# Editor's Overview

THIS 27TH ISSUE OF THE *International Productivity Monitor* features a symposium on priorities and directions for future productivity research with five contributions from leading productivity researchers. In addition, the issue includes articles on the impact of the oil boom on Canada's labour productivity performance, the contribution of intangible assets to productivity growth in Ontario, productivity trends in the forest products sector in Canada, and the influence of natural resource inputs on productivity.

The closing session at the international conference "Productivity: Measurement, Drivers and Trends" organized by the International Association for Research in Income and Wealth and the University of New South Wales held in Sydney, Australia in November 2013, was devoted to a panel discussion on priorities and directions for future productivity research. Panelists were asked to identify three priority areas for future productivity research. The first part of this issue of the *International Productivity Monitor* features a symposium based on the presentations of the five panelists, all leading productivity researchers.

In the first contribution to the symposium, **Paul Schreyer**, Deputy Chief Statistician at the OECD, puts forward three priority areas for future productivity research. He first identifies important data gaps related to non-produced, non-financial assets such as land and sub-soil assets, as the exclusion of these assets can lead to biased multifactor productivity growth estimates. He then highlights the health and education sectors as a focus for future productivity research, given the challenges of capturing quality change in these sectors as well as the public provision of much of the output and absence of market prices. Finally, he points out that research is needed on the implications of globalization on productivity measurement, giving the example of intellectual property, which is produced in one country, but used in many.

In the second contribution, **Dennis Fixler**, Chief Statistician at the U.S. Bureau of Economic Analysis, identifies hard-to-measure services, land/natural resources, and factory-less goods manufacturing as his three priority areas for productivity research. He highlights three hard-to-measure sectors for special attention: health, education, and financial services, given the difficulty of measuring prices and output in these sectors. Fixler also argues that with the increased attention to the environment it has become increasingly important to incorporate land and natural resources into the production function. Finally, he points out that the classification issues associated with factory-less goods producers have implications for the measurement of inputs and outputs at the sectoral level and hence for productivity estimates.

In the third contribution, **Dan Sichel,** until recently with the Federal Reserve Board and now at Wellesley College, identifies health care, intangible capital, and the high-tech sector as his priority areas for productivity research. In terms of health care, he highlights the importance of getting prices right and the key role that a satellite account for health care can play for productivity measurement. Regarding intangible capital, he stresses the importance of developing better prices deflators for investment in intangible capital as well as better depreciation rates. Finally, Sichel notes that because of the rapidly changing nature of the high-tech sector, measurement issues remain, giving as an example how changing market dynamics for microprocessors may be biasing the price index for semiconductors.

In the fourth contribution, **Bart van Ark**, Chief Economist at The Conference Board and Professor of Economics at the University of Groningen, identifies three priorities for future productivity research: intangible assets, a better understanding of the impact of innovation on productivity, and a bridging of the gap between firm-level measures of productivity and industry-level and aggregate measures. Van Ark also makes the case for greater emphasis on historical measurement of productivity performance in the tradition of Angus Maddison.

In the final contribution to the symposium, **Barbara Fraumeni** from the Central University for Economic Research in China highlights intangible capital, management practices, and human capital as areas for future productivity research. She stresses the importance of developing reliable productivity estimates for emerging and developing countries, and of enhancing collaboration between national statistical offices and academic researchers.

The symposium reveals that there exists broad agreement among the contributors on directions for future productivity research. In particular, intangible investments, education and health, and land and natural resources were identified by most contributors as priority areas.

As highlighted by the symposium, intangible capital has been identified as a priority for productivity research. Following the symposium, the first article in this issue by **Tatiana Muntean** from the Ontario Ministry of Finance furthers our knowledge in this area by estimating the contribution of intangible assets to labour productivity growth in Ontario. Intangible capital is defined to include: economic competencies such as spending on brand equity, training and organizational change; innovative property which includes R&D; and computerized information such as software and computerized databases. The author estimates that the intangible capital totaled $51.6 billion dollars in the Ontario business sector in 2008 and accounted for slightly over one quarter of labour productivity growth over the 1998-2008 period. Innovative property made the largest contribution, followed by economic competencies and computerized information.

The oil and gas industry has been the leading sector in the Canadian economy in the 2000s. The high oil prices which the sector has enjoyed until recently have contributed substantially to living standards growth. But the effect of the oil boom on Canada's mediocre aggregate productivity performance are complex and poorly understood. This article by **Andrew Sharpe and Bert Waslander** from the Centre for the Study of Living Standards explores the various channels, both direct and indirect, by which the oil and gas sector affects productivity growth.

They find that the large fall in labour productivity in the Canadian oil and gas sector between 2000 and 2012 was offset by a positive reallocation effect, reflecting the high labour productivity level of the sector and the net inflow of workers. These offsetting factors resulted in the oil and gas sector making a very small, but not negative contribution to labour productivity growth. A second key finding is that labour productivity has been very strong in the non-conventional oil and gas industry, that is the oil sands in 2007-2012. This reflects the increasing importance of steam-assisted gravity-drainage (SAGD) technologies and learning-by-doing. It was the recourse to lower-quality, higher-cost conventional oil and gas deposits, made profitable by high prices that accounts for the fall in labour productivity after 2007 in the Canadian oil and gas sector. The most important indirect effect of the oil and gas sector boom on Canada's aggregate productivity performance was its impact on the exchange rate, which reduced the competitiveness of the manufacturing sector, leading to a fall in output and much slower labour productivity growth.

Multifactor productivity (MFP) growth, often put forward as a measure of technical progress, has been more appropriately labeled a "measure of our ignorance" as it reflects the influence of the many factors not explicitly included in the growth accounting framework. In the third article in this issue following the symposium, **Vernon Topp and Tony Kulps** from the Australian Productivity Commission discuss how unmeasured natural resource inputs have affected measured MFP growth in the Australian context. They show how rainfall is an important unmeasured input for production in agriculture and that MFP growth in the sector falls in years of drought. They also find that a decline in the average quality of resource inputs into mining is responsible for much of the poor MFP growth in the industry and that a shift toward high-cost production technologies has dampened MFP growth in utilities. Despite difficulties related to the lack of market transactions on natural resource inputs, they conclude it is important for productivity researchers to attempt to adjust for natural resources inputs in computing MFP, especially in sectors where natural resources represent important inputs.

The Canadian forest products sector has experienced major economic turbulence in recent years. From 2000 to 2012 real output fell 1.7 per cent per year while hours worked plummeted 4.2 per cent per year, resulting in a 2.5 per cent annual increase in labour productivity. This is well above the business sector annual average of 0.7 per cent for output per hour. Declining sectors often experience lagging productivity as they fail to adjust employment for falling output. The forest productivity sector clearly is not an example of this type of behaviour.

In the final article in the issue **Ricardo de Avillez** provides a detailed analysis of the productivity trends and drivers in the Canadian forest products sector from 2000 to 2012. He points out that the sector was hit by a perfect storm in the mid- and late-2000s. The U.S. financial crisis and housing bust, combined with a structural shift away from paper to electronic media, as well as the appreciation of the Canadian dollar and the emergence of low-cost producers rendered the economic environment for forest product firms extremely challenging. Survival required cost reductions to maintain competitiveness. Firms responded by cutting workers so that by 2012 only around half of the employees in the industry still had jobs, relative to the 2000 employment level. This case study suggests that, in the medium term at least, positive, and even robust productivity growth can be consistent with rapidly falling output and employment.

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# Priorities and Directions for Future Productivity Research: An OECD Perspective

Paul Schreyer
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ABSTRACT

This article puts forward three priority areas for future productivity research. It first identifies important data gaps related to non-produced, non-financial assets such as land and sub-soil assets as the exclusion of these assets can lead to biased multifactor productivity growth estimates. It then highlights the health and education sectors as a focus for future productivity research, given the challenges of capturing quality change in these sectors as well as the public provision of much of the output and absence of market prices. Finally, it points out that research is needed on the implications of globalization on productivity measurement, giving the example of intellectual property, which is produced in one country, but used in many.

PRODUCTIVITY CHANGE AND ITS MEASUREMENT has long been a matter of considerable policy interest. During the economic crisis that OECD countries have experienced, productivity growth has come to play an even greater role as a longer-term source of economic growth and resilience. The measurement of productivity change is intimately connected to the measurement of economic activity in the national accounts. While nearly all parts of the non-financial national accounts are of interest to productivity analysts, some stand out due to their immediate policy relevance, share in the economy and/or persistent measurement gaps. These should constitute priority areas for data development at both the national and international level. I put forward three such domains.

