution each year equals roughly one-tenth the annual contribution of productivity growth. Moreover, quality change is the sole reason for any positive contribution arising through growth in aggregate input. Had it not been for quality change, average annual growth in aggregate input would have been negative.

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Estimating Total Factor Productivity Growth: Canadian Freight Railways, 1986 to 2009

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Abstract

Canadian railways are a vital part of the country's transportation sector, moving goods and people across the country. We perform firm-level productivity analysis of Canadian freight railways for 1986 to 2009, focusing on the two railways which dominate the market: Canadian National (CN) and Canadian Pacific (CP). We obtain total factor productivity (TFP) estimates both by constructing productivity indices and by econometrically estimating cost functions. Driven in part by operational improvements, the strong TFP growth at both firms considerably outpaced aggregate TFP growth in Canada over the period of interest. This robust TFP growth, together with significant capital deepening, led to impressive labour productivity gains. We pay special attention to the productivity effects of the 1995 privatization of CN. While CN enjoyed much stronger productivity growth over the 1986-2009 period than CP, its performance was equally superior before and after the 1995 privatization.

Drumond, Ryan, and Veall (2013) argue that research at the firm-level is one of the most promising new frontiers in the productivity literature. They note that increasingly available microdata allows researchers to focus on how and why firms enter and exit a market, investigate the growth decisions faced by new, small businesses, and study managerial and operational decisions with an economic lens. The OECD (2015) points out that firm-level data also allows researchers to test the validity of industry-level findings at a finer level of detail. In a recent report by the Centre for the Study of Living Standards, Sharpe (2015) asserts that researchers ought to focus on the firm level to help policymakers develop more targeted interventions to imrpove productivity growth. Sharpe suggests that the increasingly available microdata at the firm level provided by Statistics Canada allows research to improve understanding of drivers of productivity growth.

Canada's two major freight railways, Canadian National (CN) and Canadian Pacific (CP), operate transcontinental networks which carry more than 80 per cent of Canadian rail freight by most metrics (Cairns, 2015).[2] Even more impressive than their dominance of the Canadian freight rail market is their total factor productivity (TFP) growth, which by our estimates averaged well above the -0.11 per cent per year annual average for the Canadian business sector for the same period.[3] Given their sustained success, the

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two railways are natural candidates for firm-level productivity analysis.

CN and CP are not by any means the only freight rail firms in Canada. Over the years both firms sold off their less profitable branch lines, and dozens of shortline railways have entered the market to fill regional demand by taking over the lines. While the Canadian freight rail sector is made up of a number of firms, each of them is dwarfed by CN and CP in terms of market share. As Statistics Canada has not made any firm-level data available on the shortlines, they will not be discussed at any level of depth. Most of the literature regarding Canadian freight rail applies a similar scope to their study (Freeman *et al.*, 1987, Tretheway, Waters, and Fok, 1997; Waters and Tretheway, 1999; Iacobacci and Schulman, 2009). McKellips and Calver (2015) do provide a sector level analysis, estimating that TFP in the railway transportation sector grew 1.26 per cent per year from 2000 to 2013.

This article provides estimates for TFP growth at the firm level, as well as for the two railways combined. As Statistics Canada does not provide TFP estimates beyond the three-digit NAICS level for transportation, our estimates provide valuable information about productivity developments in freight rail.[4] Furthermore, to the best of our knowledge we are the first to apply the method of Caves, Christensen, and Swanson (1981a) to estimate TFP growth at CN and CP since Freeman *et al.* (1987).

Ultimately, we reaffirm the general finding in the literature that CN and CP are productivity success stories when compared with Canadian industry as a whole. This article estimates TFP for both railways individually, as well as other productivity measures to unpack their various successes. Ultimately, TFP for the two Canadian freight railways grew at an estimated rate of 3.94 per cent per year from 1986 to 2009.[5] Experts attribute much of this growth to operational efficiency improvements arising from Hunter Harrison's precision railroad model. Using indices, we estimate TFP growth to be 4.42 per cent per year at CN and 3.12 per cent per year at CP over the 1986 to 2009 period. Econometric estimates put annual TFP growth throughout the period at 4.23 per cent per year at CN and 3.52 per cent per year at CP.

We first review the literature regarding the major empirical methods of analysis, present relevant past findings on railway productivity, and consider operational developments described by industry specialists. Next, we discuss the data employed in this study. We then present the index method for obtaining measures of partial and total factor productivity, as well as the estimated measures themselves. Next, we present the econometric method for obtaining TFP measures via cost function esti-

2 These metrics include kilometres of rail operated, capital expenditures, and number of employees. The one exception is tonnes originated, where CN and CP only make up 60 per cent of the market. This is largely due to two railways in Northern Quebec and Labrador which are owned by the shipper and handle iron ore from nearby mines: the Cartier Railway (owned by Arcelor Mittal Mines Canada) and the Quebec North Shore and Labrador Railway (owned by the Iron Ore Company of Canada). Neither railway connects to the main line nor is under competitive pressures from other railways, being owned by the shipper. CN and CP account for more than 80 per cent of tonnes originated once these two firms are removed.

3 Compound average annual growth rate calculated using the Statistics Canada Multifactor Productivity index available in CANSIM Table 383-0021.

4 Statistics Canada does not provide TFP estimates down to NAICS 482 (Rail transportation), but rather an aggregate of NAICS 481-483, and 487. McKellips and Calver (2016) did obtain TFP growth estimates for NAICS 482 from Transport Canada, and estimate TFP to have grown 1.26 per cent per year in rail transportation from 2000 to 2013. Notably, this estimate still includes the shortlines and passenger railways in addition to CN and CP, and thereby does not provide specific information about productivity growth in the freight rail sector as we treat it. It also starts 14 years and ends four years later than our data.

5 As measured using the index approach.

mation, as well as the estimates themselves. Penultimately, we discuss the results obtained in the two previous sections, looking at what contributed to the robust partial productivity and TFP growth in the freight rail sector from 1986 to 2009. Finally, we conclude and provide some avenues for future research.

Literature Review

To situate the data analysis, we first review two of the major approaches in transportation productivity research: analysis using index numbers and the econometric estimation of a cost function. Uguccioni (2016) includes a more comprehensive discussion of the two methods, as well as an evaluation of data envelopment analysis estimation of the theoretical efficient frontier. We then proceed to review some empirical findings relevant to the Canadian experience with freight railways for reference when considering our estimates. Finally, we conclude with an overview of recent developments in the industry from the point of view of key experts involved in freight rail operations.

Methodological Approaches

Index number approach

The most widely used methodology to measure productivity growth is an index number approach, employed by official bodies such as Statistics Canada and researchers alike. The most widely used productivity measure in transportation research is TFP. Single factor productivity measures are also popular, and some studies employ more esoteric measures such as variable factor productivity.

Diewert (1992) argues that an index approach to TFP measurement is far superior to econometric estimation because it requires fewer underlying assumptions about the behaviour of firms (e.g. profit maximization versus maximizing shareholder value).

An analysis of productivity at CN and CP is undertaken using the index number approach below. We calculate partial productivity measures and employ a Tornqvist index to generate TFP growth estimates.

Econometric Estimation

Another approach to analyzing TFP growth is through econometric estimation of a cost function, and imputing productivity growth. Caves, Christensen, and Swanson (1981a) model a variable cost function for a panel of American railways using a translog approximation. By Shephard's lemma, they break up their variable cost function into factor demands, which are in turn estimated using Zellner's (1962) method of seemingly unrelated regressions. By assuming cost minimizing behaviour by the firm, Caves, Christensen, and Swanson use the factor demands to infer the structure of the firm's production function, which they then estimate over time to evaluate TFP growth. As their model assumes short run cost minimizing behaviour, they incorporate three separate time periods via dummy variables to allow fixed inputs to adjust. Caves, Christensen, and Swanson (1981b) expand the breadth of application of this method.

Many variations on the Caves, Christensen, and Swanson (1981a) approach to estimating railway TFP via the variable cost function have been developed since 1981 (for example, see De Broger, 1991a, and 1991b; McGeehan, 1993; Wang and Liao, 2006). An alternative to the Caves, Christensen, and Swanson approach was first proposed by Christensen, Jorgensen, and Lau (1973). This approach is largely the same, but estimates a total cost function in lieu of a variable cost function. Smith (2006) employs the Christensen, Jorgensen, and Lau (1973) method for British railways from 1963 to 2002. Smith argues that treating some inputs as quasi-fixed for several years when estimating the variable

cost function is highly unrealistic, as managers are able to choose annual capital expenditures in any given year to minimize costs.

The motivation for an econometric analysis of productivity is to disentangle "black box" productivity gains. Specifically, Caves, Christensen, and Swanson's goal is to disentangle movements along the production function and movements of the production function. By modelling a cost function, they separate estimates for the contributions to TFP growth made by returns to scale and technological change. Smith (2006) adds to their model, proposing a method to generate estimates for returns to density in addition to returns to scale and technological change.[6]

While Diewert (1992) prefers the use of index numbers to generate TFP, he is quite explicit in arguing that the estimation of a quadratic form of a cost function is a superior econometric approach than simply estimating a production function. The primary advantage of the cost function is the degrees of freedom which can be added to the estimation with Shephard's lemma. Diewert objects to several assumptions made by the cost function model: that firms are in reality minimizing costs; that the cost function nicely decomposes into a part which is time invariant and a part which is dynamic; and how the errors enter into the model (e.g. logarithmically or additively).

Below, we discuss the particulars of how we conducted our econometric estimation of productivity. Our method is by and large the same as Smith's (2006), with only minor modifications to the cost function to suit data realities.

Past Empirical Findings

Table 1 provides some empirical results relevant to the study of productivity growth at Canadian railways. Tretheway, Waters, and Fok (1997) undertake a major study of CN and CP using data from 1956-1991. Waters and Tretheway (1999) extend the Tretheway, Waters, and Fok analysis to 1995. While the period of

Table 1: Relevant Empirical Results Regarding Canadian Freight Rail

Paper	Subject of Study	Results
Tretheway, Waters, and Fok (1997)	**CN and CP, 1956 to 1991**	CP had slightly higher levels of TFP relative to CN for most of the period, but was overtaken by CN around 1990. Average TFP growth for both railways from 1956-81 was 3.4 per cent per year, but it slipped to 3.0 per cent per year for CN and 2.7 per cent per year for CP in the period of 1981-91. They argue that 1.8-1.9 percentage points of annual TFP growth was due to technical progress while the remainder was due to operational efficiency, and that significant productivity gains could be reaped if the railways were allowed to abandon unprofitable lines.
Waters and Tretheway (1999)	**CN and CP, 1956 to 1995**	Extends the analysis of Tretheway, Waters, and Fok (1997) to 1995, and reports TFP growth of 3.1 per cent per year for CN and 2.8 per cent per year for CP during the period of 1981-1995. For both firms, accounting for the newly added period of 1991-1995 indicates CN and CP averaged TFP growth around 3.4 per cent per year and 3.1 per cent per year respectively during those 4 years.
Iacobacci and Schulman (2009)	**Canadian railways, 1981 to 2006**	Reports average TFP growth of 3.6 per cent per year at CN and CP during the period of 1981 to 2006. Attributes this strong growth to deregulation, changes in governance structures (e.g. 1995 privatization of CN) and increased competition through the proliferation of regional, short line carriers.
Cairns (2015)	**Canadian railways, with emphasis on CN and CP, 1981 to 2013**	The operating ratios of CN and CP decreased towards their values in 2013 of 63.4 per cent and 76.8 per cent respectively. CN and CP have averaged 3 per cent per year TFP growth between 1981-2012, compared to less than 1 per cent per year in the Canadian economy. Cairns argues the sources of the productivity gains include the CN and CP ridding themselves of unprofitable lines, a shrinking workforce, improved locomotives, and improved operational practices.

6 Whereas returns to scale is the effect of firm growth on output (e.g. increasing all inputs results in some change in output), returns to density is the effect of increased throughput for a given transportation network (e.g. increasing all inputs excluding track employed results in some change in output). See Keeler (1976) for full discussion.

interest for these two articles only provides 9 years of overlap with our 1986-2009 data, it can be used to verify some of our results. Studies by Iacobacci and Schulman (2009) and Cairns (2015) provide an overview of recent sources of productivity growth in the Canadian freight rail context.[7]

Many studies of rail productivity in other geographic contexts exist, and can be in part relevant to the study of Canadian freight railways. That is, the locations of ports and the road network versus the location of rail networks mean that the effects of competition among different modes of transportation in each country are unique.

Tretheway, Waters, and Fok (1997) argue American Class I railways exhibited higher TFP growth than CN and CP in the 1980s because they exploited economies of density, as the American railways tended to reduce track inputs for a fairly steady output level while the Canadian railways tended to increase outputs relative to inputs. Network density is an important factor, and is considered in the discussion of results below. Some other studies investigate small, regional railways in Belgium (De Borger, 1991a and 1991b), Ireland (McGeehan, 1993), and Taiwan (Shi, Lim, and Chi, 2011).

Operational Developments in the Freight Rail Sector

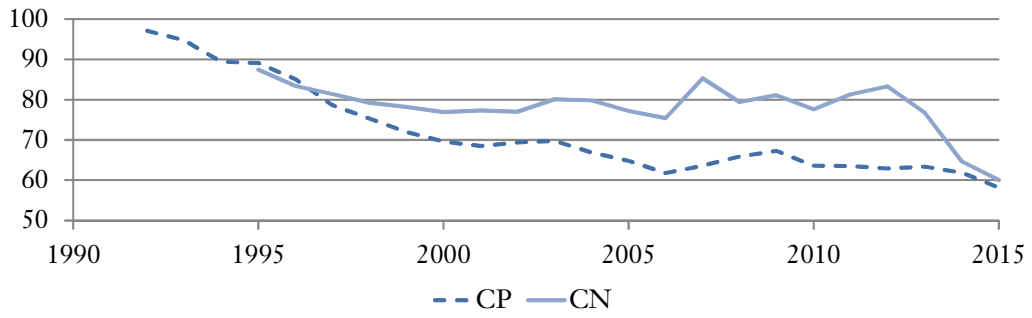
While economists can provide estimates on productivity growth in the freight rail sector, industry executives are better suited to discuss the specifics of where efficiency is lost or improved. In late 2010, CN CEO Claude Mongeau was asked by the Railway Association of Canada to reflect on the first 15 years of CN as a private firm (Railway Association of Canada, 2011). Mongeau lauded CN's first CEO, Paul Tellier, for leading the charge towards privatization and expanding CN across North America through acquisitions. He then proceeded to discuss how Hunter Harrison, Tellier's successor, improved CN operations by turning it into a precision railroad.

Harrison served as President and CEO of Illinois Central before the firm was acquired by CN in 1998. From 1998 to 2003, he served as COO under Tellier. In 2003, Harrison took over from Tellier as CEO of CN, stepping down in 2009. Harrison (2000) dates the beginning of CN's metamorphosis into a precision railroad in September 1998. Under his operational framework, CN not only scheduled trains and their cars, but also the support processes underlying their service provision (e.g. maintenance and car inspections). This meant that each individual railcar had its own personalized timetable to ensure that most delays to deliveries were expected. Two years after CN's transformation into a scheduled railroad, Harrison had drastically reduced the number of late arrivals and managed to shrink CN's active locomotive fleet by 600 vehicles. In 2002, Harrison won the prestigious Railroader of the Year award from *Railway Age*, an industry journal, for changing the face of the industry with his concept of a precision railroad (Railway Age, 2002).

Harrison (2000) distills operating a precision railroad to a handful of operational goals, including: minimizing car dwell time in rail yards; using general purpose trains; balancing train movement by direction across corridors; minimizing power requirements; and optimizing yard schedules. Reductions in down time spent in yards and time spent by trains "dead heading" (waiting for oncoming traffic to clear the line) have obvious productivity effects, as decreasing the amount of time spent per output frees up resources to produce more. By keeping yard schedules with the steady arrival and depar-

7 Some other studies investigate small, regional railways in Belgium (De Borger, 1991a, 1991b), Ireland (McGeehan, 1993), and Taiwan (Shi, Lim, and Chi, 2011).

Chart 1: Operating Ratios for CN and CP, Per Cent, 1992-2015



Source: CSLS tabulation based on CN and CP annual shareholder reports.

ture of trains, rather than an ebb and flow, railways eliminate the need to keep excess capacity on hand at yards for high volume periods. Minimizing power requirements per train is an important, but admittedly counter-intuitive, prescription of a scheduled railroad. Under Harrison, CN balanced train velocity against horsepower requirements, sometimes sacrificing velocity. As adding a locomotive to a train results in a large step of horse power (think 3000 horsepower increments), Harrison found instances where the removal of a locomotive did not affect the network's schedule and reaped net savings from slowing trains.

Many freight rail experts use operating ratios (ratio of operating expenditures to revenues) of railways as their primary productivity metric. In 2011, CN posted the lowest operating ratio of any North American Class I at 63.5 per cent, while CP posted the highest at 81.3 per cent (Barrow, 2012). Interestingly, in 2012 Pershing Square Capital Management lead a coup at CP and replaced CEO Fred Green with the recently retired Hunter Harrison. After a single year in charge, Harrison was able to reduce the operating ratio at CP by 4.5 percentage points to 76.8 per cent, while CN only reduced their operating ratio by 0.1 percentage points over the same period (Cairns, 2015).[8] Chart 1 provides time series of the operating ratios from 1992 to 2015 for CN and from 1995 to 2015 for CP.