## Land and Sub-soil Assets

First, the measurement of wealth should be a priority for future work on productivity. The System of National Accounts (SNA) 2008 provides a complete accounting framework with, at its heart, a consistent link between stocks of assets and flows of output, income and expenditure. While data on economic flows tend to be relatively well covered, and while data on *produced* and *non-produced financial* capital are also rather complete, there are important gaps for *non-produced, non-financial assets*. Probably the single most important such asset is land. Despite the fact that most countries have entertained land registers for a long time, volumes and values of land, in particular broken down by type of land and consistent with national accounts definitions, are scarce statistics. Yet, land plays an

1 The author is Deputy Chief Statistician at eh OECD. This article is based on a presentation to the closing panel on priorities and directions for future productivity research at the conference "Productivity: Measurement, Drivers, and Trends" organized by the International Association for Research in Income and Wealth and the University of New South Wales held in Sydney, Australia November 26-27, 2013. Email: paul.schreyer@oecd.org

important role as an asset and land prices have been driving large swings in real estate prices with significant consequences on economic activity. Services from land are also an important input into agricultural and other production and consequently a determinant of productivity. Further, excluding land from the stock of assets risks over-estimating rates of return on capital when these rates are computed 'endogenously', that is by relating profits to the stock of assets. Such an over-estimation can in turn affect computations of multi-factor productivity.

Closely linked to land are sub-soil assets. What holds for land is true for theses assets also: in some countries, they produce important natural capital services with a potential impact on measured productivity. Admittedly, measuring and valuing the stock of sub-soil assets is a difficult task but so are other statistical areas. The new international standard for environment-economy accounting, the System of Environmental Economic Accounting (SEEA), provides important guidance for the measurement of sub-soil assets.

## Services

A second priority for future productivity research should be work on services. One might ask whether this is specific enough given that services account for two-thirds of economic activity in most OECD countries. Indeed, some priority areas stand out given their size and policy relevance. These include health and education services, which are large parts of overall economic activity and important for individual well-being above and beyond the incomes generated through these services. Demand for health services is likely to increase further with the aging of the population. Ensuring steady productivity growth in the provision of health services is thus key to ensure their financing. Demand for educational services is also rising with skills becoming ever more important on the labour market. But productivity in health and education services is not well measured. One reason is the difficulty of capturing quality change of these services. Another reason is the public provision of services and the absence of market prices in many countries, which complicates the measurement of health and education output. Other services industries whose output tends to be particularly hard to measure include communications and financial services.

## Impact of Globalization

Third, going forward, the implications of globalization for productivity measurement need to be taken up in data development and productivity research. One example is intellectual property. To date, intellectual assets are often produced in one country but used in many other places in return for payments. In practice, it is often not clear whether these transactions constitute payment for a service, whether they constitute property income that moves between countries or whether assets are sold. A differential treatment will affect values and volumes of imports, exports and GDP as well as measures of R&D stocks and associated capital services. Consequently, measures of productivity will be affected as well, but neither the size nor sometimes even the direction of the measurement impact are clear.

Dealing with the three issues outlined above is a tall agenda but necessary for our better understanding of productivity growth and its sources. Work has started in the various areas: there exists a good conceptual basis to build on and empirical evidence is sprouting for some industries, countries and time periods. In some areas, such as in health measurement, the emergence of new administrative systems helps statistical developments as an unintended but most welcome spin-off. But more can and should be done. International initiatives and cooperation, as shown by conferences such as the 2013 IARIW-UNSW conference on productivity where these remarks were presented,[2] are crucial for the exchange of information and experiences and avoiding duplication of efforts where time and money are scarce. The OECD continues to work in all these fields and stands ready for further active engagement.

2 The papers presented at this conference are available at http://iariw.org/c2013australia.php. A supplementary issue of the *Review of Income and Wealth* based on selected papers from this conference will be published in 2015.

# Priorities and Directions for Future Productivity Research: A BEA Perspective

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Abstract

This article identifies hard-to-measure services, land/natural resources, and factory-less goods manufacturing as three priority areas for productivity research. It highlights three hard-to-measure sectors for special attention: health, education, and financial services, given the difficulty of measuring prices and output in these sectors. It also argues that with the increased attention to the environment it has become increasing important to incorporate land and natural resources into the production function. Finally, it points out that the classification issues associated with factory-less goods producers have implications for the measurement of inputs and outputs at the sectoral level and hence for productivity estimates.

The task given to the participants in the panel was to identify areas to which efforts in productivity measurement should be directed. In my view efforts should be turned to three main areas: hard-to-measure services; land/natural resources; and factory-less goods producers.

## Hard-to-measure Services

It has been recognized for some time that better measures of the productivity in the service sector are important for understanding productivity trends. Since that recognition in the late 1980s, there have been enormous strides. Yet for hard-to-measure services there are still some hurdles to overcome. The reason is that prices and output for these services are less amenable to measurement than other services. The three hard-to-measure services I want to focus on are: health, education and financial services.

In the United States, the measurement of the output of the heath sector is complicated by the numerous providers that sell products/services that are intertwined. For example, physician offices constitute an industry and one can look at the output of that industry. But the output is not generally an end in itself. These services are often combined with diagnostic services (another industry) and pharmaceutical products (yet another industry) to produce a treatment for some ailment plaguing the visitor to the physician's office. What then is the relevant productivity measure? Are we interested in the productivity in treating the disease or the productivity of the individual providers? Both productivity concepts are important and answer

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different questions. Certainly the productivity in treating diseases is not a matter of simply adding the outputs and the inputs. For some time, the Bureau of Economic Analysis (BEA) has been developing a health satellite account which focuses on treatments of diseases and has paid particular attention to the construction of diseased-based price indexes (Aizcorbe, Retus and Smith, 2008 and Aizcorbe, 2013).

Education is similarly difficult. As Griliches (1970) pointed out, the output of education involves the student's ability as well as the effectiveness of the instructor and the other inputs. More broadly, the attributes of the consumer play a role in determining the output of the producer. This feature of education also affects the measurement of human capital to which much recent attention has been directed in international forums as it relates to the measurement of intangible assets. The BEA has undertaken some preliminary research in measuring education and human capital.

Financial services have received much attention of late because of the role played by financial forces at the outset of the recent recession. However, measuring the output and prices of financial services has been a topic of interest from the beginning of the national accounts (Fixler and Zieschang, 1991). The reason is that the role of financial markets and financial intermediation in the functioning of the non-financial part of the economy has been historically viewed as a black box. Though there has been much progress in measuring the output and price of commercial bank services, especially with respect to implicitly paid-for financial services, the black box has not become a white one. In today's world, especially in light of the financial market triggers to the most recent recession, the attention has shifted to other components of the financial services industry. How do we measure the output of shadow banks? What should be done to incorporate the financial services output of non-financial firms?

## Land/Natural Resources

Early characterizations of production commonly included land as an input. The practice fell out of favor in part due to the decreased reliance of most economies on agriculture. But with the attention devoted to the environment and the use of natural resources the incorporation of land in the production function has returned. The papers presented at this conference by Diewert (2013) on the decomposition of productivity growth and by Brandt, Schreyer and Zipperer (2013) show the importance of land and natural resources to the production process.

Putting land and natural resources in the production function has been aided by developments in the accounting for land and natural resources. The System of National Accounts (SNA) 2008 relegates the measurement of natural assets to the recently revised System of Environmental Economic Accounting (SEEA). In particular, the SNA recommends that the disaggregation of land be based on the SEEA.

As with other inputs there are consequences for measurement that arise from technological change. For example, the mining technology known as fracking (hydraulic fracturing) has increased the extent and quantity of subsoil assets. Some exploratory work is going on at the BEA to augment the treatment of subsoil assets.

The BEA is also conducting research on valuing land that will be included in the sector balance sheets in the integrated macroeconomic accounts.

## Factory-less Goods Manufacturing

This issue derives from the rise in both globalization and the fragmentation of production. Recent changes in SNA 2008 and the sixth edition of the Balance of Payments and International Investment Position Manual (BPM6) recommend that establishments that do not actually produce products but control the production - the degree and manner of control are stipulated differently in the two manuals - should be classified as manufacturing firms. Ironing out these differences and coming up with ways to identify Factory-less Goods Producers (FGP) has been the subject of many groups and meetings such as the Task Force on Global Production and the conference on the Factory Free Economy that was held in June 2013 in Paris

Though the FGP issue is largely one of classification, it will likely have a large impact on the measurement of productivity. There are two main implications of the classification of FGPs. First, a large number of workers will be reclassified to manufacturing. Second, there will be a change in the way that international transactions are recorded so that domestic gross output would include the value of foreign manufacturing services. To give some context, consider the fact that in the United States many establishments in the computer and semiconductor industries were classified as wholesalers and are now in manufacturing.

Because these changes involve the reclassification of activity in one sector to the activity in another sector, there will in principle be no change in GDP, though the net exports component can be different. At this point it is hard to estimate the impact of the changes because only now are data being studied from various Census and BEA surveys that asked questions regarding FGP activity.

But the upshot is clear: there will be an impact on inputs and outputs and thus on measured productivity. To give some magnitude of the impact on labour, a study by Federal Reserve economists showed that there would have been 7-30 per cent more manufacturing employment in 2002 and 2007 (Bayard, Byrne, and Smith, 2013). The implementation of any reclassification of FGPs is still some time away as there are many challenges to be addressed. For example, how would time series consistency be preserved? This question is inextricably linked to the question of how the data on FGPs should be presented. Should there be a separate code in each manufacturing industry or should "of which" lines be used when reporting output? Second, suppose that the data reveal that it is not possible to identify FGPs at the establishment level, what would be the alternative? Looking at the enterprise level is the obvious next step but what would be the implications? Why all of this matters, is that it directly bears on the discussions about competiveness and growth; the topics addressed at this conference in the paper by Bart van Ark *et al.* (2013) with respect to Europe.

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# Priorities and Directions for Future Productivity Research: Health Care, Intangible Capital and High-tech

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ABSTRACT

This article identifies health care, intangible capital, and the high-tech sector as priority areas for productivity research. In terms of health care, it highlights the importance of getting prices right and the key role that a satellite account for health care can play for productivity measurement. Regarding intangible capital, it stresses the importance of developing better price deflators for investment in tangible capital as well as better depreciation rates. Finally, it notes that because of the rapidly changing nature of the high-tech sector measurement issues remain a priority.

I AM VERY PLEASED TO HAVE an opportunity to participate in this panel discussion. Each panelist was asked to discuss three agenda items for future research on productivity. It is challenging to be limited to just three items as many topics are worthy of further research. That said, I will focus on three items in the area of economic measurement.

## Health Care

Health care makes up a large and rising share of GDP in advanced economies. Accordingly, getting prices right for health care is of paramount importance for accurate productivity measurement in that sector and for the economy overall. Progress is being made, with a CRIW conference in Washington, D.C., in October 2013 that focused on measuring and modeling health care costs; in addition, the U. S. Bureau of Economic Analysis has made significant progress developing a satellite account for health care. Akin to what happened with R&D, a satellite account for health care should help to focus attention and spur additional work on the key measurement issues.

## Intangible Capital

Intangible capital is another area in which I believe further work would bring substantial benefits. In particular, developing better price deflators for business investment in intangible capital and better estimates of depreciation rates for intangible capital should be high priorities. Regarding price deflators, in many cases GDP deflators (or something close) are being used as deflators for investment in intangible capital.

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While this is a reasonable stand-in until something better can be developed, trends in deflators for some categories of intangible capital could be quite different from the GDP deflator. Accordingly, measures of real GDP and productivity could look different with improved deflators for intangible investment goods. Similarly, developing better estimates of depreciation rates for intangible capital would be valuable. More generally, there is scope for considerable further work on estimates of depreciation rates. For example, depreciation rates for many types of capital in the U.S. accounts are based on empirical work from quite some time ago. Developing more up-to-date estimates could have important implications for measures of capital services and multifactor productivity. Fortunately, progress is being made in these areas. For example, some of the papers in this conference (Corrado, Goodridge and Haskel, 2013; de Rassenfasse, 2013) touched on these issues.

## High-tech sector

This might be an overly strong a statement, but I think there is a sense in some quarters that the measurement problems of the high tech sector have been tackled. Notwithstanding the significant progress made previously, I would argue that significant measurement challenges remain. This sector remains exceptionally dynamic and its scope continues to broaden. Even for high-tech hardware, changes in market dynamics may require updating current techniques that once seemed sufficient. For example, the paper I presented at this conference (Byrne, Oliner, and Sichel, 2013) highlighted how changing market dynamics for microprocessors may be biasing the Producer Price Index (PPI) for semiconductors. More generally, while price deflators for personal computers (PCs) often are estimated with hedonic techniques, the nexus of innovation has moved beyond PCs to mobile devices and areas that are, perhaps, less visible like navigation equipment (GPS). As these new market segments grow, it will become increasingly important to ensure that the best possible price deflators are being used.

Another area warranting additional work is import and export prices. For the United States, a significant share of high-tech goods are imported (and some important categories are exported in significant quantities as well). Getting export prices right will matter directly for measures of real GDP and productivity. While import prices largely wash out of real GDP measures, they are becoming increasingly important for measures of real business investment as the import share for high-tech investment goods (and some other categories of business investment) has risen. Currently, in the United States, import prices largely are calculated using matched-model rather than hedonic methods, raising the possibility that import prices for some products could suffer from bias. And, if import prices affect (and potentially) bias measures of real business investment, they also will affect measures of capital services. Hence, getting import prices right is important for getting measures of capital services and multifactor productivity right. Here too, this conference highlighted some important work in this area (e.g. Reinsdorf, 2013) that highlighted the potential of using hedonic indexes for import prices for high-tech products and the possibility of biases in current matched-model import price indexes for high-tech products.

Software prices remain another critical area. In the United States, the Bureau of Economic Analysis is using sensible proxies for software prices. That said, further development and refinement of these price indexes is important given the large and growing share of software in nominal business investment. Beyond these traditional types of software, new and rapidly growing types of software—like Apps for mobile devices—also need to have accurate deflators developed.

Looking further ahead, it likely will become necessary for national income accountants to think beyond pricing hardware and software as separate products. As more and more computing moves to the cloud, the distinction between hardware and software becomes less and less relevant for many users. Users purchasing computing services from, say Amazon, are interested in the price of computing services, not the price of the individual bits of hardware and software that Amazon is using to produce those computing services. One other recent example of the blurring distinction between hardware and software is instructive. For laptop computers, we normally would think of battery life as a characteristic of the hardware. But, Apple recently introduced a new operating system, Mavericks, that changed the sequencing of calculations in a way that significantly increased battery life. Accordingly, battery life is no longer a characteristic of hardware alone, but rather is a joint outcome of hardware and software.

For those interested in economic measurement, there remains plenty to work on!

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# Priorities and Directions for Future Productivity Research: The Need for Historical Perspective

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Abstract

This article identifies three priorities for future productivity research: intangible assets, a better understanding of the impact of innovation on productivity, and a bridging of the gap between firm-level measures of productivity and industry-level and aggregate measures. It also makes the case for greater emphasis on historical measurement of productivity performance in the tradition of Angus Maddison.

Economists have a wide range of perspectives on the productivity issue, depending on the environment in which one works. I have been fortunate to have worked in more than one work environment, which has given me different perspectives on productivity. The first part of my career was spent in academia at the University of Groningen in the Netherlands. Since 2008, I have worked for The Conference Board, a business research organization.

When I was in academia I worked primarily on international productivity comparisons. From that perspective I would argue that priorities for future productivity research include more contributions to World KLEMS, greater integration of growth accounts in the national accounts, additional work on the prices of new goods and services, and research on services output. Advances in these areas are overdue.

In my current position, I work with business, to help them understand and improve productivity performance. In that capacity, I would argue that priorities for future productivity research include more work on intangible assets, a better understanding of the impact of innovation on productivity, and a bridging of the gap between firm-level measures of productivity and industry-level and aggregate measures. There is much to do here.

As other panelists have addressed several of these priorities, I would like to emphasize a third priority or direction for future productivity research which has not been focused on. In the tradition of that great empirical economist, and my mentor, Angus Maddison, I argue for continued emphasis on historical measurement of productivity performance. Surprisingly, there has been no paper in this conference specifically focused on historical

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analysis, and there has only been limited discussion about the long term. If he were still alive, Angus would probably have presented a paper on productivity in the Roman Empire, or how the development of the Maya population has changed growth from extensive to intensive. And we would all be wondering how this exotic work contributes to our understanding of today's growth challenges.

Now, I am not arguing that no one has taken up the baton on the study of the dynamics of long-term economic growth. Nick Crafts, Barry Eichengreen, Kevin O'Rourke, Alan Taylor, and Stephen Broadberry have all made important contributions in this field. And let us not forget Bob Gordon, whether we agree with him or not. And I am sure I am omitting other excellent scholars in economic history.

But where are the productivity experts, present at this conference, who are developing state-of-the-art methodologies in this field? Would not we be able to learn much from applying our methodologies to historical data? To be sure, these data are weaker and more spotty than contemporary data, but at least we do not have to ask for new surveys! Long-term estimates of GDP, labour and capital are widely available. There is some sectoral detail (agriculture, industry, trade), allowing the construction of simple growth accounts data set, as have been produced by such pioneering economists as Simon Kuznets, Edward Denison, Moses Abramovitz, John Kendrick, and of course Angus Maddison.