From an economist's point of view, an operating ratio is a less than ideal metric for productivity because it is sensitive to input price shocks. For example, if a railway benefits from a windfall one season simply because of a light winter, it is captured as a decrease in the operating ratio, though no productivity gains actually took place. So long as these shocks are more or less rare, however, operating ratios ought to more or less inversely track TFP growth (as firms are able to create more output per input). With this rough interpretation, Chart 1 shows that CN had a much higher level of productivity (be it labour productivity or TFP) than CP for most of 2002 to 2015 and that CP experienced massive productivity improvements under Harrison starting in 2012.

Unfortunately, as our data end in 2009, we are not able to analyze Harrison's time at CP beyond looking at operating ratios. We are, however, able to assess his effect at CN. Below, four major events are considered concurrently with Iacobacci and Schulman's (2009) assertion that the privatization of CN lead to its stellar productivity growth: the installation of Tellier at the head of CN in 1992; the appointment of Harrison as COO and the advent of precision

8 Admittedly, CN did have a lower operating ratio at the beginning of 2011, and likely had less slack to remove than CP.

railroading in 1998 and 1999 (as Harrison only implemented the precision railroad in September 1998, the first full year of the precision railroad) was 1999; and Harrison's move to CEO in 2003.

Data

Below, we first summarize how the data used in our analysis was obtained by Statistic Canada and specifics of what is made available to the public. We then present trends of individual factors of production to gain an overall understanding of the trends in inputs employed at CN and CP during the 1986-2009 period. Next, we undertake a similar analysis of the outputs of CN and CP. Finally, we present the varying importance of individual inputs to production overtime, as measured by their share of overall cost.

Data Employed

All data employed are publicly available from Statistics Canada's CANSIM data repository.[9] Specifically, the data come from the annual *Railway Transport Survey*.[10] The survey collects operational, financial, and employment statistics on all common carrier railways (both freight and passenger) in Canada. Response is mandatory and data are reported directly by the firms themselves. The publicly available dataset covers the period from 1986 to 2009. While both CN and CP have networks which extend into the United States, the *Railway Transport Survey* dataset only covers operations in Canada. All inputs and outputs are strictly evaluated within Canadian borders (e.g. labour costs assigned to a Canadian line).

Conducting our analysis in 2016 but ending the scope of study in 2009 is unfortunate. However, in order to publish detailed rail data Statistics Canada requires permission from the large carriers. Beginning in 2010, Statistics Canada was unable to secure the cooperation of all parties involved, and as such the data are not publicly available beyond this point.[11] A longer and more recent time series would improve the precision of the estimates we obtain and the overall relevance of our work.

One unique aspect of the *Railway Transport Survey* dataset is that it contains physical values of inputs and outputs. This means our productivity estimates do not rely on deflating nominal values to obtain real values as most other studies do, and thereby avoid any measurement error arising from the use of deflators which do not capture price developments for specific inputs and outputs at a specific firm.

Trends in Inputs

All inputs (locomotives, freight cars, kilometres of track operated, labour, and fuel) experienced declines over the period of 1986-2009.[12]

The most striking trend of all the inputs is the stark decline in labour over the period – by 2009 CP employed 43.6 per cent and CN employed 31.4 per cent of the labour it employed in 1986.[13] The largest source of the labour declines at both CN and CP were equipment maintenance positions, which may reflect higher quality equipment (e.g. more reliable locomotives)

9 Specifically, we use CANSIM tables 404-0004 (financials), 404-0010 (track), 404-0012 (fuel), 404-0014 (operating statistics), 404-0017 (equipment), and 404-0019 (labour).

10 For specific details, refer to: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=2734 and http://www23.statcan.gc.ca/imdb/p3Instr.pl?Function=assembleInstr&Item_Id=138433&TET=1.

11 Information obtained in correspondence with Statistics Canada.

12 Ideally we would also include a land input in our production function, as the track does not exist in a vacuum. Unfortunately, Statistics Canada does not publish any figures on land used by the railways and as such we are unable to construct a land input.

13 CP had 11,310 employees in 2009 compared to 25,953 in 1986, and CN had 14,484 employees in 2009 compared to 46,074 employees in 1986 – falls of 68.6 per cent and 56.4 per cent respectively

or improvements in the track infrastructure causing equipment to require servicing less frequently. Another striking trend in the inputs is the decline in kilometres of track operated, as both railways sold off or closed lines which were not economically sustainable (Cairns, 2015).

Overall, both firms reduced their labour, track, and freight car inputs over the 24 year period. CN also reduced its locomotive input, whereas CP's number of operational locomotives has stayed fairly steady since 1986. Looking at the time trend of locomotives in use at CN, there is some evidence of CN's reduction gaining steam in 1998 with the advent of Harrison's precision railroading. However, as there is also an obvious long term trend toward fewer locomotives in service, this may not be attributable to Harrison. Both CN and CP used slightly less diesel in 2009 than they did in 1986, but there is little evidence of a steady, downward trend.

Trends in Outputs

Revenue-tonne kilometres (RTKs) are the principal unit of output measurement in freight rail. One unit of RTK measures a tonne of freight which will generate revenue transported one kilometre. The outputs of CN and CP are almost exclusively RTKs — they tend to account for between 89 per cent and 97 per cent of revenue depending on the firm and year.

Both CN and CP enjoyed strong output growth from 1989 to 2007, at which point the output of both firms declined until 2009. As a rough measure of productivity, it is important to observe that output was increasing despite significant falls in inputs, meaning both CN and CP were able to produce much more with less over the period.

It is also worth noting that the severe drop in output begins in 2008 with the financial crisis. The drop in gross tonne kilometres freight output from 2007 to 2009 is the most stark change in either direction over the entire period.

Trends in Factor Cost Shares

Factor cost shares are key parts of both the index and econometric methods employed to obtain TFP estimates for the two firms, and consequently deserve some discussion. First and foremost, it is worth noting that the cost shares employed in the analysis are not equal to the costs of the individual inputs over the total operating expenses because the data includes some costs which do not have an underlying physical value to include in our index. Rather, we sum the costs of each of our inputs to obtain our "total cost" denominator used in input cost shares. This is purely for technical purposes, as cost shares must sum to 1 for both the Tornqvist index used below and in equations (ii) through (v). [14]

The cost shares of variable inputs such as labour and diesel are calculated simply using expenses on the inputs in a given year. Capital expenses are slightly less straightforward given that a purchase of a capital asset in one year can factor in as an input for years in the future. Statistics Canada publishes numbers on amortization of capital assets. The expense on a capital input in a given year is maintenance and servicing costs assigned to the input plus amortization of capital stock. We acknowledge that weighting our capital assets this way likely underestimates their contributions to production, particularly

14 This could result in the underweighting of certain inputs and the overweighting of others if miscellaneous costs are not equally distributed across inputs. For example, if most of the miscellaneous costs relate to the locomotive input, then the cost share of locomotives is understated. This could distort any productivity estimates which employ the underestimated cost shares. While this is a concern, we have no evidence of any such underweighting. Comparing the total cost we used to construct our cost shares with the total operating costs published in the Statistics Canada dataset, our numbers typically account for 70 to 80 per cent of total operating expenditures reported by the firms depending on the year. Most of this gap is accounted for by expenses categorized as miscellaneous (e.g. miscellaneous way and structure expenses) and net equipment rents. However, as we have no a priori reason to allocate these costs to one specific input over another, we leave them aside.

for locomotives and freight cars, by valuing the user cost of capital across new and old inputs the same. While this is certainly an issue, better data on the user cost of capital is not available from Statistics Canada at this time.

Cost shares strive to capture the "importance" of an input to overall production. Trends in the costs indicate changes in the importance of inputs overall. Appendix Tables 3 and 4 give the cost shares attributed to each input in every period.[15] At CN, the cost shares of labour, locomotives, and freight cars fell over time while the shares of diesel and track both increased. The changes in diesel and labour cost shares were especially important, with each rising and falling 10 percentage points respectively from 1986 to 2009. At CP, the cost share of labour fell around 7 percentage points and the cost share of diesel increased 10 percentage points. The cost shares of locomotives and freight cars slightly decreased and the cost share of track slightly increased.

Productivity Analysis: Index Approach

This section employs the index approach to transportation productivity research. We first provide an overview of the Tornqvist index and the specific form we employ in our analysis. Next, we explore partial productivity measures in Canadian freight rail. We then report our total factor productivity estimates for CN and CP over the course of the 1986-2009 period.

Index Methodology

The revenue-weighted multilateral Tornqvist index employed by Caves, Christensen, and Diewert (1982a) and by Tretheway, Waters, and Fok (1997) for their analysis takes the following form:

$$ln\left(\frac{TFP_s}{TFP_t}\right) = \left[\sum_i \frac{1}{2}(R_{i,s} + \bar{R}_i) ln\left(\frac{Y_{i,s}}{\bar{Y}_i}\right) - \sum_j \frac{1}{2}(C_{j,s} + \bar{C}_j) ln\left(\frac{X_{j,s}}{\bar{X}_j}\right)\right] - \left[\sum_i \frac{1}{2}(R_{i,t} + \bar{R}_i) ln\left(\frac{Y_{i,t}}{\bar{Y}_i}\right) - \sum_j \frac{1}{2}(C_{j,t} + \bar{C}_j) ln\left(\frac{X_{j,t}}{\bar{X}_j}\right)\right] \quad (1)$$

This index computes TFP growth between years s and t, by evaluating the ratios of outputs to inputs for each year. Y_i and X_j are output i and input j. R_i and C_j are the revenue and cost shares of output i and input j. Terms with bars and no time subscripts denote the variable's average value throughout the 24 year period.

The Tornqvist index can be easily modified to generate estimates for the relative TFP levels between firms. This can be done by fixing the first and second terms in the same year, making the first term all CN variables and the second all CP variables. The results is an index of TFP levels at CN relative to CP. See Panel B of both Chart 2 and Chart 3 for this comparison.

The index weights inputs by the arithmetic mean of the input's cost share in a given year and the input's average cost share throughout the 24 year period. This weighting procedure allows the index to capture the importance of an input to the firm, while smoothing out annual variability with the input's average "importance" throughout the period.[16] The inputs used for analysis are locomotives, freight cars, kilometres of track operated, diesel, and labour.

Anticipating the criticism from Cooper, Seiford, and Tone (2007), Tretheway, Waters, and Fok (1997) do note that estimates obtained in this fashion are sensitive to the weights used, but

15 Available at: <http://www.csls.ca/ipm/30/uguccioniappendix.pdf>

16 While this weighting procedure is quite standard in the literature, there is one notable flaw with it. By smoothing out annual variability, we could inadvertently diminish the importance of trends within the cost shares themselves described above. For example, the physical amount of labour fell quickly from 1986 to 2009, but so did its cost share. By smoothing cost shares with the period's average, we may be overemphasizing the importance of labour in production in the later periods. We test the robustness of our TFP growth estimates to an index constructed without cost share smoothing later in this article.

ultimately argue that results are not too sensitive to weights. Tretheway, Waters, and Fok (1997) use the same weighting procedure for outputs (in this case, passenger and freight outputs) with revenue shares. However, as passenger outputs are not considered in the analysis below, no weights are needed for output.

Notably, the revenue-weighted multilateral Tornqvist index can be easily modified to provide estimates of productivity for subsets of inputs, such as the three capital inputs. Capital productivity growth can be obtained by weighting capital inputs by the cost share of the capital asset to total capital costs and comparing it to our index of output as usual

Finally, as suggested by Diewert (1992), the procedure above was employed to generate the growth in productivity between pairs of years. These growth rates were then applied sequentially (i.e. chain-linked) to an arbitrary base value of 100 in 1986 to generate the series shown in Panel A of Chart 3.

Partial Productivity Measures

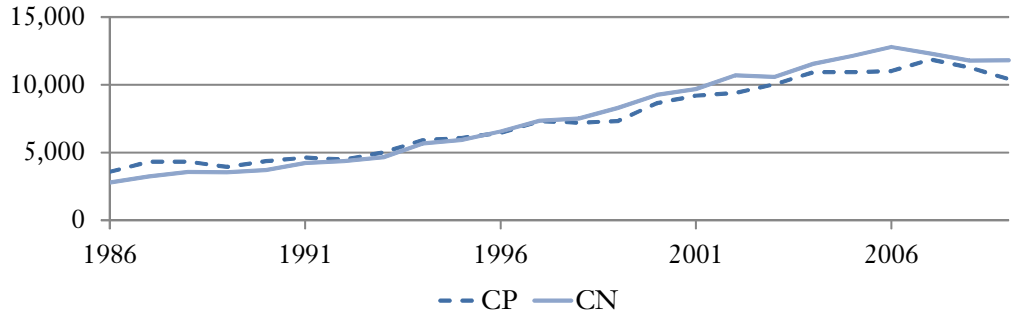
Chart 2 measures labour productivity in thousands of RTKs per employee and shows the spectacular growth experienced by both CP and CN over the 1986-2009 period.[17] CP labour productivity grew at an average rate of 4.76 per cent per year and CN labour productivity at an average rate of 6.49 per cent per year. In absolute terms, labour productivity at CP grew from 3.6 million RTKs per employee to 10.4 million RTKs per employee and labour productivity at CN grew from 2.8 million RTKs per employee to 11.8 million RTKs per employee. Panel B of Chart 2 compares the levels of labour productivity between CP and CN. Notably, CP achieved higher RTKs per employee than CN from 1986 until around 1996. From around 1998 to 2009, CN has attained higher RTKs per employee than CP. As such, CN's labour productivity growth over the period falls into two slightly different categories. Prior to around 1996, CN was converging to a level of labour productivity which had already been attained by CP, and its higher growth rate may have been driven in part by excess slack in its system. Following 1998, CN's growth is more of a matter of productivity gains by technological change.

McKellips and Calver (2016) provide a framework for decomposing our labour productivity numbers. Our figures in part reflect increasing capital intensity over the period, as labour declined much more quickly than the capital inputs. Capital intensity grew 3.17 per cent per year from 1986 to 2009 at CN and 2.31 per cent per year at CP. The number of workers employed at CN in 2009 fell to 31.4 per cent of its 1986 value (shrinking 4.90 per cent per year), while the number of workers employed at CP fell to 43.6 per cent of its 1986 value (3.55 per cent per year). At CN, the labour input fell more than 2 percentage points per year faster than any other input; at CP, labour fell over 1.5 percentage points per year more than any other input. The increased labour productivity may also reflect disembodied technical change which led to increased productivity of each unit of labour, such as Harrison's precision railroading. Finally,

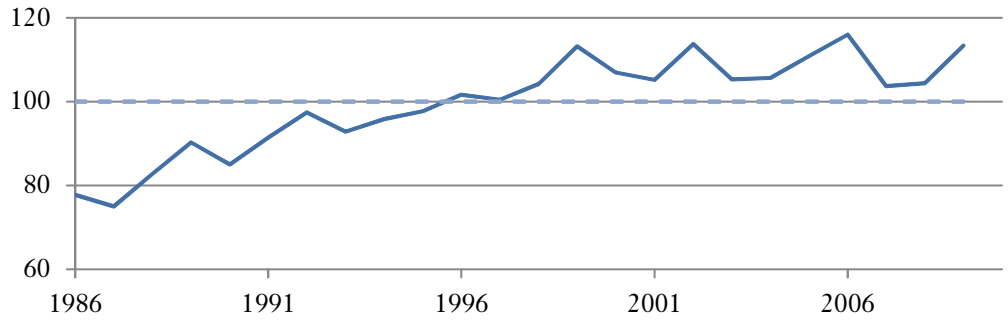
17 We recognize that by measuring labour productivity in terms of output per employee rather than output per hour worked, we may be somewhat underestimating labour productivity growth. We use employees instead of hours because no direct data on hours of work is provided in our dataset. We are able to generate indirect estimates of hours worked per employee from average annual compensation and average hourly compensation, but we do not employ these numbers because it is unclear how (if at all) salaried workers are accounted for in the average hourly compensation data. Using our indirect method, we do find that in 2009 employees worked 95 per cent of the hours per year that they did in 1986. This result is broadly similar with the Canadian experience on the whole, as a back of the envelope calculation from CANSIM table 383-0012 shows that the average Canadian worker worked just under 95 per cent of the hours in 2009 that she did in 1986. Assuming hours worked per worker fell 5 per cent on average at both CN and CP over the 1986-2009 period, our labour productivity estimates are understated by about 0.2 percentage points per year.

Chart 2: Firm-Level Labour Productivity, 1986-2009

Panel A: Labour Productivity Levels, Thousands of RTKs per employee, 1986-2009



Panel B: Relative Labour Productivity, CN relative to CP, per cent, 1986-2009



Source: Data from Statistics Canada Tables 404-0016 and 404-0019, obtained from CANSIM October 5, 2015.

improved labour productivity could also reflect a change in the quality of labour (e.g. changes in the stocks of human capital).

Uguccioni (2016) also provides estimates of capital and fuel productivity for both firms. Capital productivity measures show broadly the same trend as labour productivity (CN converging with and then surpassing CP). CN had higher fuel productivity levels than CP throughout the period, likely reflecting geographical differences in the networks of the two railways.