It is also possible to develop good proxies of explanatory factors of productivity growth, including innovation, global integration, and institutional stability. The many gaps in our understanding of productivity require creativity, but collectively we can advance our knowledge. The applications are plentiful.

Nick Oulton at this conference presented a paper on the impact of financial crises on productivity (Oulton, 2013). I think this question should and could be taken back before 1950. It would help us to better understand whether this time is really different, now that we have a better understanding of the impact of the depression of the 1930s, and the other 200-odd banking crises that Reinhardt and Rogoff (2011) examined.

I would also like to highlight a new paper from Gilbert Cette and colleagues at the Banque de France (Cette, Bergeaud and Lecat, 2014) on productivity growth, trend breaks, and levels for 13 advanced countries over the 1890-2012 period. They identify two productivity waves, one following the second industrial revolution and another following the ICT revolution.

It is also crucial to better understand the impact of globalization, or more precisely the pace of globalization, on productivity. Some fear that the pace of globalization, as measured for example by trade flows, capital flows, including foreign direct investment and portfolio capital, and international migration, has slowed considerably, with a negative effect on resource reallocation and productivity.

And finally, to develop more accurate projections, we need a better understanding of historical productivity dynamics. At The Conference Board, we produce annual projections of key economic variables including output for 55 economies based on a growth accounting model.[2] In this model, we develop projections for capital and total factor productivity on the basis of historical relationships. This exercise is grounded in historical analysis of productivity trends. Without the discipline provided by this historical work it would be difficult to know whether some of the blue sky projections that are out there are blue, grey or black.

2 Details on the model used for the projections are available at http://www.conference-board.org/pdf_free/GEO2014_Methodology.pdf.

To conclude my recommendation for directions for future productivity research is simple: LOOK MORE AT THE PAST.[3]

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3 Recognition of the importance of historical perspective appears to be re-emerging in the economics profession. For example, Thomas Piketty (2014:675), author of the best-seller *Capital in the Twenty-First Century,* has written: "The new methods [in economics] often lead to a neglect of history and of the fact that historical experience remains our principal source of knowledge."

# Frontiers and Opportunities in Productivity Research

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Abstract

This article highlights intangible capital, management practices, and human capital as areas for future productivity research. It also stresses the importance of developing reliable productivity estimates for emerging and developing countries, and of enhancing collaboration between national statistical offices and academic researchers.

Frontiers in productivity research include, but are not limited, to research on intangibles, management practices and human capital. The pioneering work of Corrado, Hulten, and Sichel (2009) kicked off investigation into the role of intangibles in economic growth and productivity. How and why do some firms' management practices lead to higher productivity and what can be done to disseminate such practices across countries and borders? Nick Bloom and others (Bloom *et al.*, 2012) are important contributors to this line of research. An early contributor to the notion that not only physical capital matters for productivity was Eric Brynjolfsson (Brynjolfsson and Hitt, 2000).

What are the implications for future economic growth and productivity of younger workers being much more highly educated than older workers in many countries (although not in the United States)? Detailed human capital estimates for a growing number of countries, including China and India, are facilitating investigation of such questions (Gundimeda *et al.*, 2006; Li *et al.*, 2013; and Liu, 2011). Expectations are that the specific role of human capital in current and future productivity will more often enter into academic discussions in the near future.

It is important to develop productivity estimates for all countries, but particularly for emerging and developing countries. Most understand the importance of China, whose GDP has apparently recently surpassed that of the United States. Data issues make measurement of productivity in China particularly challenging. In my opinion, analysis of economic growth and productivity in Latin America will become an increasingly fertile area for research. I have noted that there is a growing presence of Latin American economists, as well as national statistical office staff, at international meetings I have attended. Challenges facing such research may still be very significant, but I expect they will lessen.

As this conference illustrates, our understanding of the forces that shape productivity has been enhanced by interactions, and even collab-

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orations, between national statistical agency staff and academic researchers. Events organized by the International Association for Research in Income and Wealth (IARIW), EU KLEMS and World KLEMS, the US-based NBER Conference on Research in Income and Wealth (CRIW) and the new Society for Economic Measurement are all important vehicles for dissemination and presentation of such research. Hopefully these linkages will continue and even strengthen despite statistical agency budget stresses.

The good news is that there are more than enough opportunities to keep anyone interested in the productivity field busy. I hope that as we move forward younger researchers will continue to be become engaged in this line of research as the grey beards such as those on this panel become less active.

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# Intangible Assets and Their Contribution to Labour Productivity Growth in Ontario

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ABSTRACT

Recent empirical studies confirm that the contribution of intangible capital investment to labour productivity growth is comparable to that of tangible capital investment for a wide range of countries, including the United States, the United Kingdom, Canada, Germany, and France. Following Corrado *et al*. (2005) and Baldwin *et al*. (2012), this article assesses business sector investment in intangible assets and analyses the contribution of intangible capital to business sector labour productivity growth at the provincial level in Canada, in particular in Ontario. The results of this growth accounting exercise demonstrate that intangible capital contributes significantly to labour productivity growth in Ontario. In 1998-2008 intangible capital contributed on average 26.2 per cent to labour productivity growth while tangible capital contributed 17.9 per cent and labour composition contributed 8.7 per cent. Innovative property contributed the most among all categories of intangible capital, followed by economic competencies and computerized information.

*Research has highlighted the important role played by intangible capital, such as the knowledge embodied in the workforce, business plans and practices, and brand names. This research suggests that technological progress and the accumulation of intangible capital together accounted for well over half of the increase in output per hour in the United States during the past several decades.*

— Ben Bernanke, Chairman of the Federal Reserve, keynote address to the opening of the *New Building Blocks for Jobs and Economic Growth Conference* (May 2011)

CANADA IN GENERAL AND ONTARIO in particular has a significant prosperity gap with international peers, most notably relative to the United States. According to the Task Force on Competitiveness, Productivity and Economic Progress (2010), this prosperity gap is a productivity gap. In Ontario, average annual labour productivity growth decelerated from 1.3 per cent between 1985 and 2000 to 0.4 per cent between 2001 and 2011 (Government of Ontario, 2013).

1 The author is Senior Economist in the Office of Economic Policy in the Ontario Ministry of Finance. She thanks her colleagues at the Office of Economic Policy, Wulong Gu, Andrew Sharpe, and Ricardo de Avillez for their support, help and valuable comments. The author also thanks Nazim Belhocine, International Monetary Fund, for sharing data, and the anonymous reviewers, for useful comments and suggestions. The views expressed herein are those of the author and do not necessarily reflect the views of the Ontario Ministry of Finance or the Ontario Government. Any remaining errors are the author's responsibility. Email: tatiana.muntean@ontario.ca.

Productivity growth comes from various sources. The contribution of labour composition and physical, or tangible, capital deepening to labour productivity has been well researched. In contrast, until recently, intangible assets were not considered as contributors to labour productivity growth. Currently, the major challenge is to measure investment in intangible assets and assess the size of the stock of intangible capital as well as the contribution of intangible assets to labour productivity growth.

Intangible assets are generally defined as assets that provide future benefits but do not have a physical embodiment, such as software, research and development (R&D), market and consumer research. A study of intangibles, conducted by Corrado *et al.* (2009), pioneered research of intangible assets and their contribution to labour productivity growth in the United States. Similar studies have been conducted in Canada, Japan, Australia and Europe.

Until recently, spending on intangible assets was counted as an intermediate expense in the systems of national accounts rather than as investment in intangible capital. Corrado *et al.* (2009) indicate that specific features of some intangible assets, such as non-rivalness and the lack of verifiability, visibility and appropriability of returns explain the fact that the majority of intangible assets are disqualified as capital. The authors, however, argue that these distinct features do not make intangible assets an intermediate good. They simply differentiate intangible capital from other types of capital. Despite their uniqueness, intangible assets share core characteristics of physical capital. As any other type of capital, intangibles are used in production of goods and services and provide future benefits. As investment in physical capital, investment in intangible assets represents foregone current consumption for the benefit of greater future consumption.

Thus, intangible assets should be classified as capital; and spending on intangibles should be counted as investment rather than operational or intermediate expenses. Otherwise, the aggregate level of output remains underestimated. This potentially creates distortions in business investment and resource allocation. In addition, effectiveness of public policy may also be adversely affected if investment and capital in the economy are measured imprecisely. These distortions could ultimately lead to a decline in productivity and economic growth.

The recent empirical evidence shows that intangible capital contributes significantly to productivity growth, which is ultimately reflected in economic growth. Belhocine (2009b) finds that in Canada, if spending on intangible assets is not included in aggregate investment, real gross domestic product (GDP) growth is on average underestimated by 0.1 percentage point per year from 1999 to 2001. It is underestimated by about 0.25 percentage point for 2004. Corrado *et al.* (2009) indicate that in the United States, if investment in intangibles is not included, GDP growth is underestimated by about 0.25 percentage point per year from 1995 to 2002.

Van Ark *et al.* (2009) examined the contribution of intangible capital deepening to the labour productivity growth in the market sector in the United States and selected European countries for the 1995-2006 period. The authors found that intangible capital deepening contributed on average 0.83 percentage point, or about a quarter, to the annual change in labour productivity in the United States. A similar picture emerges in the larger European countries where growth in intangible capital per unit of labour contributed 0.72 percentage point to labour productivity growth in Denmark, 0.69 percentage point in the UK, 0.50 percentage point in France, and 0.40 percentage point in Germany.

According to a study of intangible assets and productivity growth conducted by the Australian Government Productivity Commission in 2010, the estimated average annual labour productivity growth rate in Australia's market sector between 1993-1994 and 2005-2006 is 0.24 percentage point higher when all intangibles are capitalized. Moreover, in both the manufacturing and the service sectors, labour productivity growth rate increased after capitalizing all intangibles. Labour productivity growth rates are 0.43 and 0.19 percentage point (or around 19 and 8 per cent) higher in the manufacturing and the services sectors respectively when intangibles are treated as capital.

Growing global interest in intangible capital has drawn much attention to knowledge-creating investments and has led to world-wide recognition of intangibles as an important source of productivity and economic growth. As a result, some categories of intangibles have already been capitalized in the systems of national accounts. In Canada, prior to December 2012, only software and mineral exploration expenditures were treated as investment in the System of National Accounts. As a result of a historical revision of the national accounts (Statistics Canada, 2012), completed by Statistics Canada in December 2012, spending on research and development, along with software and oil and gas and mineral exploration, is treated as investment and capitalized in the national accounts in the intellectual property products category.

The capitalization of intangible assets is important for evaluating both the level and the growth of labour productivity. This capitalization alters the level of output, which in turn affects the labour productivity level. It also affects the labour productivity growth rate if the rate of growth of output with intangibles is different from that without intangibles.[2]

Given the importance of intangible capital as a contributor to output and productivity growth and the lack of studies at the provincial level, this study aims to estimate both investment in intangibles and the stock of intangible capital in Ontario and to evaluate the contribution of intangible assets to the business sector productivity growth in the province. A discussion of the merits of data collection methods and estimation approaches is beyond the scope of this study. Similar to other studies, this article provides rough estimates of business investment in intangible assets and focuses on the relative importance of intangibles for output and productivity growth in Ontario.

The article is organized as follows. Section 1 describes the data sources for the estimates of business sector investment in intangibles in Ontario. Section 2 examines the state of investment in intangibles in the province. Section 3 summarizes the results of growth accounting that includes intangible assets as inputs of production. Section 4 concludes.

## Data Sources

Corrado *et al.* (2009) have defined the main categories of intangibles to include:

- Computerized information:
  - software, which consists of purchased software and own-account spending on software;
  - computerized databases, i.e. expenditures on data processing and database activities.
- Innovative property:
  - scientific and engineering R&D that leads to a patent or a licence, including industrial R&D, R&D expenditures in mining, oil and

2 Thanks to Andrew Sharpe for this point.

gas extraction and other geophysical and geological explorations;
    - non-scientific R&D, including information sector R&D that leads to a copyright or license and service industries R&D that might not lead to a patent or copyright;
    - new product development costs in the financial industry;
    - new architectural and engineering design; and
    - other science and engineering services.
- Economic competencies:
    - brand equity, i.e. purchased advertising and market and consumer research;
    - investment in human capital that includes direct and indirect expenses on training;
    - organizational structure that comprises cost of purchased and own-account organizational change.

Baldwin *et al.* (2009) expended the list of categories proposed by Corrado *et al.* (2009) by including scientific activities that are not captured in R&D statistics.[3] In order to ensure comparability of the results with the national and international studies, I follow the definitions of both Corrado *et al.* (2005, 2009) and Baldwin *et al.* (2009) regarding the categories of intangible assets. I also use the estimation methods suggested by these authors as much as possible. In the instances where provincial data are not available I use either national data[4] or estimates based on the shares of investment in a particular category of intangibles in the national data or all-industries (i.e. total economy) data.[5] Hence, the findings of the present study may not be fully comparable with those for Canada and other countries.

### Computerized Information

Computerized information comprises two categories: software and computerized databases. Since spending on software has been capitalized in the Canadian System of National Accounts, Statistics Canada publishes provincial all-industries software investment data as part of non-residential investment (CANSIM Table 031-0004) and provincial business sector investment in total intellectual property products, which includes oil and gas and mineral exploration, research and development, and software (CANSIM Table 031-0002). Ontario's business sector investment in software is estimated using the all-industries average for the share of investment in software in the intellectual property product category.

Statistics Canada also provides detailed estimates of own-account and purchased software expenditures at the national level. Data are currently unavailable for both business sector own-account and purchased software expenditures at the provincial level.

Computerized databases are not capitalized in the national accounts. Expenditure on computerized databases is used as a proxy for investment in this category of intangibles. Such an expenditure, however, is not directly observed, so as in Belhocine (2009b), expenditure on computerized databases is approximated by the operating revenues of the data processing, hosting and related service industries (NAICS 51821), which are published by Statistics Canada in CANSIM Table 354-0005.

### Innovative Property

Two categories of innovative property – "research and development" and "oil and gas and mineral exploration" – are capitalized in the Canadian System of National Accounts. Currently, business investments in R&D and in oil

3 See Innovative Property section for details.

4 For example, direct and indirect annual spending on training per employee.

5 For example, estimates of Ontario's business sector investment in software.

and gas and mineral exploration are not available at the provincial level. Statistics Canada publishes total economy investments in R&D and in oil and gas and mineral exploration as parts of non-residential investment (CANSIM Table 031-0004) at the provincial level, as well as provincial business sector investment in total intellectual property products (CANSIM Table 031-0002). As with investment in software, I estimate Ontario's business sector investments in R&D and in oil and gas and mineral exploration using the total economy shares of investment in R&D and investment in oil and gas and mineral exploration in the intellectual property product category.

As in Corrado *et al.* (2009) and Baldwin *et al.* (2012), other categories of innovative property are approximated by expenditure on:

- new product development costs in the financial industry;
- new architectural and engineering design; and
- other science and engineering services (purchased and own-account).

Similar to other industries, the financial industry is engaged in R&D of new processes and products. According to Baldwin *et al.* (2012), this industry's R&D expenditure should be accounted for in the total investment in intangible assets. Since it is not explicitly observed, development cost in the financial industry is approximated by total intermediate purchases by the financial industry (NAICS 521 and 522).[6] Following Corrado *et al.* (2005), I count only 20 per cent of the purchases as investment.

Following Corrado *et al.* (2005), I estimated Ontario's business sector investment in new architectural and engineering design as 50 per cent of the revenues of architectural and engineering design industries (NAICS 5413). Data on the revenues of these industries are obtained from Statistics Canada's input-output tables for Ontario. The revenue of architectural and engineering design industries data are combined with "purchased other science and engineering services" so as to meet confidentiality requirements. Purchased other science and engineering services are approximated by Ontario's business sector spending on royalties and licensing fees, which are also obtained from the Ontario input-output tables.

Baldwin *et al.* (2009) suggest that knowledge creation happens not only in the natural and social sciences, humanities, finance and other fields, as outlined by Corrado *et al.* (2005), but also in other industries, the scientific activities of which are not captured in R&D statistics. Thus, the innovative property category of intangibles should include own-account other science and engineering expenditures and purchased other science and engineering expenditures.

Similarly to Baldwin *et al.* (2009), I approximate own-account other science and engineering investment by the labour compensation of scientists and engineers and count only 20 per cent of total expenditure as investment. As in Baldwin *et al.* (2009), I exclude the following industries: financial services (NAICS 521), architectural, engineering and related services (NAICS 5413), management, scientific, and technical consulting services (NAICS 5416), scientific research and development services (NAICS 5417), advertising and related services (NAICS 5418), and other professional, scientific and technical services (NAICS 5419). Investments in intangible assets in these industries are already captured in other categories of intangibles. To avoid double-counting, the wage component of software and R&D expenditure is also excluded from this category.

6 Baldwin *et al.* (2012) indicate that partial double-counting is possible.

### Economic Competencies

Economic competencies is the third broad category of intangible assets. It is commonly accepted that knowledge that is imbedded in brand names, firm-specific human capital and organizational structure should be treated as intangible assets, and that business expenditure on these assets should be counted as investment.[7] Following existing studies of intangible investment, this study includes advertising expenditure as brand equity, direct and indirect firm expenses on training as firm-specific human capital and purchased and own-account organizational structure in the economic competence category of intangible assets.