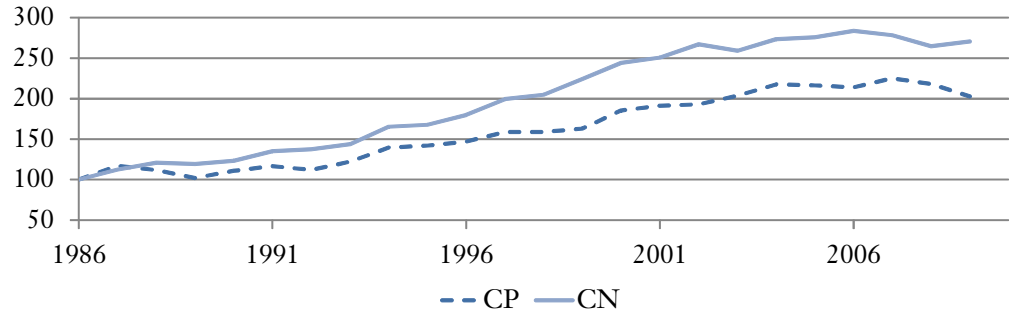
Total Factor Productivity

Following Tretheway, Waters, and Fok (1997), TFP is estimated by weighting each of the five inputs discussed by their share of factor costs in a Tornqvist index for comparison with RTKs, using the methodology discussed above. TFP growth was evaluated in pairs of consecutive years, and these values were then chained to build the series shown in Panel A of Chart 3. Over the course of the period, CP's estimated TFP grew at an annual average rate of 3.12 per cent per year and CN at an annual average rate of 4.42 per cent per year.

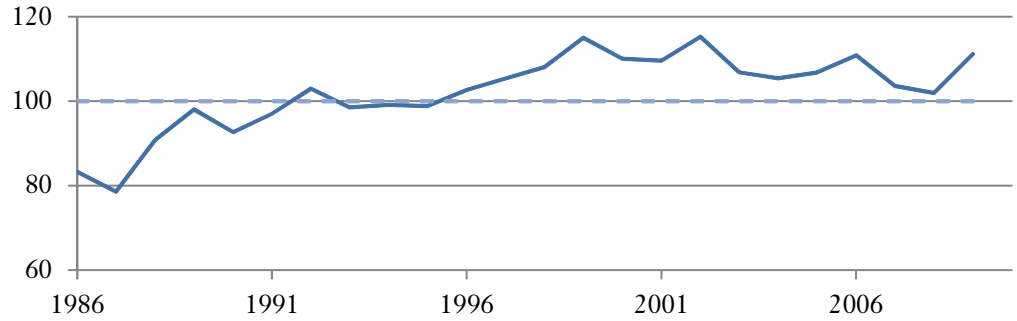
Our estimates are contingent on a weighting procedure which smoothes cost shares with annual averages, and thereby dampens the effect of secular changes to an input's cost share over time. To test the robustness of our weighting procedure, we constructed our TFP index and weighted inputs only by their cost shares in the period of interest. With this methodology, we estimate TFP growth at CN to have been 4.36 per cent per year and at CP to have been 3.26 per cent per year. While our weighting procedure somewhat underestimated TFP growth at CP and overestimated TFP growth at CN, the magnitude of the bias is quite small. Consequently, we are not concerned that our estimates are not

Chart 3: Firm-Level Total Factor Productivity, 1986-2009

Panel A: TFP Growth, 1986-2009 (1986 = 100)



Panel B: Relative TFP, CN relative to CP, per cent, 1986 to 2009



Source: Data from Statistics Canada Tables 404-0004, 404-0010, 404-0012, 404-0016, 404-0017, and 404-0019, obtained from CANSIM October 5, 2015.

dependent enough on the "importance" of an input in any given period.

We compare the level of TFP at CN relative to the level of TFP at CP in Panel B of Chart 3. In 1986, CN had a level of TFP which was 83.3 per cent that of CP; in 2009, CN had a level of TFP which was 111.1 per cent that of CP. Much like with labour productivity, CN's TFP growth is largely a matter of convergence prior to the mid-1990s and pulling away from CP afterwards.

Productivity Analysis: Econometric Approach

This section employs the econometric approach to productivity estimation described above. Below, we first detail the specific model employed in the analysis. Next, we provide an overview of some of the estimates obtained, and evaluate the stability of the CN productivity parameter estimate throughout the period, with direct reference to Iacobacci and Schulman (2009). Finally, we compare the results obtained using econometric estimation with those obtained using the index approach.

Econometric Model

Caves, Christensen, and Swanson (1981a) pioneered an econometric method for estimating TFP in freight rail. They estimated the variable cost functions for railways and obtained the TFP growth rates implied by the functions. Caves, Christensen, and Swanson (1981a) originally applied their method to an unbalanced panel dataset of American railways covering 19 years with three cross-sections, with each cross section having between 40 and 58 firms. Their method has since been widely used.

One example is Smith (2006), who applies the Caves, Christensen, and Swanson (1981a)

approach to a balanced panel dataset of Britain's railways with annual observations. As our data is much more similar to Smith's than Caves, Christensen, and Swanson's, our methodology adapts Smith for the Canadian case to obtain estimates for annual rates of TFP growth for CN and CP.

We assume that each railway is minimizing its total cost, rather than its variable cost. While this assumption is somewhat controversial, we are not the first to make it.[18] Smith also estimates the total cost function rather than the variable cost function, arguing that managers have sufficient control over capital inputs over time to make any assumption of fixed inputs untenable. Looking at the trends of the capital inputs, we believe that there is sufficient variation to argue that managers have enough control for the inputs to be considered variable, and therefore enter as objective variables in the neoclassical cost minimization problem.

Turning to the theoretical model, consider some total cost function (C) which is a function of the level of outputs (Y) and inputs (X). By Shephard's lemma, each input is itself a function of output level and input prices (W), characterized by a cost-minimizing factor demand. More formally,

$$C = \sum_i W_i X_i(Y,W) = C(Y,W) \tag{2}$$

By differentiating logarithmically with respect to factor prices, we can also obtain the factor cost shares,

$$\frac{\partial ln(C)}{\partial ln(W_i)} = \frac{W_i X_i(Y,W)}{C} = S_i \tag{3}$$

As with most of the rail productivity literature, we approximate the cost function using the translog functional form to take advantage of its flexibility. The translog total cost function takes the following general form,

$$\begin{aligned} ln(C) &= \alpha + \phi ln(Y) + \sum_i \beta_i ln(W_i) + \frac{1}{2}\xi ln(Y)^2 \\ &+ \frac{1}{2}\sum_i \gamma_i ln(Y) ln(W_i) + \frac{1}{2}\sum_i \sum_j \delta_{i,j} ln(W_i) ln(W_j) \\ &+ \zeta t + \eta\, ln(Y) t + \sum_i \theta_i ln(W_i) t, \\ &where\ \delta_{i,j} = \delta_{j,i} \end{aligned} \tag{4}$$

Making use of the definition of factor cost shares, we can obtain the share equations by differentiating logarithmically with respect to factor *i*'s price,

$$\begin{aligned} S_i &= \frac{\partial ln(C)}{\partial ln(W_i)} = \beta_i + \frac{1}{2}\gamma_i ln(Y) + \sum_j \delta_{i,j} ln(W_j) \\ &+ \sum_i \theta_i t, \\ &where\ \delta_{i,j} = \delta_{j,i} \end{aligned} \tag{5}$$

Instead of imposing linear homogeneity restrictions, we follow Smith (2006) in dividing total cost and input price through by one of the input prices.[19] When estimating, we also restrict the coefficients in the share equations to be equal to their counterparts in the cost function, as the share equations are simply partial derivatives of the cost function. This is made explicit in equations (4), (5), and below (i) through (v) by using the same notation. For example,

$$\beta_i^{(4)} = \beta_i^{(5)}$$

where (4) denotes the parameter from equation (4) and (5) denotes the parameter from equation (5).

To estimate the cost function, we employ the same output, inputs, prices, and expenditure shares as in the index portion of the report. One output and five inputs creates a system of five equations to estimate: a cost function and four factor share equations. We do not estimate the

18 The assumption that tracks are quasi-fixed is controversial. There is significant debate whether tracks ought to be considered variable or fixed from the point of view of managers at the firm.

19 It is arbitrary which input price is chosen, in this case the price of track per kilometre was chosen. Prior to dividing through by the price of track per kilometre, we normalize prices and expenditure. Like Smith (2006), we use the sample means to do so.

factor share equation for tracks as it must be dropped to obtain a non-singular system of equations. We estimate the system using Zellner's (1962) method. Results from the econometric model at the firm-level are presented in Table 3 and Appendix Table 5.

Our TFP estimate obtained from this method of estimation understood as the rate at which inputs can be decreased over time to produce a given level of output. Following Caves, Christensen, and Swanson (1981a), we take the total differential of (4) and hold output constant to obtain our annual TFP growth estimate,

$$TFP = \frac{\left(-\frac{\partial ln(C)}{\partial t}\right)}{\left(\sum_i \frac{\partial ln(C)}{\partial ln(W_i)}\right)}$$

Estimation of the Freight Rail Cost Function

Estimates for the system presented below were obtained after dropping the interaction terms involving time from the cost function (see equation (4) above), as Smith (2006) did. This simplification serves several ends. First and foremost, dropping the interaction terms ultimately makes the interpretation of the coefficient of the time trend variable become the annual per cent change of TFP over the period. Second, given our small sample of firms, it avoids the estimation of six additional parameters which are not remotely statistically significant when included. Third, unlike the interaction terms among input shares (S_i) and between input and output shares, the time interaction term lacks any theoretical interpretation. Specifically, the following system of equations was estimated:

$$(i)\ ln(expense) = \alpha_{CN} + \alpha_{CP} + \phi ln(Y) + \sum_{i=1}^{4} \beta_i ln(P_i) + \frac{1}{2}\xi ln(Y)^2 + \frac{1}{2}\sum_{i=1}^{4} \gamma_i ln(Y) ln(P_i) + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} \delta_{i,j} ln(P_i) ln(P_j) + \zeta t_{CN} + \zeta t_{CP} + \varepsilon_{(i)}$$

Table 3: Summary of Key Productivity Growth Estimates, Per Cent Per Year

		CN	CP
Labour productivity	1986-2009	6.49	4.76
	1986-1995	8.78	6.07
	1995-2009	5.04	3.93
TFP	1986-2009 (Index number)	4.42	3.12
	1986-1995 (Index number)	5.91	3.98
	1995-2009 (Index number)	3.47	2.58
	1986-2009 (Econometric)	4.23	3.52

$$(ii)\ S_1 = \beta_1 + \frac{1}{2}\gamma_1 ln(Y) + \sum_{j}^{4} \delta_{1,j} ln(P_j) + \varepsilon_{(ii)}$$

$$(iii)\ S_2 = \beta_2 + \frac{1}{2}\gamma_2 ln(Y) + \sum_{j}^{4} \delta_{2,j} ln(P_j) + \varepsilon_{(iii)}$$

$$(iv)\ S_3 = \beta_3 + \frac{1}{2}\gamma_3 ln(Y) + \sum_{j}^{4} \delta_{3,j} ln(P_j) + \varepsilon_{(iv)}$$

$$(v)\ S_4 = \beta_4 + \frac{1}{2}\gamma_4 ln(Y) + \sum_{j}^{4} \delta_{4,j} ln(P_j) + \varepsilon_{(v)}$$

$$where\ P_i = \frac{W_i}{W_{track}},\ and\ Expense = \frac{C}{W_{track}}$$

The data for both firms was pooled to estimate the model, with firm-specific time variables and intercepts included. All results are presented in Appendix Table 5 as well as in Uguccioni (2016).

Our model estimates annual TFP growth of 4.23 per cent per year and 3.52 per cent per year at CN and CP respectively for the 1986-2009 period. One of the major advantages of the Caves, Christensen, and Swanson (1981a) approach is its ability to pull returns to scale out the TFP growth estimate by logarithmically differentiating with respect to gross tonne kilometres and manipulating the results. Smith (2006) takes their method a step further by adding a measure of track usage to capture economies of density. Unfortunately, as estimation of our

model does not return significant point estimates for the coefficient of our gross tonne kilometre variable we are unable to unpack TFP growth into returns to scale and technological change. We suspect this is largely a multicollinearity issue between gross tonne kilometres and the time trend. Moreover, we were unable to attempt to estimate returns to density using Smith's method due to a lack of appropriate data. Consequently, the interpretation of our productivity coefficients is still that they are "black box" measures. They represent the annual per cent reduction in the total cost function at either railway holding output constant.

Our model is, however, able to add some value that the index number approach was unable to. Specifically, we are able to statistically test parameter stability to evaluate whether or not TFP growth at some point fundamentally changed.[20]

Following Iacobacci and Schulman's (2009) claim that the privatization of CN was a major contributor to the stellar productivity growth exhibited by the Canadian freight rail sector, we test the stability of CN's TFP growth estimate in 1995. While it is entirely plausible that the effects of privatization on productivity could have led or lagged the 1995 breakpoint, a parameter stability test using 1995 as the break point a priori should split up productivity growth under public ownership and under private ownership. We fail to reject the null hypothesis that CN's annual productivity growth was unchanged after privatization.[21]

We also consider the possibility that CN's productivity improved drastically when the time it privatized, but not precisely in 1995. We consider the installation of Tellier at the head of CN in 1992, the appointment of Harrison as COO and the implementation of precision railroading at CN in 1998 and 1999 (as Harrison (2000) only established the precision railroad at CN in September 1998, the first full year of the precision railroad at CN was 1999), and Harrison's move to CEO in 2003 as four alternatives. At the 1998 and 2003 alternative thresholds, we fail to reject the null hypothesis that CN's annual productivity growth did not differ on either side of the break.[22]

For the 1992 and 1999 breaks, we reject the null that CN's annual productivity growth did not differ on either side of the break at the 1 per cent level and 5 per cent level respectively. As we failed to reject the null at CP for both the 1992 and 1999 thresholds, there is evidence that the shock to TFP growth was firm specific.[23] These results are discussed at length below.

Differences with Index Estimates

First and foremost, the productivity estimates obtained via either form of estimation go hand in hand with the assumptions they rely on. Diewert (1992) argues that the use of indices to measure TFP is preferable to econometric esti-

20 These parameter stability tests simply perform an F-test of an unrestricted model with two productivity coefficients (time trends for only one side of the break and are zero otherwise) against a restricted model with only the one. Ideally we would perform a Chow test, but our sample size is insufficient to support a doubling of the number of parameters to estimate. To ensure we are not simply capturing a technology shock hitting both firms, we run our parameter stability tests on CP as well.

21 Specifically, the test returns an F-statistic of 0.221 and an associated p-value of 0.6388. We fail to reject the null at CP as well, returning an F-statistic of 1.8044 and a p-value of 0.1807.

22 The test results were: 1998 - F-statistic of 2.3999 and a p-value of 0.1229; 2003 - F-statistic of 0.0146 and a p-value of 0.9030. We fail to reject the null at CP as well, returning: 1998 - F-statistic of 1.1177 and a p-value of 0.2917; 2003 - F-statistic of 1.0005 and a p-value of 0.3184.

23 The test results were: 1992 - F-statistic of 8.0169 and a p-value of 0.00511; 1999 - F-statistic of 5.7117 and a p-value of 0.01778. However, we fail to reject the null at CP, indicating that the shock to TFP growth was firm specific. The tests returned: 1992 - F-statistic of 0.1615 and a p-value of 0.6882; 1999 - F-statistic of 2.2611 and a p-value of 0.1342.

mation of productivity because indices do not require assumptions regarding firm behaviour. As noted above, we believe the most tenuous assumption in our econometric model is the treatment of capital inputs as variable. This results in us estimating a total cost function in lieu of a variable cost function.

Indices, however, do rely on cost shares to approximate the "importance" of an input to production and are therefore sensitive to price shocks. For example, a price shock in labour costs from a union renegotiating its collective bargaining agreement resulting in a one time increase in wages could over-estimate the importance of labour to production between years. If the price shock for labour costs raised its cost share by several percentage points, output increased and the physical quantities of all inputs except labour fell in the same period, the TFP growth estimate between these two years would be underestimated due to the increased weight suddenly put on labour. Contrarily, if the underlying model assumed cost minimization by the firm, the productivity estimate between these same two years in question would not *a priori* be biased because the firm is purposely choosing its input levels taking costs into account. As the share equations in our system (equations (ii) through (v)) model this behaviour, an exogenous price shock can be handled by the econometric model.

Another important difference between the index and econometric TFP estimates is what the "black boxes" we obtain actually contain. The traditional method of estimating TFP in economics is the residual change in output that is not captured by the change inputs, and this is effectively what our index method is measuring. The econometric method estimates another productivity catch-all measure but it is not technically TFP. Our catch-all captures all changes in total cost not explained by changes in output levels, input levels, or prices. *A priori* we expect both of the "black boxes" to contain the standard components, such as disembodied technological change and operational efficiency, but we have no way of confirming our suspicions. Consequently, our measures of productivity may well be identical.

More technically speaking, there is also the issue of how our productivity estimates are calculated. The index method allows us to compute a compound average annual growth rate, while the econometric estimates compute annual productivity growth using least squares estimation. As such, estimates obtained from either method are broadly comparable, but not perfectly so.