Investment in advertising is estimated as 60 per cent of total business sector expenditure on various advertising services and products.[8] It can be argued that advertising spending only redistributes sales among firms, and does not create value.[9] However, "such spending is necessary for developing new brands and maintaining the value of existing brands" (Corrado *et al.*, 2005). Direct firm expenses on firm-specific human capital comprise the costs of developing workforce skills, such as on-the-job training, and tuition reimbursement. Indirect expenses are related to the opportunity cost of employee time spent on formal and informal training. Direct and indirect expenses are estimated as the annual spending by the business sector on learning and development. Currently, provincial data are not available, thus business investment on firm-specific human capital in Ontario is estimated using the data on Canadian business sector direct annual spending per employee.

Investment in organizational structure plays an important role in building the stock of intangible capital. According to the economic literature, successful implementation of information and communication technology (ICT), namely achievement of a significant productivity improvement, is possible if the implementation is accompanied by organizational change (Guiri *et al.*, 2005). As in Corrado *et al.* (2005), purchased investment in organizational structure is approximated by the total revenue of the management consulting services industry (NAICS 54161). Own-account investment in organizational structure is estimated as 20 per cent of labour compensation of total management occupations.

It should be noted that the estimates of intangibles for Ontario in this study are not entirely comparable to the estimates for Canada in Baldwin *et al.* (2012) due to the use of different data sources and measurements: some data, such as direct and indirect business expenses on learning and development, are unavailable at the provincial level; and the investment in intangible assets in this study is mainly estimated from the supply side,[10] as opposed to from the demand side.[11] Further research is needed to develop comparable measures of intangibles at the provincial level.

## Investment in Intangibles in Ontario

It is estimated that in 2008, Ontario's businesses spent \$51.6 billion[12] on intangibles – an increase of \$22.2 billion as compared to 1998 (Chart 1). According to these estimates, in every year starting from 2001, business investment in

7 See Corrado *et al.* (2005, 2009), Baldwin *et al.* (2012), Van Ark *et al.* (2009).

8 See Appendix for a complete list.

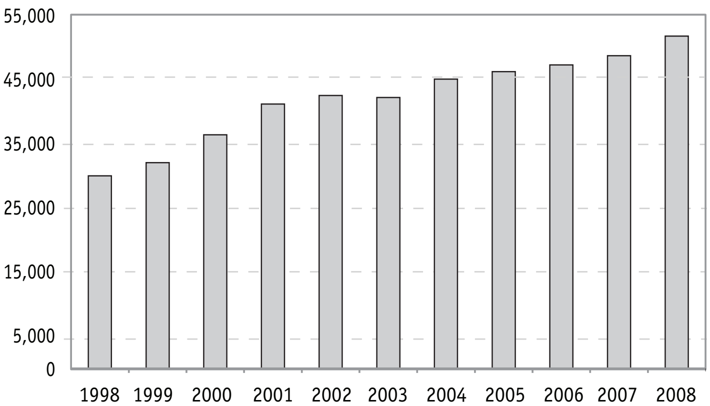
9 Thanks to Andrew Sharpe for bringing this to my attention.

10 This approach was taken in Corrado *et al.* (2005, 2009).

11 This approach was taken in Baldwin *et al.* (2012).

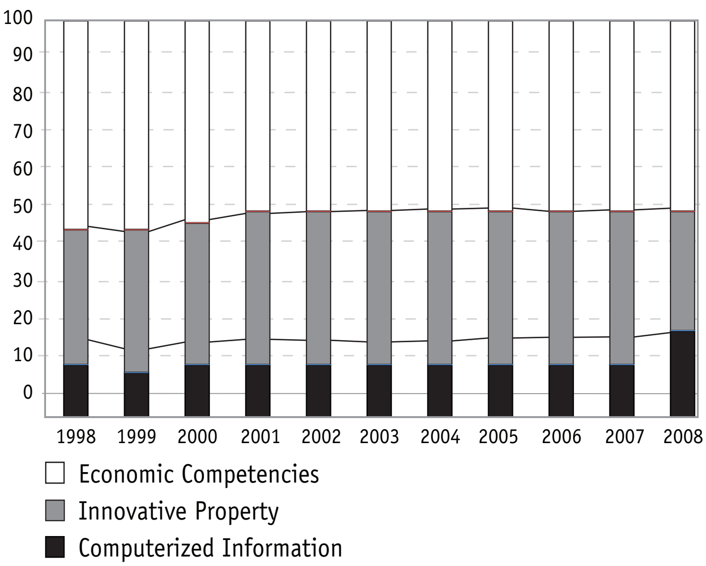
12 All monetary values given in the article are expressed in current Canadian dollars, unless otherwise indicated.

**Chart 1**
**Nominal Investment in Intangibles in Ontario, 1998-2008**
(million dollars)




Source: Statistics Canada, author's calculations.

**Chart 2**
**Composition of the Total Investment in Intangibles in Ontario, 1998-2008**
(per cent)




Source: Statistics Canada, author's calculations.

intangibles assets in Ontario exceeded business investment in tangible assets.

Similar to existing studies of intangible assets in the United States, the United Kingdom, Canada, Europe and Australia, this study found that economic competencies is the largest category of investment in intangibles in Ontario (Chart 2).

In 2008, the Ontario business sector spent almost $26 billion on brand equity, firm-specific human capital and organizational change. The share of the economic competencies category in the total amount of nominal investment in intangibles was around 50 per cent for the better part of the last decade.

Brand equity (advertising expenditure) and organizational structure are the largest components of the economic competencies category. In 2008, businesses in Ontario spent around $12 billion on brand equity and $10 billion on organizational structure. Estimated expenditure by Ontario businesses on advertising contributed almost 70 per cent to total business spending on advertising in Canada in 2008 (as estimated by Baldwin *et al.* (2009)). In the same year, estimated expenditure by Ontario businesses on organizational structure accounted for almost 15 per cent of business spending on organizational structure in Canada. Given that some data are not available at the provincial level and that the estimation approach that we used for the purpose of this study differs from the one adopted by Baldwin *et al.* (2009), the estimates of business sector expenditure in Ontario on firm-specific human capital cannot be compared with the national estimates.[13]

Innovative property is the second largest component of investment in intangibles in Ontario. According to the estimates, Ontario businesses

13 In this paper, purchased organizational assets is estimated by the output of the management consulting services industries. Baldwin et al. (2009) estimate purchased organizational assets from the demand side - by actual expenditures on organizational assets by Canadian industries. The difference is net exports and production in the other industries.

**Table 1**
**Estimates of Business Sector Nominal Investment in Intangible Capital, Ontario**
(millions of dollars)

| | Ontario | | Percentage of Total | |
|---|---|---|---|---|
| | 2000 | 2008 | 2000 | 2008 |
| Total Intangible Assets | 35,896 | 51,560 | 100 | 100 |
| 1 Computerized information | 4,946 | 8,410 | 13.78 | 16.31 |
| 1.1 Software | 3,993 | 6,615 | 11.12 | 12.83 |
| 1.2 Computerized databases | 963 | 1,795 | 2.68 | 3.48 |
| 2 Innovative property | 11,784 | 17,207 | 32.83 | 33.37 |
| 2.1 Business R&D | 4,508 | 6,589 | 12.56 | 12.78 |
| 2.2 Oil, gas and mineral exploration | 81 | 588 | 0.23 | 1.14 |
| 2.3 New product development costs in the financial industry | 978 | 1,408 | 2.72 | 2.73 |
| 2.4 New architectural and engineering design, and 2.5 Other science and engineering services | 6,216 | 8,621 | 17.32 | 16.72 |
| 3 Economic competencies | 19,166 | 25,943 | 53.39 | 50.32 |
| 3.1 Brand equity | 8,381 | 11,877 | 23.35 | 23.04 |
| 3.2 Firm-specific human capital | 3,998 | 4,445 | 11.14 | 8.62 |
| 3.3 Organizational structure | 6,787 | 9,621 | 18.91 | 18.66 |

Source: Baldwin *et al.* (2012), Statistics Canada, author's calculations.
* data are combined to meet confidentiality requirements

spent around $17 billion on this category of intangible assets in 2008. This expenditure amounted to 33.4 per cent of total business spending on intangibles.