As shown in Table 3, we estimate TFP growth to be 4.42 per cent per year at CN and 3.12 per cent per year at CP using indices. Econometric estimates put annual productivity growth throughout the period at 4.23 per cent per year at CN and 3.52 per cent per year at CP. The gap in annual productivity growth between CN and CP over the period is significantly larger when estimated using indices (1.30 percentage points) than econometric estimation (0.81 percentage points). This difference in the size of the gap in growth rates is likely driven by the implicit assumption that both firms face the exact same production function, which lowers the number of parameters to estimate. Some intuitive evidence of this is the econometric estimates lying between the index estimates of the two firms. Minor variations in the production function (driven, for example, by geographical differences) could result in our estimates for CN and CP somewhat diverging.

The crux of the matter is that the structure imposed by econometric estimation gives the model more explanatory power but it also sacrifices some realism (i.e. accuracy) at the firm-level because capital inputs may be quasi-fixed throughout the period of interest and the underlying production function may differ between firms or over time.

Ultimately, our concerns likely account for most of the differences between estimates obtained using the two estimation procedures. We are partial to Diewert's criticism of the use of firm behaviour assumptions in the econometric estimation, and are more confident in the accuracy of our index number results.

Discussion

We first discuss our partial productivity results, and consider where they stand in the literature as a whole. Next, we discuss our TFP growth results, and propose several sources which explain them. Productivity growth at both CN and CP significantly outperformed the Canadian economy on the whole

Partial Productivity Growth

The narrative of labour productivity growth, capital productivity growth, and TFP growth at CN and CP over the period of 1986 to 2009 is broadly similar. In the earlier years, CP enjoyed higher productivity levels than CN, and CN exhibited higher growth rates in part due to the removal of the greater slack in their system that comes with being the less productive firm. However, in the mid-1990s the growth narrative changed. CN did not slow to a rate of productivity growth similar to CP's once its level of productivity converged. Rather, CN's productivity growth steamed ahead of CP, and by 2009 it had almost entirely reversed the gap which existed between the levels of productivity at the two firms in 1986.

The improvement in labour productivity is captured in Chart 2, with CP and CN growing 4.76 per cent per year and 6.49 per cent per year respectively. McKellips and Calver (2016) show that labour productivity growth can be broadly decomposed into changes in capital intensity and total factor productivity growth. The number of workers employed at CN in 2009 fell to 31.4 per cent of its 1986 value (shrinking 4.90 per cent per year), while the number of workers employed at CP fell to 43.6 per cent of its 1986 value (3.55 per cent per year). At CN, the labour input fell more than 2 percentage points per year faster than any other input; at CP, labour fell over 1.5 percentage points per year more than any other input. With such steep falls in labour, both CN and CP were in the odd position of experiencing fairly rapid capital deepening while the capital stock at either company was also falling fairly quickly. Sources of TFP growth are discussed below, but its robust growth also sustained strong labour productivity progress throughout the period of 1986-2009.

Our narrative of the sources of labour productivity growth is very much in line with Cairns (2015). He argues that Canadian freight rail productivity benefitted significantly from selling off the marginally profitable lines to regional shortlines and the discontinuance of lines which did not make economic sense (i.e. marginal costs of operation exceed marginal revenue). Cairns also argues that reduction in the freight rail labour force in tandem with the new profit sharing labour agreements with unions contributed significantly to productivity growth from 1981 to 2012.

Capital productivity at CN and CP grew 2.92 per cent per year and 1.93 per cent per year from 1986 to 2009. Cairns (2015) argues that the productivity growth experienced by CN and CP came through improved quality of capital assets (i.e. embodied technological change). Specifically, he cites: locomotives with more horsepower which allow longer trains to travel faster, locomotives able to sense weakened axles or tracks before they fail, lighter freight cars able to bear greater loads, and continuously welded tracks.

Evidence of Cairns' proposed improvements of the capital stock are evident in the data. For example, the free fall in the equipment maintenance workers employed by both CN and CP

from 1986 to 2009 is likely due to the improved quality of the rolling stock and not neglect, as railway safety has steadily improved in recent decades (Cairns, 2015). Some of these gains were also captured in fuel productivity growth over the period, as better engines could produce more RTKs with less diesel. While less obvious, the improvements in the capital stock also contribute to labour productivity growth implicitly through capital intensity.

Total Factor Productivity Growth

While TFP growth follows the same narrative as labour and capital productivity growth, what it measures is less straightforward. TFP is a "black box" or a "measure of our ignorance" which captures growth in output not explained by adding inputs. By its nature the contents of the black box are general deemed not be measurable, particularly in index number studies. As discussed above, one of the main advantages of econometric estimation is the ability to separate out returns to scale and returns to density from technical change. While we were not able to do so in this article, it is still entirely possible that increasing and/or decreasing returns to scale and/or returns to density make up part of our TFP growth estimate.

Based on developments in the 1956-1991 period, Tretheway, Waters, and Fok (1997) point out that Canadian railways stood to make significant productivity gains if they were allowed to abandon lines as freely as their American counterparts were able to following the 1980 Staggers Rail Act. Specifically, Tretheway, Waters, and Fok argue that productivity at American railways benefited from economies of density in the wake of the Staggers Rail Act.

CP's kilometres of track operated steadily declined at an average annual rate of 1.99 per cent per year from 1986 to 2009, and in 2009 it sat at 62.9 per cent of its 1986 value. CN's kilometres of track operated has also declined steadily since 1986. Although CN's reduction of kilometres of track operated effectively ended in 2006, in 2009 CN operated 72.1 per cent of the track it did in 1986 (a decline of 1.41 per cent per year). Given the TFP growth during this period when lines were abandonned, CN and CP may well have benefited from the economies of density Tretheway, Waters, and Fok predicted.

Cairns (2015) argues that Canadian freight rail productivity benefitted significantly from selling off the marginally profitable lines to regional shortlines and the discontinuance of lines which did not make economic sense (i.e. marginal costs of operation exceed marginal revenue). While selling off unproductive capital assets contributes to capital productivity growth, it could lead to TFP growth if the firms back been experiencing diseconomies of scale or they benefitted from economies of density as a result of more throughput on the central lines.

Most of the literature on Canadian freight railways agrees that one of the major sources of their stellar TFP growth was operational efficiency. Iacobacci and Schulman (2009) argue that the operational efficiency gains came by way of the privatization of CN in 1995. Harrison (2000) and Cairns (2015) offer more specific operational changes which fundamentally altered the way firms transported goods.

Iacobacci and Schulman (2009) argue that one key driver of TFP growth in the rail sector was the privatization of CN in 1995. McKellips and Calver (2016) also argue that CN's decreased operating ratio after 1998 is evidence that the privatization of CN significantly improved productivity. Anecdotally, CN does exhibit more significant declines in locomotives, freight cars, and track operated after 1995. Labour productivity, capital productivity, and TFP levels of CN also converged with CP around 1995, so it could be the case that incoming market pressures helped CN remove excess slack from its system.

Iacobacci and Schulman (2009) are not, however, supported by CN's TFP growth trajectory. In the 10 years prior to privatization, CN's average annual TFP growth was 5.91 per cent per year while over the 10 years following privatization its average annual TFP growth rate was only 5.58 per cent per year. For comparison, CP grew 3.75 per cent per year in the decade prior to 1995 and 4.85 per cent per year in the subsequent decade, so CN's growth slowdown doesn't appear to reflect new realities facing the market. Econometric estimation also showed no evidence of the effect of privatization in 1995.

Admittedly, using 1995 itself as the break point for productivity gains from privatization is not ideal for this sort of analysis. Seamless privatization of a firm the size of CN would not be possible on short notice, and no doubt senior-management at CN knew of the coming privatization well in advance of its arrival. It is entirely possible that the pressures of the privatization came in advance of 1995, and therefore its effects were manifest prior to 1995. As such, we performed stability tests on the productivity coefficient estimate for CN employing other key years in the railway's history: the installation of Tellier at the head of CN in 1992, the appointment of Harrison as COO and the advent of precision railroading in 1998 and 1999 (as Harrison (2000) only established the precision railroad in September 1998, the first full year of the precision railroad was 1999), and Harrison's move to CEO in 2003. We fail to reject the null hypothesis of no change in productivity growth before and after the 1998 and 2003 thresholds.

While we are not able find direct statistical evidence of Iacobacci and Schulman (2009)'s argument, we are able to provide two credible alternatives. We found statistically significant evidence that TFP growth differed before and after 1992, and before and after 1999. Admittedly, 1992 may provide some evidence of Iacobacci and Schulman's hypothesis, as Tellier was installed as CEO to prepare CN for privatization. With Tellier at the helm and the 1995 IPO only a handful of years away, looming market pressures may have bolstered TFP growth.

Cairns (2015) argues that further productivity gains arose due to improved operational practices, such as the addition of a locomotive in the middle of long trains, and improved management due to better informational technologies at the firm's disposal. While neither of these claims are directly measurable, their productivity improvements ought to be captured in the TFP series estimated by reducing the inputs required to produce an output. Some of these gains were likely captured in fuel productivity growth over the period.

Harrison (2000) touts the operational successes CN experienced under his precision railroad regime, and our results indicate that there was a statistically significant difference in productivity after 1999. Other than slight accelerations in the declines of operational locomotives and freight cars at CN around 1998, there is little cursory evidence of his strong operational management in the data. This, however, is not surprising, as operational efficiency is primarily captured in the residual output growth which TFP measures.

Conclusion

Labour productivity growth at CN and CP from 1986 to 2009 was sustained by capital deepening, improvements in the quality of stock of capital, and robust TFP growth. Operational changes, especially the introduction of precision railroading, were central contributors to TFP growth during the period. There is little evidence that the privatization of CN in 1995 changed the trajectory of its TFP growth. However, the econometric evidence showed that TFP growth at CN systematically changed following the installation of Tellier as CEO in

1992. As Tellier's marching orders were to prepare the firm for privatization, the fundamental changes to productivity that were results of privatization may well have have occurred in 1992. The implemenation of precision railroading at CN starting in 1999 was also a major turning point for productivity growth.

Using indices, we estimate productivity growth to be 4.42 per cent per year at CN and 3.12 per cent per year at CP. At the industry level, we estimate annual TFP growth of 3.94 per cent per year. Econometric estimates put annual productivity growth throughout the period at 4.23 per cent per year at CN and 3.52 per cent per year at CP.

Future research into Canadian railways should strive to extend the period of analysis to include the years of sluggish economic growth which followed the 2008 financial crisis and investigate whether the large falls in the operating ratio at CP under Harrison were in fact driven by rapid TFP growth. Future research using alternative estimation methods with the *Railway Transport Survey* dataset would help enhance the understanding of the successes of Canadian freight railways.

Further research should also expand the breadth of analysis into studies of passenger railways (e.g. VIA rail) and shortlines, the data for which are also available from the *Railway Transport Survey* dataset. Statistics Canada should consider making the microdata from the Railway Transport Survey on shortlines publicly available to fuel future research. They should also consider the addition of throughput variables and land variables in the *Railway Transport Survey*, to allow researchers to estimate returns to density and generate TFP estimates which include land inputs.

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Appendix I: Data Tables

Appendix Table 1: Partial Productivity Measures				
Year	CP RTK per employee	CN RTK per employee	CP RTK per 1000L of diesel	CP RTK per 1000L of diesel
1986	3574.5	2779.7	111.0	124.4
1987	4313.1	3235.9	122.0	137.2
1988	4323.4	3577.8	118.7	136.1
1989	3933.9	3551.0	114.0	143.0
1990	4370.0	3714.8	118.9	145.4
1991	4630.0	4231.3	120.4	148.4
1992	4482.3	4366.4	117.7	150.4
1993	5013.2	4655.3	122.1	153.4
1994	5904.0	5657.4	129.1	169.2
1995	6072.9	5932.3	128.0	158.7
1996	6457.4	6564.1	135.3	155.4
1997	7322.5	7354.2	135.3	150.0
1998	7209.8	7513.5	140.6	153.6
1999	7328.1	8292.6	141.2	179.9
2000	8648.9	9249.3	153.0	192.0
2001	9201.2	9677.1	159.1	185.8
2002	9401.4	10690.3	153.5	188.3
2003	10035.1	10569.3	156.5	180.0
2004	10926.7	11543.9	163.6	177.5
2005	10935.6	12126.6	165.4	178.3
2006	11022.6	12787.7	161.9	181.0
2007	11875.0	12313.9	160.4	180.9
2008	11281.7	11776.9	159.5	178.5
2009	10417.7	11807.4	163.1	187.6

Appendix Tabel 2: Multifactor Productivity Indices				
Year	CP VFP	CN VFP	CP TFP	CN TFP
1986	100	100	100	100
1987	116.32	111.93	117.03	112.33
1988	114.64	119.02	111.67	120.90
1989	103.77	116.09	102.11	119.31
1990	111.40	118.91	110.97	123.25
1991	116.49	129.75	116.79	135.07
1992	110.81	131.65	111.92	137.46
1993	119.75	137.44	122.07	143.80
1994	136.67	158.00	139.67	165.40
1995	138.30	157.87	142.03	167.72
1996	142.40	168.27	146.89	179.79
1997	154.44	182.27	158.92	199.51
1998	153.02	183.18	158.96	204.93
1999	153.71	198.92	163.03	224.42
2000	173.41	215.24	185.47	244.10
2001	179.45	219.52	191.29	250.63
2002	178.56	232.80	192.91	266.98
2003	188.91	225.94	203.54	259.20
2004	203.23	238.25	217.51	273.38
2005	204.94	247.18	216.39	275.65
2006	202.06	255.90	213.91	283.75
2007	211.27	249.07	225.24	278.24
2008	202.16	237.30	218.07	264.66
2009	185.49	239.16	202.79	270.50

Appendix Table 3: CN Expense Shares					
Year	Track	Locomotives	Freight Cars	Deisel	Labour
1986	0.1404	0.0918	0.0807	0.1144	0.5727
1987	0.1452	0.0942	0.0753	0.1209	0.5644
1988	0.1421	0.0925	0.0778	0.1207	0.5669
1989	0.1422	0.0954	0.0690	0.1197	0.5737
1990	0.1390	0.0879	0.0797	0.1257	0.5678
1991	0.1377	0.0795	0.0786	0.1318	0.5724
1992	0.1362	0.0704	0.0767	0.1177	0.5991
1993	0.1519	0.0754	0.0867	0.1151	0.5709
1994	0.1539	0.0781	0.0774	0.1291	0.5615
1995	0.1536	0.0740	0.0733	0.1312	0.5679
1996	0.1540	0.0728	0.0729	0.1497	0.5505
1997	0.1589	0.0610	0.0744	0.1568	0.5488
1998	0.1728	0.0535	0.0735	0.1289	0.5713
1999	0.1859	0.0537	0.0739	0.1149	0.5716
2000	0.1744	0.0517	0.0735	0.1516	0.5488
2001	0.1660	0.0801	0.0588	0.1640	0.5311
2002	0.1775	0.0739	0.0675	0.1525	0.5286
2003	0.1701	0.0786	0.0802	0.1554	0.5157
2004	0.1806	0.0752	0.0756	0.1749	0.4936
2005	0.1652	0.0651	0.0759	0.2243	0.4695
2006	0.1706	0.0611	0.0712	0.2459	0.4512
2007	0.1822	0.0609	0.0625	0.2650	0.4295
2008	0.1766	0.0523	0.0482	0.3324	0.3905
2009	0.2132	0.0672	0.0531	0.2191	0.4475

Appendix Table 4: CP Expense Shares					
Year	Track	Locomotives	Freight Cars	Diesel	Labour
1986	0.1386	0.1228	0.0849	0.1382	0.5154
1987	0.1422	0.1207	0.0909	0.1442	0.5020
1988	0.1422	0.1138	0.0917	0.1381	0.5141
1989	0.1484	0.1151	0.0946	0.1270	0.5149
1990	0.1442	0.1055	0.0929	0.1452	0.5122
1991	0.1492	0.0956	0.0882	0.1391	0.5280
1992	0.1624	0.0873	0.0897	0.1274	0.5332
1993	0.1545	0.0856	0.0916	0.1338	0.5345
1994	0.1461	0.0966	0.0815	0.1422	0.5336
1995	0.1433	0.1092	0.0745	0.1448	0.5282
1996	0.1380	0.1133	0.0823	0.1496	0.5169
1997	0.1442	0.1101	0.0851	0.1635	0.4972
1998	0.1464	0.1094	0.0773	0.1433	0.5238
1999	0.1352	0.1018	0.0759	0.1426	0.5446
2000	0.1430	0.1027	0.0734	0.1971	0.4839
2001	0.1345	0.1133	0.0876	0.1891	0.4755
2002	0.1444	0.1181	0.0633	0.1808	0.4933
2003	0.1379	0.1209	0.0671	0.1890	0.4850
2004	0.1501	0.1134	0.0576	0.2011	0.4777
2005	0.1413	0.1058	0.0567	0.2351	0.4611
2006	0.1373	0.1085	0.0534	0.2643	0.4366
2007	0.1516	0.1078	0.0535	0.2811	0.4061
2008	0.1498	0.0959	0.0417	0.3307	0.3819
2009	0.1558	0.1007	0.0549	0.2439	0.4448

Appendix Table 5: Econometric results
method: SUR

	N	DF	SSR	detRCov	OLS-R2
system	240	206	0.10601	0 0.96168	0.924675

	N	DF	SSR	MSE	R2	Adj R2
totalcost	48	24	0.036519	0.001522	0.985165	0.970949
locomotiveinput	48	42	0.007215	0.000172	0.653145	0.611853
freightcarsinput	48	42	0.008447	0.000201	-0.115659	-0.248475
fuelinput	48	42	0.017719	0.000422	0.879818	0.865510
labourinput	48	42	0.036110	0.000860	0.719924	0.686582

Coefficients:

	Estimate	Std. Error	Pr(>|t|)
totalcost_CN	86.13993559	99.08141861	0.38564821
totalcost_CP	86.14083837	99.05543453	0.38551885
totalcost_CNprod	-0.03424049	0.00393706	1.1102e-15 ***
totalcost_CPprod	-0.02851169	0.00415587	7.8707e-11 ***
totalcost_log(grosskm)	-9.42442806	10.63219400	0.37643303
totalcost_log(price_loco)	0.43247569	0.12702216	0.00079600 ***
totalcost_log(price_freightcar)	0.49764158	0.13772726	0.00038002 ***
totalcost_log(price_diesel)	-1.27747132	0.22977388	8.3171e-08 ***
totalcost_log(price_labour)	0.91157586	0.29287629	0.00211856 **
totalcost_lint_kmlabour	-0.02073394	0.01576925	0.19002781
totalcost_lint_kmloco	-0.01751996	0.00685656	0.01133373 *
totalcost_lint_kmdiesel	0.07699865	0.01234726	2.5011e-09 ***
totalcost_lint_kmfreight	-0.02299786	0.00741065	0.00218207 **
totalcost_lint_locofreight	1.10553436	0.81381614	0.17580442
totalcost_lint_locodiesel	-1.51664471	0.34555530	1.8182e-05 ***
totalcost_lint_locolabour	1.44469984	0.72237111	0.04682008 *
totalcost_lint_freightdiesel	-1.77128918	0.51955966	0.00078372 ***
totalcost_lint_freightlabour	0.60861181	0.60688084	0.31710868
totalcost_lint_diesellabour	4.18390580	1.01816811	5.7284e-05 ***
totalcost_self_loco	0.36785501	0.32367921	0.25707598
totalcost_self_freight	0.03058799	0.38060330	0.93602331
totalcost_self_diesel	-0.23227850	0.25081396	0.35547832
totalcost_self_labour	-0.47828309	0.98848075	0.62900149
totalcost_self_km	0.51625027	0.57055133	0.36661402
locomotiveinput_(Intercept)	0.43247569	0.12702216	0.00079600 ***
locomotiveinput_log(grosskm)	-0.01751996	0.00685656	0.01133373 *
locomotiveinput_log(price_loco)	0.06949663	0.00728884	< 2.22e-16 ***

locomotiveinput_log(price_freightcar)	-0.02305688	0.00556593	5.0128e-05 ***
locomotiveinput_log(price_diesel)	-0.03393857	0.00651902	4.6551e-07 ***
locomotiveinput_log(price_labour)	0.03158663	0.01042327	0.00275535 **
freightcarsinput_(Intercept)	0.49764158	0.13772726	0.00038002 ***
freightcarsinput_log(grosskm)	-0.02299786	0.00741065	0.00218207 **
freightcarsinput_log(price_loco)	-0.02305688	0.00556593	5.0128e-05 ***

	Estimate	**Std. Error**	**Pr(>|t|)**
freightcarsinput_log(price_freightcar)	0.04165321	0.00709573	1.7209e-08 ***
freightcarsinput_log(price_diesel)	-0.05092685	0.00677446	1.6849e-12 ***
freightcarsinput_log(price_labour)	0.05563769	0.00959623	2.4965e-08 ***
fuelinput_(Intercept)	-1.27747132	0.22977388	8.3171e-08 ***
fuelinput_log(grosskm)	0.07699865	0.01234726	2.5011e-09 ***
fuelinput_log(price_loco)	-0.03393857	0.00651902	4.6551e-07 ***
fuelinput_log(price_freightcar)	-0.05092685	0.00677446	1.6849e-12 ***
fuelinput_log(price_diesel)	0.16635578	0.01164848	< 2.22e-16 ***
fuelinput_log(price_labour)	-0.10787525	0.01326082	3.8414e-14 ***
labourinput_(Intercept)	0.91157586	0.29287629	0.00211856 **
labourinput_log(grosskm)	-0.02073394	0.01576925	0.19002780
labourinput_log(price_loco)	0.03158663	0.01042327	0.00275535 **
labourinput_log(price_freightcar)	0.05563769	0.00959623	2.4965e-08 ***
labourinput_log(price_diesel)	-0.10787525	0.01326082	3.8414e-14 ***
labourinput_log(price_labour)	0.07178829	0.02831217	0.01196760 *

Signif. codes: '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1**

Productivity to the Rescue: Review Article on the McKinsey Global Institute Report *Global Growth: Can Productivity Save the Day in an Aging World?*

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ABSTRACT

This review article provides a synthesis and critical assessment of the McKinsey Global Institute (MGI) report *Global Growth: Can Productivity Save the Day in an Aging World?* The key stylized fact that motivates the report is the expected fall-off in GDP growth for the G-19 and Nigeria from an average annual rate of 3.6 per cent in the 1964-2014 period to a projected 2.1 per cent in the next fifty years (2014-2064). All of this slowdown is due to a fall-off in employment growth and none to slower labour productivity growth. MGI believes that there is great potential to accelerate productivity growth to offset the fall in employment growth and prevent any fall-off in GDP growth. Indeed, the report makes the case that it is feasible, although extremely challenging, to boost productivity growth in the G-19 and Nigeria to 4 per cent a year over the next decade, largely through catch-up to best practices. The report outlines public policies and private sector actions to achieve this target.

IT IS WELL RECOGNIZED that in recent years the rate of economic growth has slowed down throughout the world, with important consequences in many areas. A return to the rate of economic growth of the past would make the resolution of many economic and social problems easier. That is indeed what the report *Global Growth: Can Productivity Save the Day in an Aging World?*, published by the McKinsey Global Institute (MGI), advocates, putting forward a detailed strategy to achieve the objective of faster economic and productivity growth.[2] This review article provides a synthesis and a critical assessment of the key arguments of this ambitious proposal.

First, the argument in a nutshell. The key stylized fact that motivates the report is the expected fall-off in GDP growth for the G-19

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2 Six individuals associated with the McKinsey Global Institute are listed as authors of the report. James Manyika, Jonathan Woetzel, and Richard Dobbs are MGI directors, Jaana Remes is a MGI partner, Eric Labaye is MGI chairman, and Andrew Jordan is a McKinsey consultant. The report, released in January 2015, is posted at http://www.mckinsey.com/~/media/McKinsey/dotcom/Insights/Growth/Can%20long-term%20global%20growth%20be%20saved/MGI_Global_growth_Full_report_February_2015pdf.ashx

Table 1: Trends and Prospects for Output, Employment, and Productivity Growth, 1964-2014 and 2014-2064
(average annual rate of change)

	1964-2014			2014-2064			2014-2024
	Output	Employment	Productivity	Output	Employment	Productivity	Productivity Target
G-19 and Nigeria	3.6	1.7	1.8	2.1	0.3	1.8	4.0
Developed G-19	2.8	0.9	1.9	1.9	0.1	1.9	2.0
Emerging Economies (G-19 and Nigeria)	4.8	1.9	2.8	3.1	0.4	2.8	6.0

Source: Exhibit 19 (MGI, 2015:49).

and Nigeria,[3] which currently account for around 80 per cent of world GDP, from an average annual rate of 3.6 per cent in the 1964-2014 period to a projected 2.1 per cent from 2014 to 2064 (Table 1).[4] All of this slowdown is due to a fall-off in employment growth from 1.7 per cent per year over the last half century to a projected 0.3 per cent in the next 50 years. None of the projected fall-off in GDP growth is due to slower labour productivity as the report projects this crucial variable to continue growth at its historical rate of 1.8 per cent for the next 50 years.

MGI believes that there is great potential to accelerate productivity growth in the world. Indeed, MGI asserts that it is possible, although extremely challenging, to boost productivity growth in the G-19 and Nigeria to 4.0 per cent a year over the next decade. This would more than offset the fall in employment growth and prevent any fall-off in GDP growth. The chapters of the report make a case that this doubling of the historical rate of productivity growth is feasible, largely through catch-up to best practices. The report outlines public policies and private sector actions needed to achieve this objective.

This review article is organized into two main parts. The first part outlines the key arguments of the report. The second part provides a critical assessment.

The MGI Global Growth Report: A Synthesis

The report is organized into six chapters. Key points from each chapter are presented in this part.

The Contribution of the MGI Report to the Productivity Debate

The first chapter provides an overview of the debate regarding the prospects for long-term growth. In what is now the conventional wisdom across the political spectrum, MGI sees growth as a critical enabler for meeting a much broader set of societal goals, largely related to well-being, rather than as an ultimate goal in itself. In developing economies, growth reduces poverty, while in mature economies growth funds government programs, such as pension obliga-

3 There are 19 countries in the G-20, which also includes the European Union (EU). Data for the non-G-20 EU members are excluded from the G-19 category. The nine developed country G-19 members are South Korea, Japan, Germany, Italy, France, the United Kingdom, Australia, Canada, and the United States. The ten emerging country G-19 members are China, Turkey, India, Mexico, Brazil, Saudi Arabia, Argentina, Russia, Indonesia, and South Africa.

4 Unless otherwise specified, all growth rates in this review article refer to compound or average annual rates of change, expressed in per cent. To lighten the text, the average annual modifier may be dropped.

tions. The report notes that economic growth has been exceptionally rapid over the last 50 years, but that there is no consensus on prospects for the next 50 years.

MGI points out that there are two broad levers for improving productivity: efficiency gains that reduce input for any given output, and innovations that increase the volume and value of output for any given inputs.

The report contributes to the growth debate in three ways. It provides:

- an approach to framing the long-term growth debate with a simple decomposition of GDP growth into changes in employment and labour productivity. Such an approach allows the identification of the impact of demographic trends on growth;
- a microeconomic examination of the productivity-improvement opportunities at the sector level. Drawing on McKinsey industry expertise and productivity studies, the report assesses the productivity gaps related to best practices across sectors for eight or more countries as well as the prospects for technology and business innovations to 2025. This allows for an estimate of the productivity growth potential in the sample sectors and countries in the coming decade and an extrapolation to the global economy; and
- an agenda of what needs to change for the productivity potential to be realized, as synthesized into ten priorities for enabling global growth.

Employment Trends and Prospects

Chapter two provides an overview of employment trends over the last half century, and employment prospects for the next half century. It is noted that from 1964 to 2014 in the G-19 plus Nigeria employment grew at a 1.7 per cent average annual rate and accounted for nearly one half (48 per cent) of economic growth. The emerging economies enjoyed employment growth of 1.9 per cent and the developed economies 0.9 per cent (Table 1). In both groups of countries, it was population growth, not an increase in the employment rate or an increase in the share of the working age population in the total population, that accounted for almost all of the employment growth.

The report projects that employment growth in the G-19 plus Nigeria will be much slower over the next half century, averaging only 0.3 per cent per year. This fall-off affects the developed economies (employment growth of 0.1 per cent, down 0.8 percentage points), and even more the emerging economies (0.4 per cent, down 1.5 points). The demographic tailwind that has powered the world economy over the past half century has lost its force, and in some countries, such as China, Russia, Japan, Germany, Italy and South Korea, it is even turning into a headwind, with negative employment growth projected for these countries for the 2014-2064 period.

Aggregate Productivity Growth and Prospects

Chapter three discusses labour productivity prospects at the aggregate level.[5] The key message is that faster productivity growth can make up for the changing demographic trends. Labour productivity growth averaged 1.8 per cent per year in the G-19 and Nigeria in 1964-2014. Productivity growth was considerably higher in the emerging G-19 economies at 2.8 per cent compared to 1.9 per cent in the developed economies (Table 1). Note that the aggregate productivity growth rates for the two groups was higher than the G-19 average due to a negative composition effect from the growing

5 The only productivity concept discussed in the report is labour productivity so any reference to productivity signifies labour productivity, unless otherwise specified.

weight of the low-productivity level emerging economies.

In addition to slower productivity growth than the emerging economies, the developed economies have experienced a marked slowdown in productivity growth within the 1964-2014 period, from 3.2 per cent per year in 1964-1974 to 1.8 per cent in each of the three 10-year periods between 1974 and 2004 and to 0.8 per cent in 2004-2014. In contrast, since 1994 productivity growth has accelerated in the emerging economies of the G-19, advancing at a 3.6 per cent pace in 1994-2004 and an amazing 5.6 per cent in 2004-2014. This is up from a very weak 1.0 per cent in both the 1974-1984 and 1984-1994 sub-periods. Very strong economic growth in China, and to a lesser degree India, accounts for the revival in productivity growth in the emerging world since the mid-1990s.

Since the developed economies are on, or close to, the world technology frontier, it is somewhat disconcerting that labour productivity growth in those countries has been on a marked downward trend. As technological progress is the main driver of labour productivity advance, this fall in trend productivity growth may bode poorly for attempts to boost productivity growth as they would be going against an unfavourable technological headwind.

Despite the fall-off to 0.8 per cent labour productivity growth in 2004-2014 in the developed economies of the G-19, the MGI report is projecting a strong revival of productivity growth going forward. Output per worker is projected to rise at 1.9 per cent per year from 2014 to 2064, the same rate as enjoyed in the past half century. It appears that the productivity performance in the most recent decade is considered an anomaly with no effect on future productivity growth, an issue that will be revisited later in this review article.

In the emerging economies, productivity growth over the next 50 years is also projected to continue at the rate of the last 50 years, namely 2.8 per cent. This may be more realistic than the projection for the developed economies as the emerging economies have experienced an upturn in productivity growth in recent years, not a downturn.

Given the assumption of no slowdown in productivity growth between the 1964-2014 and 2014-2064 periods in the G-19 and Nigeria (also in all the G-19 countries and Nigeria taken individually), all the slowdown in GDP growth is accounted for by slower employment growth which is in turn very closely linked to population growth. This means that once one controls for population, as one does with per capita measures, the economic growth slowdown does not translate into a major slowdown in the growth of living standards. Per capita GDP for the G-19 and Nigeria is projected to fall only 0.4 percentage points from 2.1 per cent in 1964-2014 to 1.7 per cent in 2014-2064, compared to the 1.5 percentage point fall in GDP growth.

Welfare is more closely associated with per capita metrics than absolute metrics. The relatively small fall-off in per capita GDP growth suggests the economic prospects for the next half century are much less dire than implied by the nearly four times larger fall-off in GDP growth. Perhaps the world is in less need of saving from its aging population than the authors believe. What in my view is more relevant is the assumption that productivity growth does not fall-off. If it does decelerate from the trend of the last half century, as recent trends suggest, then the pace of living standards growth will indeed be endangered.

Opportunities for Productivity Growth

Chapter four provides an assessment of the opportunities for rapid productivity growth

based on MGI case studies of five sectors: agriculture, food processing, automotive, retail, and health care. Given the great uncertainty associated with future productivity growth, the time horizon for this discussion is the next ten years, not the 2014-2064 period. Extrapolating from the studies, the report finds sufficient potential to accelerate productivity growth to about 4 per cent per year in the G-19 and Nigeria. It is estimated that three quarters of the global potential productivity growth would come from the broader adoption of best practices, that is catch-up, and one quarter from pushing the frontier.

The 4 per cent productivity target is not uniform across the world. For the developed G-19 the target is only 2 per cent, barely up from the 1.9 per cent in the projections, with 55 per cent of productivity gains from catch-up and 45 per cent from pushing the frontier. It is the emerging world that is key for the 4 per cent global productivity growth target, with productivity growth more than doubling from 2.8 per cent in the projections to a potential 6 per cent, with 82 per cent (5 percentage points) due to catching-up and 18 per cent from pushing the frontier.

MGI does not see a drying up of technological or business innovations acting as a constraint to growth, but rather believes there is a strong innovation pipeline in both developed and developing countries.

This chapter provides a wealth of details about the potential productivity gains to 2025 in the five sectors examined. These include raising the share of modern retail formats, increasing the scale and capacity utilization of auto assemblers, and improving operational efficiency and reducing waste in health care and food processing. One is particularly struck by the large disparity in relative productivity levels within developing countries. For example, Brazil is the world's most productive chicken producer (page 66), yet its relative aggregate productivity level in 2014 was only 19 per cent of that of the United States (Exhibit 16).

MGI provides interesting insight into the role of government in fostering productivity. The main divide is between developed and emerging economies. In the developed economies MGI estimates for three sectors (retail, automotive and agriculture) that only 13 per cent of potential productivity growth is dependent on government action, compared to 45 per cent in the emerging economies. The role of government also varies by sector. In developed economies, only 5 per cent of potential productivity growth in automotive is dependent on government action, compared to 10 per cent for retail and 25 per cent for agriculture. MGI suggests that one-size-fits-all solutions are rare and governments need to tailor their interventions to the sector.

MGI recognizes that a step change in productivity growth is no easy task. It would

> "… necessitate strenuous efforts by business owners, managers and workers to change established ways of doing things and to adopt new approaches that improve how they operate. To incentivize broad-based change, companies need competitive pressure to perform better, a business environment and institutions that enable change and creative destruction, and access to infrastructure and talent" (pg. 87).

Enablers to Boost Productivity Growth

Chapter five puts forward ten key enablers to unlock long-term growth potential and "retool the world's productivity engine." The enablers are classified into four broad groups:

1. Enable catch-up by creating transparency and competition, which includes three enablers:
   - remove barriers to competition in service industries;

- focus on efficiency and performance management in public and regulated sectors; and
- invest in physical and digital infrastructure, especially in emerging markets.