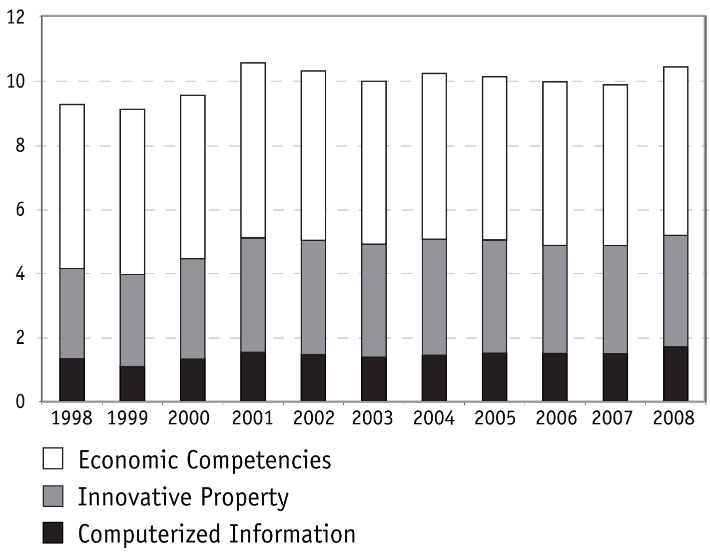
Expenditure on research and development and combined expenditure on new architectural and engineering design and purchased other science and engineering are the major business sector investments in innovative property in Ontario. In 2008, these two categories amounted to 38.3 per cent and 50.1 per cent of total business expenditure on innovative property respectively. Development cost in the financial industry is a non-negligible component of investment in innovative property. In Ontario, estimated business spending on this type of intangibles was around $1.4 billion in 2008.

In Canada, oil, gas and mineral exploration is a relatively significant part of business spending on innovative property, accounting for about 8 per cent of total business investment in intangibles in 2008. Perhaps because other provinces in Canada are either better endowed with natural resources or at a more advanced stage of resource exploration, Ontario's share of business expenditure on oil, gas and mineral exploration is quite modest – 1.1 per cent of total business spending on intangibles in the province.

Computerized information is the smallest category of total investment in intangibles. In 2008, the share of computerized information in total business spending on intangibles was $8.4 billion or 16.3 per cent of the total spending on intangibles by businesses in Ontario. Software is the largest component of this category of intangible assets. In 2008, Ontario business sector spending on software amounted to 79 per cent of total business sector spending on computerized information.

**Chart 3**

**Investment in Intangibles as a percentage of Ontario's Business Sector Output, 1998-2008**




Source: Statistics Canada, author's calculations.

Empirical evidence shows that investment in intangible capital contributes significantly to the total value of business sector output. In Ontario, as a share of the total business sector output, business investment in intangible assets increased from 9.2 per cent in 1998 to 10.4 per cent in 2008 (Chart 3).[14] At the same time, the share of investment in tangible assets (i.e. machinery and equipment and buildings and structures) fell from 12 per cent of business sector output in 1998 to 10 per cent in 2008.

In real terms, business investment in intangible assets in Ontario has been growing steadily for the better part of the 1998-2008 period (Table 2). Similar to business investment in tangible capital, investment in intangibles is highly volatile and very sensitive to business cycles. According to the estimates, the peak of the annual growth in real investment in intangibles in Ontario was in 2001, when investment in intangibles grew at the annual rate of 5.6 per cent. After the "dot com" bust in 2000, the growth rate of investment in intangibles dropped to -0.3 per cent in 2003, but recovered quickly to 2.7 per cent in 2004. After a dip to 0.9 per cent during the recent recession of 2007, the annual growth rate of investment in intangibles increased to 2.1 per cent in 2008. In contrast, the growth rate of investment in tangible capital was only 1.1 per cent in 2008.

During the 1998-2008 period, expenditure on software, computerized databases and oil, gas and mineral exploration and evaluation were the fastest growing categories of business investment in intangibles in Ontario. However, given its modest contribution to total intangible investment, Ontario's business expenditure on mineral exploration and evaluation did not have a significant impact on the overall growth rate of expenditure on intangibles.

## Growth Accounting

The Solow-Jorgenson-Griliches source-of-growth framework is traditionally used to evaluate the contribution of various inputs of production to labour productivity growth (Jorgenson and Griliches, 1967). The method is based on an evaluation of the income shares, *s*, and the growth rates, *g*, of the inputs of production:

$$g_{Q,t} = s_{L,t} \times g_{L,t} + s_{K,t} \times g_{K,t} + g_A \quad (1)$$

where $Q$ is business sector output, $A$ is technology, $K$ is tangible capital, and $L$ is labour.

Corrado *et al.* (2009) argue that since intangible capital is not included in this framework, the framework underestimates output and productivity growth and the

14 Revised output – estimates of business sector investment in intangibles are included in business sector output. In this paper "business sector output" refers to revised, or adjusted, output. Growth accounting is also based on adjusted output.

**Table 2**
**Real Investment, Business Sector**
(average annual per cent change)

| | 1999-2003 | 2003-2008 | 1999-2008 |
|---|---|---|---|
| Total Tangible Assets | 0.4 | 2.3 | 1.3 |
| Total Intangible Assets | 1.3 | 2.9 | 2.2 |
| 1 Computerized information | 4.5 | 4.2 | 4.6 |
| 1.1 Software | 5.9 | 3.0 | 4.6 |
| 1.2 Computerized databases | -0.6 | 9.1 | 4.5 |
| 2 Innovative property | 0.4 | 3.4 | 2.1 |
| 2.1 Business R&D | 0.8 | 4.1 | 2.3 |
| 2.2 Oil, gas and mineral exploration | 11.7 | 8.4 | 9.2 |
| 2.3 New product development costs in the financial industry | 1.0 | 1.8 | 1.3 |
| 2.4 New architectural and engineering design, and 2.5.2 Purchased other science and engineering services | -0.5 | 4.2 | 2.1 |
| 2.5.1 Own account other science and engineering services | 1.0 | 0.7 | 1.0 |
| 3 Economic competencies | 0.7 | 1.9 | 1.5 |
| 3.1 Brand equity | 0.5 | 2.6 | 1.8 |
| 3.2 Firm-specific human capital | 0.4 | 1.3 | 0.8 |
| 3.3 Organizational structure | 1.0 | 1.5 | 1.5 |

Source: Statistics Canada, author's calculations.

estimates of the contribution of physical capital, labour and technology are biased. Thus, intangible capital should be included in the analysis of output and productivity growth.

The first step is to estimate intangible capital stock. I construct the series of estimates of the real intangible capital stock, $R_t$, by using the perpetual inventory method. This method uses the capital accumulation equation and an estimate of the initial capital stock, $R_0$.

$$R_t = N_t + (1 - \delta) \times R_{t-1} \quad (2)$$

$$R_0 = \frac{N_0}{\delta + g} \quad (3)$$

Real investment in all categories (excluding software) of intangibles, $N_t$, is estimated using output deflators. Real investment in software is estimated using a software price index. The investment growth rate, g, is estimated as the annual average growth rate of investment in intangibles for the first three years of the available data series. Depreciation rates, $\delta$, for each category of intangible assets are taken from Corrado *et al* (2009) and Baldwin *et al.* (2012) (Table 3).

The estimates indicate that real intangible capital stock grew steadily for the better part of the last decade and reached $163 billion in 2008. Innovative property is the largest category of intangible capital. It accounts for more than half of the total stock of intangibles. Innovative property is followed by the economic competencies and computerized information categories of intangible capital, which reached $49 and $21 billion in 2008 respectively. Real intangible capital stock grew at an average annual growth rate of 2.5 per cent in the 1998-2008 period. Computerized databases, being one of the smallest categories of intangibles, was the fastest growing category of intangible capital. It grew at an average annual rate of 5.8 per cent for the same period. "Business R&D" and "new architectural and engineering design" combined with "purchased other science and engineering services"

### Table 3
### Depreciation Rates for Intangible Capital

| | |
|---|---|
| 1 Computerized Information | 0.33 |
| 2 Innovative Property | |
| 2.1 Business R&D | 0.2 |
| 2.2 Oil, gas and mineral exploration and evaluation | 0.134 |
| 2.3 New product development costs in financial the industry | 0.2 |
| 2.4 New architectural and engineering design | 0.2 |
| 2.5 Other science and engineering services | 0.2 |
| 3 Economic Competencies | |
| 3.1 Brand equity | 0.6 |
| 3.2 Firm-specific human capital | 0.4 |
| 3.3 Organizational structure | 0.4 |

Source: Corrado *et al.* (2009), Baldwin *et al.* (2012).

also grew at the above average rate of 4.1 per cent and 3.1 per cent respectively. The annual average growth rate of intangible capital in the software and firm-specific human capital categories was the lowest among all intangible assets. In the period 1998-2008, each of these two categories grew at the average annual growth rate of 0.9 per cent.