2. Help push the frontier by incentivizing innovation, which includes four enablers:

- craft a regulatory environment that incentivizes productivity and supports innovation;
- foster demand for R&D investment in innovative products and services;
- exploit existing and new data to identify transformational improvement opportunities; and
- harness the power of new actors in the productivity landscape through digital platforms and open data.

3. Mobilize labour to counter the waning demographic tailwinds, which includes two enablers:

- put in place regulation and social support to boost labour market participation among women, young people, and older people; and
- improve education and matching skills to jobs and make labour markets more flexible.

4. Open up economies to cross-border economic flows, from trade in goods and services to flows of people.

MGI states that it does not underestimate the extent of changes needed to raise the rate of global productivity growth by a significant margin and acknowledges that such a development would require modifying longstanding political, judicial and regulatory practices. Based on MGI's body of analysis, the report provides a fascinating and insightful discussion of the ten enablers.

Trade-offs and Productivity Growth

The sixth and final chapter in the report assesses briefly the trade-offs that will be needed to sustain and accelerate productivity growth. Trade-offs and issues discussed include the treatment of losers in the growth process, data accessibility versus privacy concerns, risks from labour flexibility, the relationship between GDP growth and happiness, rising GDP and environmental sustainability, alternatives to GDP as metrics of progress, and most importantly, the link between economic growth and income distribution.

The MGI Global Growth Report: An Assessment

This section of the review article provides an assessment of the MGI global growth report.

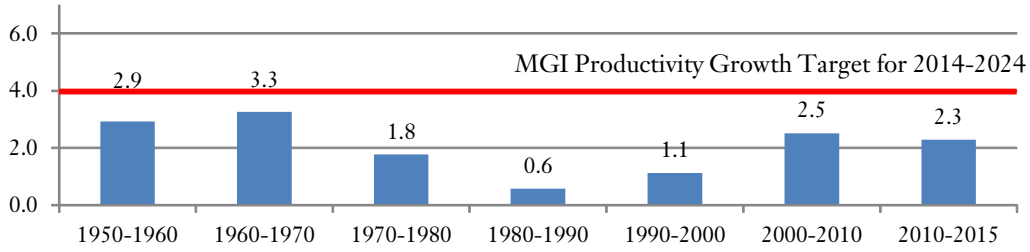
The Deep Insights of MGI Productivity Studies

The report draws on the extensive knowledge base of the economic and productivity growth processes that has been constructed by the McKinsey Global Institute studies and McKinsey consulting projects over many years. The report lists over 90 MGI and McKinsey publications directly related to economic and productivity growth. These publications include country productivity studies (e.g. Australia, Europe, France, Germany, Sweden, Vietnam, Japan, Turkey, Thailand, Russia, Poland, South Korea, Latin America, Nigeria, China, Brazil, Netherlands, Mexico), sector productivity studies (e.g. automotive, service sector, retail trade, government, the social economy, health care, manufacturing), and productivity driver studies (e.g. capital productivity, innovation, technologies). This impressive body of work, freely accessible on the MGI website, represents a public good that can be used by persons responsible for developing strategies and policies to boost productivity

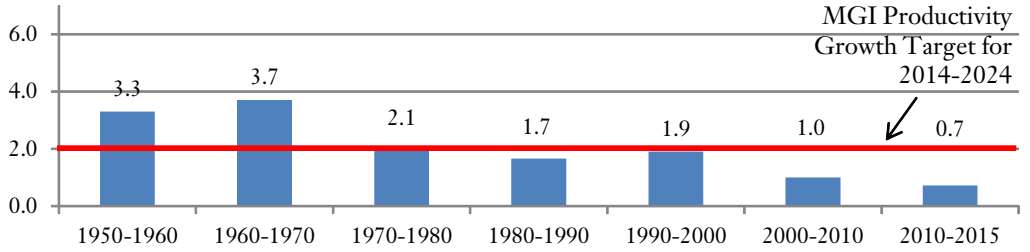
Chart 1: Labour Productivity (Output Per Worker) Growth, Developed and Developing World, 1950-2015, with McKinsey Global Institute (MGI) Productivity Growth Target for 2014-2024

(average annual rate of change)

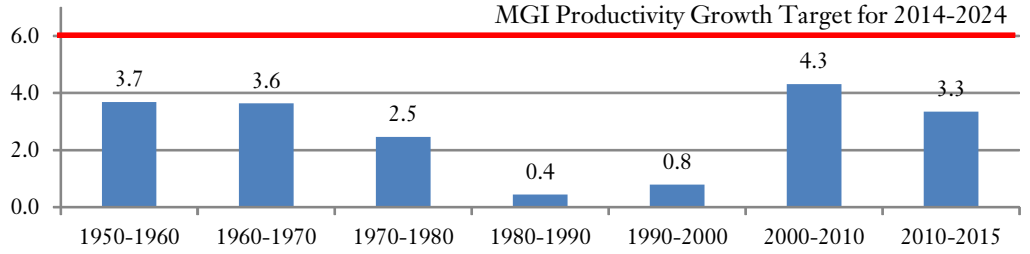
Panel A: World



Panel B: Developed World



Panel C: Developing World



Source: The Conference Board (2015) The Conference Board Total Economy Database, May 2015, http://www.conference-board.org/data/economydatabase/.

This real-world orientation of the McKinsey approach in addressing the productivity issue is refreshing. It lies in stark contrast to theoretical, often ahistorical, academic research on productivity whose only real world interface is generally regression analysis. Such research generally does not benefit from knowledge and insights gained through industry studies of the topic under investigation, which includes interaction with the actors who are directly responsible for decisions affecting productivity. To be sure, both approaches have their strengths and can be complementary. The MGI contribution is to increase the amount of high-quality, observation-based productivity research, which is in much shorter supply than productivity research from the academy.

How Realistic Is a 4 per cent Productivity Growth Target for the World?

The report makes the case, based on its five sector studies, that a 4 per cent productivity growth rate is a realistic target for the 2014-2024 period for the G-19 and Nigeria, with 2 per cent productivity growth in the developed economies and 6 per cent in the emerging economies. I question the feasibility of this target for several reasons. First, such a productivity growth rate is historically unprecedented. Second, the motivation of firms to vigorously pursue such an objective is unclear. Third, potential productivity growth identified in the five sectors presented may not be representative of the overall productivity potential of the economy. Fourth, recent trends point to a productivity growth slowdown more than the continuation of the 1964-2014 trend. Fifth, the demand-side drivers of such strong productivity and output growth are not identified.

Chart 1 shows output per worker growth rates for the world economy, the developed countries, and developing countries for ten-year periods since 1950. In terms of the world economy, in not one of the six ten-year periods was 4 per cent productivity growth achieved. For the developing countries the 6 per cent target was also never achieved. The developed economies did exceed the 2 per cent productivity growth in the 1950s and 1960s and were close to 2 per cent in the 1970s, 1980s, and 1990s, but have been well below 2 per cent since 2000. Given this historical reality, it seems audacious if not somewhat farfetched to propose such productivity targets. Of course, the productivity targets may just be meant to be aspirational, that is to inspire governments and firms to better their game.

Firms already have a financial incentive to maximize profits, and one of the means to accomplish this is through adopting best-practises. Given existing incentives for cost-minimization, there must be some reason firms have not already adopted best practices. However, the report does not grapple with this. What are the market failures or structural frictions that keep firms from adopting best practices? One possibility might be a knowledge gap, but there could be others. It is important to understand the details of this because different frictions may imply different strategies or policy interventions. In addition, the report never identifies a political strategy or specific policies that governments can adopt to boost productivity growth. At the world level, does the productivity issue need global champions such as the OECD for the developed world and the World Bank for the developing world?

The report identifies the potential to accelerate productivity growth in five sectors from a recent base period to 2025 (Exhibit 22 on Page 58). It finds that at the world level productivity has the potential to increase at a 5.5 per cent average annual rate in automotive, 4.4 per cent in agriculture, 3.4 per cent in retail, 2.9 per cent in food processing, and 2.2 per cent in health care (the unweighted average is 3.6 per cent).[6]

Based on these estimates and the assumption that other sectors have similar productivity growth potential, MGI concludes that 4 per cent is a realistic productivity target, but the representative nature of the five sectors is unproven.

6 The report finds that for developed countries, productivity growth to 2025 has the potential to advance at 3.5 per cent in automotive, 2.0 per cent in agriculture, 2.0 per cent in food processing, 2.0 per cent in retail and 2.2 per cent in health care. The unweighted average is 2.3 per cent, above the 2 per cent target for G-19 developed countries. For emerging economies, the report finds that productivity growth in automotive has the potential to advance at 8.1 per cent, agriculture at 4.9 per cent, food processing at 4.7 per cent, retail at 5.3 per cent and health care at 2.2 per cent. The unweighted average is 5.0 per cent, below the 6 per cent productivity growth target for G-19 emerging economies.

The report projects that productivity growth in the 2014-2064 period will be identical to that observed in the 1964-2014 period, and makes the case that it can be even stronger in the 2014-2024 period. As noted earlier, the developed G-19 economies have experienced a marked slowdown in productivity growth within the 1964-2014 period, from 3.2 per cent per year in 1964-74 to 1.8 per cent in each of the three 10-year periods between 1974 and 2004 and to 0.8 per cent in 2004-2014. The United States, the world technology leader, has experienced business sector output per hour growth of only 0.8 per cent per year since 2004, down from 2.2 per cent from 1995 to 2004.

Surprisingly, the report does not address the reasons for the recent slowdown in trend productivity growth nor discuss the implications for its productivity projections. But even the continuation of the 1964-2014 productivity trends may be optimistic, not to mention the acceleration of productivity growth to 4 per cent. In the long run productivity growth is largely driven by technological progress. If the supply of major new productivity-enhancing innovations is dwindling, as some technological pessimists like Robert Gordon (2016) believe, then future productivity growth may be closer to recent trends than those enjoyed over the past half century.

In other words, the slowdown in GDP growth between the 1964-2014 and 2014-2064 periods may be much worse than the report projects, because of the failure of productivity growth to maintain its past growth rate.

The focus of the report is on increasing productivity (and output) growth by boosting the supply-side potential of the world economy. But output (and productivity) growth is determined by both supply-side and demand-side forces. Potential increases in supply due to technological advances do not automatically translate into actual increases if demand is deficient. The report fails to identify the demand-side forces that will ensure that the increased productive capacity is actually realized. For example, China's rapid output and productivity growth in recent years was driven by very strong growth in exports. Will export growth also drive output and productivity growth in the emerging world in the 2014-2064 period, or will internal demand play a larger role? Say's Law may hold in the long run, but how this is expected to happen needs to be fleshed out.

In defense of the report, it can be noted that all of the potential productivity acceleration in the 2014-2024 period takes place in the emerging G-19 countries (Table 1). The productivity growth target for these countries at 6.0 per cent is more than double projected productivity growth (2.8 per cent). In the developed G-19 countries target productivity growth at 2.0 per cent is virtually the same as projected productivity growth (1.9 per cent). Thus virtually all the acceleration in productivity growth for the G-19 and Nigeria from the 1.8 per cent figure in the projection to the 4.0 per cent target is due to the emerging economies. This is consistent with a technological slowdown as such a development is largely confined to the developed world. The emerging countries can still continue to enormously benefit from catch-up to the frontier, even if this frontier is not advancing as rapidly as it once did.

Do We Really Need 4 per cent Productivity Growth?

The motivation for the report is that without a substantial broad-based productivity agenda, global growth is likely to decline substantially from rates enjoyed in the past half century. But this decline is based on slower employment growth and consequently has a small impact on per capita metrics. Indeed, with 4 per cent productivity growth and population growth projected to be 0.4 per cent in the 2014-2064 period in the G19 and Nigeria, GDP per capita growth

would be around 3.6 per cent, well above the 2.1 per cent experienced in 1964-2014. A case might be made that what matter for well-being are trends in living standards measured as growth in GDP per capita, not growth in total GDP.

Of course, the options open to humanity would be greatly enhanced by 4 per cent productivity growth and aspirational targets can positively affect behaviour. But would a more realistic productivity target be preferable, especially when the attainment of such an objective not only sustains living standards growth, but boosts it considerably? Does the report lose credibility by championing such overly ambitious objectives? Analysts will differ on their answer to this question. My view is of lost credibility.

Labour Productivity Versus Total Factor Productivity

The standard approach to productivity analysis is growth accounting, which decomposes labour productivity growth into three sources: capital deepening, labour quality or composition, and total factor productivity. The MGI report eschews this methodology, apparently on the grounds that capital is difficult to measure, although no discussion of the limitations of growth accounting is offered. Instead it focuses on the division of economic growth into employment growth and labour productivity growth, with no attempt to quantify the sources of this productivity growth, past or future.

While many economists would likely see this as a major failing of the report, I do not share this view.[7] Because so much technical progress is embodied in capital equipment, the idea that total factor productivity is a proxy for technological progress can be highly misleading. For example, Statistics Canada's official estimates for the business sector show that multifactor productivity growth in Canada was zero between 1977 and 2013. Yet the idea that no technological change (or even disembodied technological change) took place over that 36 year period is preposterous.

The Economist versus the Business Approach to Productivity

Economists and business people have different approaches to productivity. Economists focus on the changes over time in real, that is inflation-adjusted (constant price), output per unit of input. Business people on the other hand define productivity as the nominal or current price value added per unit of input, reflecting their focus on profitability, which is measured in current prices. A firm that through marketing is able to increase its margins and hence current price value added per unit input would have higher productivity. But if this increased margin has no effect on the output of the firm, measured in physical or inflation-adjusted terms, economists would register no increases in productivity.

MGI attempts to bridge this gap on the meaning of productivity between the economist and business communities. McKinsey consultants are well trained in economics and work closely with the clients in the business community, obtaining a keen understanding of business interests. Consequently, the MGI studies focus on productivity growth both in the economist sense and in the business sense. These studies discuss ways firms can increase the value of output through innovative marketing, even if such changes are not captured as real output changes, and hence do not represent productivity changes in the economist sense.

The impact of business innovation related to the introduction of new and improved goods and services on official estimates of industry prices,

7 Indeed, many economists see the term productivity as synonymous with total factor productivity as they focus on efficiency in the use of all inputs and pay limited attention to labour productivity.

real output and productivity is highly complex and still poorly understood. MGI is well positioned to advance our understanding in this area. Hopefully this will be a topic for future MGI reports.

The Dismal MGI Perspective on Canada's Past and Future Productivity Performance

Canada is of course one of the G-19 countries so the report includes productivity estimates for Canada in an international perspective. The results are not pretty. Over the 1964-2014 period Canada experienced the weakest labour productivity growth among the nine developed economies in the G-19, posting an average annual rate of growth of only 1.1 per cent.[8] This was well behind the next worst performers (Australia and the United States), both at 1.5 per cent. It is little solace that two countries in the emerging economies group of the G-19, Saudi Arabia and Mexico, had an even worse productivity performance than Canada, 0.7 per cent and 0.6 per cent respectively.

In 1964, GDP per employed person in Canada was 93 per cent of that in the United States. By 2014, it had declined 14 percentage points to 79 per cent. Not one other developed country in the G-19 saw a deterioration in its productivity level relative to the United States over the period.

Going forward for the next half century, MGI projects Canada's future productivity growth at 1.1 per cent. Based on the 0.4 per cent employment growth projection, output growth is projected to be 1.5 per cent per year for the 2014-2064 period, down from 3.1 in 1964-2004. At 53 per cent, this is the largest per cent fall in output growth between periods among the developed economies of the G-19. In terms of absolute growth rates, only Germany and Italy are expected to have worse economic growth for the next half century (1.0 per cent and 1.4 per cent respectively). This reflects actual declines in employment in these countries, as their productivity growth is projected to be superior to that in Canada.

Not surprisingly given Canada's positive employment growth, the MGI outlook for Canada's future per capita GDP growth is even worse than GDP growth. Per capita output is projected to advance at a 0.8 per cent average annual rate between 2014 and 2064, the lowest rate in the G-19 developed economies. Canada's 57 per cent decline from per capita GDP growth of 1.9 per cent in 1961-2014 to 0.8 per cent in 2014-2064 is by far the largest in the developed economies.

One is struck by the similarity of the MGI projections for Canada for the 2014-2064 period with the projections for Canada for the 2014-2038 period by Don Drummond and Evan Capeluck (2015). They project GDP growth at a 1.6 per cent average annual rate for their reference period, very close to the 1.5 per cent from MGI for its reference period. The productivity projections are also very close (1.0 per cent for Drummond and Capeluck versus 1.1 per cent for MGI), as are the employment projections (0.6 per cent versus 0.4 per cent).

Additional Comments

About a decade ago, William Lewis, the Founding Director of the MGI, published an important book entitled *The Power of Productivity: Wealth, Poverty, and the Threat to Global Stability*. That book was also based on extensive MGI research. Lewis argued that the key to improving economic conditions is increasing productivity through intense, though fair, com-

8 This estimate for Canada, based on the Conference Board Total Productivity Database, is somewhat below other productivity estimates. For example, the productivity database maintained by the Centre for the Study of Living Standards, based on Statistics Canada estimates, gives an annual compound rate of growth of 1.3 per cent for GDP per job for the 1961-2014 period in Canada, and 1.7 per cent for GDP per hour worked.

petition and protecting consumer rights. Perhaps surprisingly, the report under review makes no mention of the Lewis book. It would be interesting to know whether the current MGI perspective on productivity is the same as that put forward by Lewis or whether an additional ten years of MGI productivity studies brought to light new knowledge that has changed this perspective?

The most awkward term used in the report is "G-19 plus Nigeria." It is unclear why the authors felt it necessary to add Nigeria to the 19 country members of the G-20 group. Since the G-19 plus Nigeria accounts for 80 per cent of world GDP and 75 per cent of world employment, it would have in my view been better to conduct the analysis for all countries, with the basic breakdown between the developed world and the developing or emerging world.

Chapter six on trade-offs related to productivity is the most unsatisfying chapter in the report, largely because of its brevity in dealing with a diverse set of complex and important issues, such as the link between the environment and growth and inequality and growth. One can however understand the reluctance of the authors of the report to tackle in a substantial manner the issues outlined, given their focus on the traditional productivity calculus. One can only hope it extends and applies the framework developed in this report to the trade-offs related to productivity growth.

Conclusion

This is a very important report. It is the distillation of the collective wisdom of many very knowledgeable, well trained, and extensively experienced McKinsey staff. It is highly accessible to a general audience as it is relatively short (136 pages), written in a readable, non-technical manner, and can be downloaded without charge from the MGI website. It addresses issues that are of the utmost importance to the future of the world economy, with implications for the future of humanity. Needless to say, I highly recommend the report to all persons interested in the productivity issue.

My major concern is the report's focus on GDP, as opposed to per capita GDP. I consider the latter a much more relevant metric for assessment of future trends in living standards and welfare. Because of demographic developments, the expected slowdown in growth in per capita GDP is much less than in GDP growth. Adoption of a per capita GDP framework would consequently paint a considerably less bleak picture of the change in actual and projected economic developments between the 1964-2014 and 2014-2064 periods. Productivity of course contributes to both GDP and per capita GDP growth so use of a per capita perspective would in no way undermine the importance of productivity growth.

In my view, it is extremely unlikely that the MGI productivity targets for 2014-2024 (4 per cent at the world level (G19 plus Nigeria), 6 per cent in the emerging G19, and 2 per cent in the developed G-19) will or even can be met. As noted earlier, in no 10-year period between 1950 and 2010 did the world or the developing world ever attain the targets. At the world level the gap between target and actual productivity growth has been considerable since 1970. But such targets attract attention, which may be their real purpose.

The only conceivable scenario in which such productivity targets could be achieved is if major international organizations, such as the OECD and World Bank, or a key inter-governmental group, such as the G-19, championed the targets and took serious measures to foster best practice diffusion and to provide incentives to business to boost productivity. With a number of major issues dominating the global agenda, including international terrorism, climate change, world poverty reduction, and growing income inequal-

ity, it is very difficult for a productivity agenda to garner the sustained attention of world leaders, and perhaps rightly so. First, the other issues enumerated may be more important for the well-being of the world's population than faster productivity growth, and hence merit more attention. Second, as noted in the MGI report, the lion's share of productivity growth is not dependent on government action and is driven by private sector decisions. Productivity growth may not be the appropriate focus of the limited time and attention of world leaders.

Despite the overreach in terms of productivity targets, the report provides an exceedingly rich, real world discussion of policies and actions needed by government and employers to sustain or better yet accelerate productivity growth. This is the true contribution of the report.

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Do Poor Countries Catch Up to Rich Countries? Review Article on *Productivity Convergence: Theory and Evidence* by Edward Wolff

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ABSTRACT

This article provides a detailed review of Edward Wolff's Productivity Convergence: Theory and Evidence. Wolff examines the long run productivity growth and convergence experience of a variety of countries from across the world. Wolff's main contribution is the definition of two general classes of forces of convergence. He delineates "strong" forces of productivity convergence, such as the catch-up effect, capital formation, and education, from "weak" forces contributing to convergence like international trade, economic geography, and regulation. While some of the individual forces of convergence may switch categories as new research emerges, the categorization remains highly relevant. The focus on convergence suggests that non-frontier countries may not yet be in dire straits as a result of the purported recent productivity slowdown, as productivity growth may well still come from forces of convergence for years to come.

THE BOOK *Productivity Convergence: Theory and Evidence*, published in 2014 by Cambridge University Press and authored by Edward Wolff from New York University, provides a wide-ranging examination of a big subject: productivity growth and convergence. The volume joins a tide of new books on productivity growth, which perhaps goes to show that although we are not sure whether productivity growth is pro-cyclical, we have growing evidence that books on productivity growth are counter-cyclical.

Although the main subject is productivity convergence, the author of necessity takes the reader through issues related to productivity levels, productivity growth, and their measurement. He does this at some length in Chapter 3, which focuses on measurement, and also in Chapter 8, which focuses on the U.S. post-1973 productivity slowdown. The rest of the chapters are much more about comparative productivity performance and convergence (or the lack of it) between countries. Work is discussed using very long data (Maddison data back to 1 AD for example), using data in rich countries and data in poor countries. Much of this work has appeared already but there is some new work, for example the analysis in Chapter 4 on long run productiv-

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Table 1: Levels of Per Capita GDP, 1000, 1500, 1820, 1990, and 2008, 1990 International Dollars

	1000	1500	1820	1990	2008
World	453	566	666	5,150	7,614
Rich	425	702	1,102	18,750	25,285
Western Europe	427	771	1,194	15,908	21,672
United States	400	400	1,257	23,201	31,178
OtherWestern Offshoots	400	400	761	17,906	24,807
Japan	425	500	669	18,789	22,816
Rest	458	538	578	2,711	4,900
China	466	600	600	1,871	6,725
India	450	550	533	1,309	2,975
Other Asia	520	565	579	3,075	5,146
Latin America	400	416	691	5,065	6,973
Eastern Europe	400	498	686	6,458	8,102
Africa	425	414	420	1,425	1,780
Rich/Rest	0.93	1.30	1.91	6.92	5.16
Coefficients of Variation					
Rich	0.04	0.34	0.31	0.16	0.17
Rest	0.10	0.15	0.17	0.66	0.47
All	0.09	0.23	0.37	0.89	0.81

Source: Maddison (2008)

ity growth among the "Maddison 16" countries (Australia, European countries, Japan, the United States, and Canada) from Year 1 to 2006.

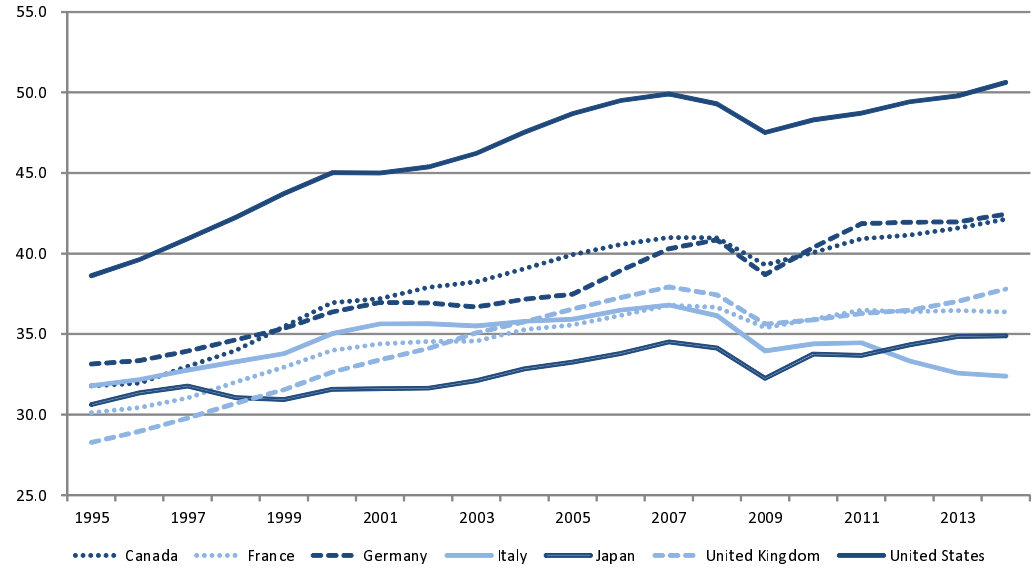
The subject is important. Indeed, productivity convergence has taken on a new significance in the light of the current heart-searching about the possible productivity slowdown and associated secular stagnation. In countries not on the productivity frontier, such as the one of your reviewer, commentators tend to be much more sanguine about productivity prospects since they often assert that productivity can grow simply by catching up to the US level. Thus the broad scope of this book to cover non-frontier countries is welcome.

As Wolff knows well, the whole question of convergence actually raises an incredibly important question: which country is the frontier country? Students, at least in my classes, are often staggered to hear this question even articulated, since only one nation designs their phones, provides their search engine and is the portal for their online social life. The realization that the United States was not always the productivity leader is, I think, often their initial step into thinking more broadly about the world and beginning to see the power of economic data and theory in asking the big questions. This book will help them on that journey.

With this historical perspective in mind, a natural starting point is Chapter 4 of the book, called "Long-term Record among the Advanced Industrial Countries." This chapter sets the stage for Chapters 5, 6, and 7, which are on post-war performance for advanced countries (chapter 8 is, as the author says, a slight digression in spirit being just on the United States), whereas Chapter 9 is about post-war performance in the world. Many of these chapters use the famous Maddison database, a small part of which I reproduce below, using the data in Maddison (2008), also drawn upon in Wolff's' Chapter 4, for Figure 4.7 updated to 2008.

The table lists in the top panel the "Rich" countries and in the middle panel the "Rest," with the rest consisting of Asia, Latin America and Africa. Let us start with some levels of GDP per head. Starting in 1000 AD, we learn that the rich countries were not always rich; indeed they were somewhat poorer than the Rest in that period. By 1500, however, the rich countries had pulled away and continued to do so by 1820. Indeed on these data, only Eastern Europe and Latin America made any appreciable progress among the Rest. By 1990, the Rich countries were dominant and the poor countries were catching up to Latin America and Eastern Europe. By 2008, the Rich countries remained dominant, but gap between the Rich and the Rest had fallen by nearly a quarter. The Rest's convergence was driven by China and India, who respectively more than trebled and more than doubled their GDP per capita between 1990 and 2008. By 2008, China had largely

Chart 1: GDP Per Capita in G7 Countries, $US, 2011 PPP, 1995-2014



Source: OECD database.

caught up to Latin America and Eastern Europe in terms of GDP per capita.

What does this tell us about convergence? The lower panel sets out the coefficient of variation among the rich, the rest and all. Looking at the rich row, we have divergence from 1000 to 1500, but, since 1500, convergence. That should give some comfort to non-frontier countries. But the "Rest" row shows a stable coefficient of variation but then a sharp rise from 1820 to 1990 and tapering from 1990 to 2008, a less comforting picture. Turning to the "All" row, the picture is of a large divergence until 2008, with large divergence up to 1990 but then some convergence since.

Thus very long history tells us that convergence is, if anything, a modern phenomenon, confined to rich nations and the poor nations only recently. What about short history? Chart 1 shows data for GDP per capita for G-7 countries, from 1995 to 2014.

Since the financial crisis in 2007-8, the United States has continued to grow relative to others G-7 countries. The sample coefficient of variation has risen from 0.10 in 1995 to 0.15 in 2014. That looks like divergence.

Wolff reviews a number of theories on the patterns of very long run growth and divergence. Many theories focus on technical progress and population growth, citing, for example, Fogel's work documenting early developments in agriculture (9000 BC), pottery (6000 BC) and the plow (4500 BC); readers familiar with Jared Diamond's *Guns, Germs and Steel* will recognise many of these points. The main sense is that if technical progress can somehow offset the scarcity of resources caused by population growth in pre-technology eras, then economies can grow past the Malthusian trap. Wolff suggests all this work puts the research ball firmly in the court of improving our understanding of technical progress, which brings us firmly up to date with the work of, for example, Gordon and Mokyr.

These very long trends are not, however, the central empirical themes of the book, which is more about post-war trends. To frame all this,

the book starts in Chapters 2 and 3 with theory and measurement.

In Chapter 2, Wolff starts with an overview of modern growth theory, beginning with the Cobb-Douglas production function $Y = cL^{a}K^{1-a}$, with notation for output Y, labour L, and capital K. He then sets out as well an approach that he credits to Mansfield (1965, 1980) and Griliches (1979) which he writes $Y = ce^{\eta t}L^{a}K^{1-a}R^{\beta}$, where R is the stock of R&D capital. A discussion then follows of various endogenous growth models.

This chapter discusses convergence. Given that this concept is the core of the book, this is a rather brief discussion. Wolff defines two notions of convergence. First, β-convergence is defined as "a narrowing of initial difference in income levels over some time horizon". Second, σ-convergence is defined as a reduction over time in the cross-country variance of productivity. β-convergence implies that initially low countries grow faster and so is often tested by the "growth-initial level" regression, a relation that β-convergence predicts to be negative. However, β-convergence does not necessarily imply a reduction in the cross-country dispersion of per capita income, i.e. σ-convergence.

Wolff also discusses unconditional and conditional convergence and a related concept called club or group convergence. He defines unconditional convergence as implying that the coefficient in a growth-initial level regression should be negative even if no other variable, such as education, is included. Conditional convergence however "requires appropriate variables be included on the right-hand side of the growth-initial level regression equation in order to control for the effects of other factors on growth (p.62)". Club or group convergence is where different groups of countries might converge to different levels.

This discussion leads directly to a discussion of why this method might produce fragile results, and Wolff refers to important papers by Temple (1999) and Levine and Renelt (1992). Indeed, in his conclusion, Wolff states (p.431) that "…many of the results reported in the works cited in this book were not robust." The remarkably candid conclusion is due to factors such as measurement error, endogeneity and lack of robustness to sample choice.

Chapter 3 is a long discussion of measurement. This covers a remarkable amount of ground. Wolff starts with Diewert's index number approach, which shows how a series of well-known index numbers are in fact quite consistent with a set of economic assumptions regarding technology and optimising behaviour. To my mind, this is an amazing synthesis of economic theory and measurement. He then discusses econometric approaches to productivity. Tucked away on p. 80 is, in my view, the central measurement point that "…the objective of productivity measurement is fundamentally to identify output differences that cannot be explained by input differences." I think this is a point worth making right up front, since non-productivity researchers often cannot understand economists' obsession with TFP.

This chapter ranges over countries, industries and firm-level productivity measurement, as befits a subject where the range of datasets (and computing power) available to economists has multiplied remarkably over even the last twenty years. One reservation, to me, was the discussion of capital services.

Capital services are addressed in a subsection entitled "Measurement of Capital Services," as part of a section called "How do we Move from Data to Theory?" This is an arresting title since the question is typically framed the other way around. The section on capital services sets out, in some detail, Berndt and Fuss' justly well-known and important 1986 contribution to the question of how to measure capital services in conditions of what Wolff calls temporary equi-

librium. In this case, the elasticity of output with respect to inputs might not equal the measured factor share, since the shadow cost of capital, when it is say, being underutilized, will not be the Hall-Jorgenson implied-rental cost.

There are at least two points to be made here. First, in the single capital type case, with constant returns, the unobserved shadow cost can be recovered as a residual from value added less other costs, thus rendering the ex post approach to capital share measurement correct under these assumptions even if there is short-run disequilibrium.

A second, much broader point, is that to my mind anyway, the measurement of capital services has been a major current of the productivity research effort in recent times, starting with Jorgenson and Griliches justly famous 1967 paper and continuing to become a standard output of many statistical agencies and the centrepiece of many contemporary descriptions of productivity growth. Witness the EU- and now World KLEMS programme developed by van Ark, O'Mahony, Timmer and partners (see Timmer et al., 2007, Timmer et al., 2011, and Jorgenson, 2012). The notion of capital services, rather than stocks, is an important intellectual breakthrough in its own right. The implementation of capital services, international harmonization, measurement of the ICT revolution, and accurate capital measurement in an era of rapidly changing investment composition, seem like subjects worthy of a longer discussion.

The remaining chapters in the book examine post-war trends in convergence. Wolff argues the data support convergence of GDP per capita among OECD countries but not others, many of whom seem to be stuck in the same low income rank as 50 years ago. Regarding convergence, Wolff's main contribution is to set out a set of "strong" and "weak" forces that contribute to convergence.[2] Of course, convergence is by no means assured, but such convergence seems to have occurred at least among rich countries for most of the post-war period. Wolff then argues the data allow us to isolate "strong" and "weak" forces in such convergence

The first strong force is the catch-up effect, referring to the negative coefficient on the initial level in the "growth-initial level" regressions. This force is, however, weak for low income countries. The second strong force is capital formation, which likely embodies new technology. The third is education, which can raise productivity directly via productive human capital formation, or indirectly, via social capacity to absorb new technology or learn. The macro findings on education are spotty. This raises a puzzle: we have near gold-standard results from birth cohort and/or twin studies that education boosts productivity (earnings) at the micro level, so how can this not show up at the macro level? Wolff rightly cites an important paper by Krueger and Lindhadl (2001) showing that measurement error in the macro data was very large, likely obscuring the results in this context. Of course, this is but one example of the major measurement challenge that hangs over this large macro literature, one that Wolff rightly acknowledges.

Finally, Wolff suggests that R&D and social institutions are also strong forces. He runs though a series of studies on R&D that seem to provide evidence for strong effects of R&D in developed countries but not in developing countries. On institutions, he reviews a set of papers in the *Quarterly Journal of Economics* (Knack and Keefer, 1997, Temple and Johnson, 1998 and Hall and Jones, 1999), all of which support the

2 Specifically, Wolff (2014) defines, "Strong forces are those that consistently show up with a positive and significant coeffict in growth regressions and [...] expalin the vast majority of the variation in economics of productivity growth in the sample of countries used. Weak forces are those consistently insignicant, or where causation is not clear, and which explain a small fraction of the variance."

idea that infrastructure, trust, and civic norms all contribute to growth.

There are many weak forces contributing to convergence: international trade and foreign direct investment (FDI), democracy and political institutions, inequality, financial development, economic geography and natural resources, the role of IT, regulation, structural change,, and foreign aid.

As Wolff notes, many studies cited are subject to lack of robustness, measurement error and other problems. I suspect that future research might move some of the weak forces into the strong forces group and vice versa. That is not a criticism of Wolff however, since the book is a reflection of how economists are using better data and statistics to navigate an ever-changing world.

Finally, Wolff offers some prospects for future growth in advanced and less-developed countries. Given the massive current interest in this topic, this section is remarkably prescient. Wolff predicts that for developed countries, labour productivity growth will "subside to its long run average of about 2% per year" (459). He makes the point also made by Gordon (20016), namely that there will be diminished growth in years of schooling, and adds to this lower potential for catch-up in many industrialized countries. Against that, he thinks there might be gains in the service sector from (a) deregulation of service industries, (b) greater use of ICT in services and (c) service outsourcing, but concludes they will be small, in that they might add only an additional 0.2 percentage points to TFP growth. As for middle and lower income countries, he suggests they cannot rely on catch-up and will only grow with appropriate institutions, capital investment and education.

Some of Wolff's conclusions on strong and weak forces contributing to convergence will be turned over by better data and changing historical circumstance. His forecast of a return to the average of 2 per cent growth in GDP per capita might be too optimistic, if, as per Gordon, that growth is historically unusual. But his encyclopaedic navigation and review of the literature on productivity convergence will remain.

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New and Promising Ideas in the Productivity Field: Review Article on *Think Like an Enterprise: Why Nations Need Comprehensive Productivity Strategies* by Robert Atkinson

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ABSTRACT

The most interesting part of Robert Atkinson's (President of the Information Technology and Innovation Foundation (ITIF)) manifesto on productivity is his recommended productivity strategy for strengthening productivity growth. Atkinson concludes that so-called framework policies are necessary but far from sufficient. The more active public policy role he calls for would include measures to lower the price of capital, moral suasion of firms to think more strategically, more direct government involvement in developing and disseminating new technologies and facilitating interactions across firms and sectors. Many will share Atkinson's view that different approaches to enhancing productivity growth are in order given the modest productivity records of many countries of late. But it is troubling that Atkinson does not suggest more stringent tests for new policy interventions. They must be subject to benefit-cost analysis to determine whether there is a net social benefit. The experiences countries have had with elements of what Atkinson recommends must be studied to see if they have yielded productivity gains.

IN MAY 2016, Robert D. Atkinson, President of the Information Technology and Innovation Foundation (ITIF), a Washington-D.C.-based think tank, released a sweeping (183 pages including endnotes) manifesto on productivity entitled *Think Like an Enterprise: Why Nations Need Comprehensive Productivity Strategies*.[2]

The document covers considerable ground, including: the definition and importance of productivity; a condemnation of "neo-Keynesian" and " neo-classical" economists for their respective indifference to productivity and laissez-faire perspective on policy interventions; and a detailed prescription of comprehensive productivity strategies that should be implemented in most nations.

This review will be highly selective in that it will only focus on what appears to be new and promising in the manifesto. Anyone seeking a broad perspective on productivity, including its

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2 The book can be downloaded without charge at http://www2.itif.org/2016-think-like-an-enterprise.pdf.

definition, importance and history, is well-advised to read Atkinson's report. However, little will be said about the context Atkinson sets for his policy ideas because the treatment is for the most part conventional and the ground covered is likely familiar to readers of the *International Productivity Monitor*. Further, this review article will not rise to the bait of challenging or even discussing at length two of the points Atkinson no doubt considers central to the manifesto, namely the declaration that governments should "make productivity the principal goal of economic policy, more important than managing the business cycle, defending liberty, or promoting equality" and the dismissal of most economists' contribution to productivity research and the formation of policies to enhance it.

I strongly concur with Atkinson's belief in the benefits of robust productivity growth. But I feel I would need a better grounding in philosophy, ethics and likely many other subjects to weigh in on a debate of productivity versus liberty. Without such grounding I even struggle with the notion that there are trade-offs between productivity and liberty. More importantly, it seems wholly unnecessary to go down that road. Few would disagree that productivity is important; that its performance in most countries has deteriorated despite the application in many countries of policies intended to enhance it; and hence that governments need to attach high priority to enhancing productivity. This means that new perspectives should be considered on how best to do this.

Much of a review article could be devoted to adding necessary nuances to Atkinson's depiction of the views of economists toward productivity. It is too much of an extreme caricature to say that neo-Keynesian economists are only interested in managing the business cycle and have no interest in longer-run growth. And neoclassical economists do not necessarily shy away from an activist public policy role in productivity due to ideology alone. Many observe, as does Atkinson, that attempts at industrial or sectoral strategies are sometimes themselves the cause of market failures, such as skewing economic activity toward small enterprises where productivity tends to be lower than in larger firms. Others recognize that policy interventions have costs. These include the need to raise taxes to finance intervention and economic distortions caused by taxation and the policy-driven shift in resource allocation (although Atkinson would argue that the interventions he recommends would shift resources in a productivity-enhancing way).

Atkinson does not apply any sort of benefit-cost analysis to his recommended policy interventions. Yet while much could be said about how Atkinson depicts and criticizes economists' views, Atkinson's productivity strategies can be considered while largely ignoring this lengthy part of the manifesto.

As a final aside before addressing Atkinson's recommendations, it will be noted that the title of the manifesto "think like an enterprise" is at odds with the author's thesis. Atkinson is quite critical of key aspects of enterprises' objective functions. He notes that many try to maximize revenues or minimize costs rather than maximize productivity and he argues their focus is much too near term and this is to the detriment of making the investments that would enhance productivity. Left to their own devices, Atkinson believes firms will not behave in a way that maximizes well-being for themselves or society.

Atkinson argues that public policy should try to influence the objective functions of enterprises. He also thinks public policy needs to facilitate relationships between firms and sectors, for example in developing and spreading the use of a new platform technology as he believes firms on their own will not form the necessary liaisons and synergies. So he seems to be saying that governments should think quite

differently than enterprises and try to modify how enterprises think and operate. But here too, it seems wise to proceed with analyzing Atkinson's ideas for improving productivity rather than carping at the title he chose.

What Is Not New in Atkinson's Productivity Strategies

Despite his considerable hype as to what is wrong with the perspectives of economists on productivity and public policy, much of what Atkinson recommends is conventional in economic analysis and actual policy approaches in many countries. This includes:

- stable fiscal policy, rule of law, correction of market-distorting regulations and other policies (such as those that favour small business);
- competitive domestic markets, although Atkinson notes that strong productivity does require firms to achieve considerable scale (he could have noted that firm size needs to be looked at relative to global and not just domestic markets as for the most productive firms the market for outputs and inputs is not just domestic);
- well-developed infrastructure (including in transportation and communication) that embraces public-private partnerships and user-pricing;
- an educated and skilled workforce including the development of high-quality managers;
- public support for scientific and engineering research, including help with the transfer of discoveries from the lab to the market; and
- minimize if not eliminate taxes and tariffs on capital goods.

These so-called framework policies are right out of the neo-classical economics playbook. To varying degrees they have characterized economic policies in many, if not most, nations over the past few decades. Yet productivity growth has slowed in most nations. Hence the appetite to search for other policies. Interestingly, Atkinson does not reject adherence to this conventional approach. Rather, he argues it does not go far enough. Although Atkinson does not use the phrase, his perspective on the so-called framework policies is that they are necessary but far from sufficient to drive strong productivity growth.

Before highlighting what is new in the report, a few comments will be made on the section concerning education and skills development. Like most discussion of framework policies, the take is quite conventional. Atkinson calls for more emphasis on education, not just on access but also on quality. Not surprisingly, he emphasizes the so-called STEM disciplines and management skills. He quite rightly calls for business to be more involved in education and skills training and for these endeavors in turn to be more attuned to business needs. More specifically, he emphasizes the importance of the "specific skills that fit existing and emerging needs of organizations."

It may be unfair to raise some qualms with this advice because it does flow rather naturally from many research studies and positions of international bodies such as the OECD. But I have a feeling that in the future different thinking will be applied to education, skills and productivity.[3] The notion of "overskilling" seems predicated on output of a firm and economy being fixed and the manner in which labour is utilized also being unchanged. Why cannot management of a firm recognize higher educated or more skillful workers as a blessing and change their operations to accommodate their potential contribution? In other words, to increase their productivity. The output of the firm can be expanded through taking a larger share of the domestic or global market, as the case might be. I also have a feeling there will be greater recog-

3 See Drummond and Rosenbluth (2015) for a discussion of this point.

nition in the future that it is extremely difficult, if not impossible, to anticipate the "emerging needs of organizations (for skills)" because everything changes so rapidly, due in good part to the technological changes Atkinson wishes to advance. Such recognition may bring about greater focus on developing broader competencies than "specific skills."

What is New or at Least Different in Atkinson's Productivity Strategies

Atkinson argues that in addition to framework policies that in good part attempt to remove barriers to investment and trade, measures are required that will more directly reduce the price of capital. This is because capital is key to increasing productivity (measured either as labour or total factor productivity) and, left alone, enterprises will under-invest because of inappropriate objective functions and a host of market failures. Of course, the notion of market failures is not new. The externalities of research are well recognized in economics and policy and used as a rationale for public research and tax incentives for private research. Atkinson's list of market failures is perhaps longer than conventionally recognized and includes:

- the return from investment (whether that be capital or knowledge) is larger for a society than for the firm as the benefits spread to other firms in the industry and broader networks of those involved, either directly or indirectly, in the production of outputs and inputs;
- firms face large risks in being early movers in developing new technologies;
- too many firms try to maximize revenue rather than productivity and have a short time horizon for considering the pay-off to investment;
- employers and/or employees impede productivity-enhancing investment because they fear it will lower employment;
- much of an economy consists of public and quasi-public institutions, which do not focus on productivity improvement, and in many instances, do not even measure their own productivity performance; and
- major innovations often require co-ordination across sectors (apps require broadband and the introduction of apps reinforced demand for broadband) and this is difficult to orchestrate within the private sector.

Atkinson's first two recommendations for lowering the price of capital – accelerated depreciation and investment tax credits – are themselves conventional in that they have been and continue to be used in many countries. Accelerated depreciation is surely not the heroic measure that will unleash investment. While this measure can address cash flow problems, it essentially just brings forward net profitability. Atkinson argues companies are too fixated with near-term financial results. More importantly, tax incentives have economic and fiscal costs. Atkinson pays no heed to this. Indeed, the only test he applies to the investment tax credit is to cite studies that show it raises capital investment. It would be surprising if lowering the price of an input in production did not increase its use. That does not mean such action represents a net benefit to society. Taxes must be raised to pay for the tax credits and their administration. That creates an economic cost due to the distortions arising from the taxation. Further economic costs could arise from the distortions created by the policy-induced reallocation of resources. Atkinson would naturally argue that the resource reallocation in this case would be welfare enhancing. A further distortion is injected from investment tax credits and accelerated depreciation allowances because they raise the price of existing capital relative to new capi-

tal. This may result in the premature write-off of capital which itself may be unproductive. Such investment incentives may also raise the price of capital.

Policy makers and economists, however they are branded, might not be too confident of a net real income gain from investment incentives. As Atkinson notes, many government policy interventions have in the past led to harmful taxation and regulatory policies. He argues that benefit-cost analysis should be applied to all these to weed out the welfare-reducing ones. Yet he does not apply or even suggest such benefit-cost analysis be applied to the interventions he recommends. Further, he is implicitly confident that new measures will not fall into the same trap as many older ones that often explicitly or at least implicitly subsidized unproductive firms and sectors.

In one of the more thorough examinations of the benefit-cost ratio of government interventions to foster economic development, John Lester (2016) has analyzed federal and provincial interventions in Canada through subsidies or tax preferences to determine which generated a real income gain. After examining costs such as the distortions from taxation required to finance the program and its administration and distortions in resource allocation, he concludes that very few initiatives raise real income. However, he does tentatively conclude that investment tax credits and accelerated depreciation allowances may yield net benefits. One of the reasons for the tentative nature of this conclusion is that Lester is concerned that his analysis to date does not capture distortions from initiatives raising the cost of existing capital relative to new capital.

As to what Atkinson labels "corporate short-termism," the only suggestion is to consider a proposal to "replace quarterly financial reports with a less frequent update, such as half-year results." It is not clear whether the suggestion is that governments regulate less frequent reporting regardless of the desire of shareholders and others. At any rate, such a move hardly seems likely to launch a new productivity era.

Atkinson argues governments need to be more involved in what he calls "platform policies." He argues that many of these are ICT-based and include innovations like smart grids, mobile payments and electronic IDs. He also refers to robotics, autonomous automobiles, and biological innovations. Greater government involvement might be direct research, support for private sector research, co-ordination of research and applications or government playing the role of early adopter. This fits well with one of Atkinson's themes that governments pay scant attention to the productivity of their own operations. In this case such policies could enhance government operations and promote externalities throughout the economy.

Atkinson also indulges in a little social re-engineering, pointing out that poor physical and mental health flowing from challenging childhood circumstances are major factors limiting productivity. Again these are not new ideas to many economists and followers of other disciplines. Atkinson could well have linked this section back to his notion of "short termism" in the private sector. The same afflicts governments in that investments in people are recognized as being solid in the longer-term but often do not pass the benefit-cost test for the next election.

The final two sections in Atkinson's productivity strategy concern a sectoral perspective on productivity and a focus on the public sector. However, the ideas in these sections have largely been addressed in what came before.

Conclusion

Despite over 100 pages of text, Atkinson's manifesto on productivity can be boiled down to a fairly straightforward proposition. Governments need to be more active on the productiv-

ity front. They need to assign it a higher priority (he argues it should be the top). They need to create the right conditions that will allow productivity to flourish. They need to gear their own operations toward being productive and recognize the positive spill-overs they can generate through smarter internal research, procurement and operating standards. And finally, but perhaps most importantly for Atkinson, they need to intervene more deeply and broadly into the economy through incentives for investment (capital and research) and co-ordination of the development and utilization of new platform technologies.

In principle and abstracting from specifics on policies, many, including a large number of the economists Atkinson claims are indifferent or intransigent on public policy and productivity, would agree with Atkinson's tenets. Yet as Atkinson acknowledges, policy interventions into economies in many cases and in many places have had negative effects. Too often industrial or even productivity strategies have ended up propping up unproductive firms or sectors.

This is not to say that Atkinson does not offer some promising ideas or that governments and others should not heed the productivity strategies he sets out. But the historical record does suggest caution. In many countries governments have done a reasonable job over the past few decades in addressing the so-called "framework policies" Atkinson refers to. Their record in driving their own operations through a productivity lens and of intervening in the economy to enhance the productivity of the private sector has been less than stellar. Is Atkinson's implicit confidence in the state warranted?

Many countries, Canada definitely included, have been following the same general recipe for productivity for many years. It has not proven successful. So new ideas should be tested. That should include some of the more activist notions of Atkinson.

This author came to the same conclusion last year in a report dealing with Canada that, along the lines of Atkinson, argued that adherence to the so-called "framework policies" wasn't getting the job done in strengthening productivity growth (Drummond, Calver and Capeluck, 2015). Like Atkinson, that report argued the dismal productivity record warranted consideration of other policy approaches to complement fixing up "frameworks." The distinction from Atkinson was the strong note of caution based upon the wreckage of previous attempts at industrial strategies and other efforts at policy activism. That caution elicited strong advice that policy measures must be subject to rigorous testing, ex ante and ex post, testing that must include a comprehensive analysis of costs of policy measures to ensure there is a net social benefit. That note of caution and that call for rigorous testing is missing from Atkinson's manifesto.

Atkinson could and should have applied stronger tests to whether the individual measures he proposed generate a positive net benefit ratio. It is not sufficient to simply demonstrate that lowering the price of capital increases its use in the production process. Further, he could have delved into productivity performances in different countries in an attempt to decipher the worth of the approaches he advocates. Many countries have offered and still offer investment incentives. Many countries have had active public policy participation in the development and dissemination of new platform technologies. Many countries have tried to facilitate clusters across firms and sectors. Can one demonstrate that such policy approaches have yielded stronger productivity growth than found in countries where the policy agenda has been less active? Such a finding might strengthen confidence in the directions Atkinson advocates.

Atkinson quotes from a paper of mine where I said governments' shyness to even refer to pro-

ductivity was similar to the situation in Harry Potter where Lord Voldemort must be referred to as "He-Who-Must-Not-Be-Named" (Drummon, 2011:5). I would like to end with another quote. I agree with Atkinson that the time has come to conclude that the so-called "framework policies" are necessary but not sufficient conditions for strong productivity growth. New ideas should be considered and this might lead to greater policy activism. But given the damage of so many government interventions in the past, we should be heedful of the advice with which Sergant Phil Estehaus from the American television police series *Hill Street Blues* always ended his instructions to his charges: "let's be careful out there".

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