Having estimated the stock of intangible capital, growth accounting can be applied. It is assumed that the production function is a constant returns to scale function:

$$Y_t = F(A_t, K_t, R_t, L_t) \quad (4)$$

where $Y_t$ is business sector output, $A_t$ is technology, $K_t$ is tangible capital, $R_t$ is intangible capital, and $L_t$ is labour.

In contrast to the conventional production function, equation (4) includes intangible capital as an input of production. The accumulation equation for intangible capital is similar to that of tangible capital and is given by equation (2). Intangible capital is also included in the output identity equation:

$$P_{Q,t} \times Q_t = P_{L,t} \times L_t + \sum_{i=1}^{n} (P_{Ki,t} \times K_{i,t}) + \sum_{j=1}^{m} (P_{Rj,t} \times R_{j,t})$$

$$= P_{C,t} \times C_t + \sum_{i=1}^{n} (P_{Ii,t} \times I_{i,t}) + \sum_{j=1}^{m} (P_{Nj,t} \times N_{j,t}) \quad (5)$$

where $Q$ is adjusted business sector output, $C$ is consumption, $I$ is investment in tangible capital, $P_K$ and $P_R$ are the user costs associated with the user services of respective input, and $i$ and $j$ are categories of tangible and intangible capital respectively.[15]

Following Corrado *et al.* (2009), intangible capital is added to the conventional growth accounting method to examine the contribution of intangible capital to productivity growth in Ontario.[16]

It is assumed that income shares, *s*, are equal to corresponding output elasticities and that each input is paid the value of its marginal product. The source-of-growth system of equations is then derived taking logarithmic differentiation of equation (4):

$$g_{Q,t} = s_{L,t} \times g_{L,t} + s_{K,t} \times g_{K,t} + s_{R,t} \times g_{R,t} + g_A \quad (6)$$

The income shares of the inputs of production are also derived from the output identity equation:

$$s_{L,t} = \frac{P_{L,t} \times L_t}{P_{Q,t} \times Q_t} \quad (7)$$

$$s_{K,t} = \frac{P_{K,t} \times K_t}{P_{Q,t} \times Q_t} \quad (8)$$

$$s_{R,t} = \frac{P_{R,t} \times R_t}{P_{Q,t} \times Q_t} \quad (9)$$

where $K_t$ is a sum of all categories of tangible capital and $R_t$ is a sum of all categories of intangible capital.

The growth rates of labour and capital inputs are calculated using annual data on labour input, tangible capital stock and annual estimates of intangible capital stock. Both tangible and intangible capital are not consumed entirely in the production process. Thus, the user cost of capital services is required to estimate an income

15 Adjusted, or revised, business sector output consists of consumption, investment in tangible capital, investment in intangible assets, and net exports.

16 Solow-Jorgenson-Griliches sources-of-growth framework.

share of each category of capital. The measure of the user cost of capital is based on the rate of return to capital and a price of investment in each category of capital. The growth accounting framework allows for either an endogenous or exogenous rate of return to capital. Following Corrado *et al.* (2009), I use an endogenous rate of return to capital. If an arbitrage opportunity exists then business investments will flow to a specific category of capital until an arbitrage opportunity is eliminated. Thus, it is assumed the net real rate of return to capital is equalized across all categories of tangible and intangible capital. There is an ongoing debate in economic literature whether the real or nominal rate of return should be used in growth accounting.[17] For the purposes of this study, I use the net real rate of return. The user cost of capital is calculated using equation:

$$P_t^{R_j} = (r_t + \delta_j - \pi_{j,\,t}) \times P_t^{N_j} \qquad (10)$$

where $r$ is the real rate of return and $\pi$ is expected capital gains. The expected capital gains term is calculated using a three-year moving average of changes in the output deflator.

The modified growth accounting equation (6) was used to estimate the contribution of tangible capital, intangible capital, and labour and technology to the labour productivity growth. The results indicate that multifactor productivity (MFP) and total capital deepening were the major contributors to labour productivity growth in Ontario in the 1998-2008 period.

Intangible assets contribute significantly to business sector output and labour productivity growth in Ontario. In the 1998-2008 period, intangibles contributed on average 0.34 percentage point, while tangible capital contributed on average 0.23 percentage point to productivity growth in Ontario. For almost every year from 1998 to 2008 the contribution of intangible assets to the labour productivity growth in the province exceeded that of tangible capital. Moreover, in contrast to tangible capital, in each year from 1998 to 2008 the contribution of intangibles to labour productivity growth was positive.

Unsurprisingly, when intangibles are included in growth accounting, the contribution of total capital deepening to labour productivity growth is greater than the contribution of tangible capital deepening.

At the same time, the contributions of labour and of MFP are smaller when compared with the results of no-intangibles growth accounting. In a study of labour productivity in Ontario, which does not include intangible assets, the Centre for the Study of Living Standards (De Avillez, 2011) estimated that capital deepening contributed 32.3 per cent to labour productivity growth in the business sector from 1997 to 2007, while labour quality and MFP contributed 18.8 and 48.1 per cent respectively. The findings of this study and the CSLS results differ because in the latter the contribution of intangible assets to the labour productivity growth was partially and implicitly counted in the contribution of labour and MFP. Thus, by including intangibles into productivity analysis we not only expand our knowledge of productivity and the sources of productivity growth but we also partially eliminate the biases inherent in the conventional growth accounting framework.

The contribution of each major category of intangibles – computerized information, innovative property and economic competencies – to the labour productivity growth varies for different jurisdictions (see Table 5).[18] According to Van Ark *et al.* (2009), in Austria, Spain

17 Baldwin and Gu (2007) provide an excellent discussion on the alternative ways to estimate capital services.

**Table 4**
**Labour Productivity Growth by Source, Ontario**

| Sources | Muntean 1998-2008 | de Avillez 1997-2007 |
|---|---|---|
| Labour productivity growth | 1.30 | 1.70 |
| Contribution of: | | |
| 1 Capital deepening | 0.57 | 0.55 |
| 1.1 Tangibles | 0.23 | 0.55 |
| 1.2 Intangibles | 0.34 | |
| 2 Labour composition | 0.11 | 0.32 |
| 3 Multifactor productivity | 0.61 | 0.82 |

Source: de Avillez (2011), author's calculations.

and Germany innovative property contributes more than half of the total contribution of intangibles to labour productivity growth in the market sector. The authors estimate that the greatest contribution of innovative property to labour productivity growth was in Germany. It reached 60.5 per cent of the total contribution of intangibles in the 1995-2006 period. Economic competencies are reported to contribute the most to labour productivity growth in the US and the UK, at 41.7 and 45.9 per cent of the total contribution of intangible assets respectively.[19] Van Ark *et al.* (2009) also reports that computerized information contributed the most to the labour productivity growth in Denmark over the same period – 40.3 per cent of the total contribution of intangibles.

In other jurisdictions, such as the United States, the United Kingdom and France, computerized information contributed almost one-third of the total contribution of intangibles. Moreover, in the United States the share of computerized information has increased from 27.9 per cent in 1973-1998 to 32.1 per cent in 1995-2003.

In Canada, according to Baldwin *et al.* (2012), innovative property and economic competencies were the major contributors to the labour productivity growth in the 2000-2008 period – 0.2 percentage point each. Computerized information contributed 0.1 percentage point to productivity growth in the same period.

This study estimates that in Ontario innovative property contributed the most to business sector labour productivity growth in the 1998-2008 period (0.15 percentage point), followed by economic competencies (0.11 percentage point) and computerized information (0.06 percentage point).

Innovative property, business research and development and new architectural and engineering design, combined with purchased other science and engineering services, contributed 0.07 percentage point each. The development costs of new products in the financial industry contributed 0.008 percentage point. The contributions of oil, gas and mineral exploration and own-account other science and engineering services were relatively small – only 0.003 and 0.004 percentage point respectively.

This study estimates that brand equity from the economic competencies category contributed 0.07 percentage point to labour productivity growth. Purchased organizational structure and own account organizational structure contributed equally – 0.02 percentage point each. Firm-specific human capital was not a significant source of productivity growth in 1998-2008 in Ontario. This category added only 0.0016 percentage point to the labour productivity growth.

In contrast to the US, the UK, France, Italy, Austria and Denmark, computerized informa-

18 Due to differences in estimation techniques and data sources and collection methods, the estimates of labour productivity growth are not entirely comparable across the jurisdictions.

19 See Corrado *et al.* (2009) for estimates for the US and Haskel *et al.* (2011) for estimates for the UK.

## Table 5
## Business Sector Labour Productivity Growth by Source, Ontario and Selected Jurisdictions

| | US 1973-1998 | | US 1995-2003 | | UK 1995-2006 | | Canada 2000-2008 | | Ontario 1998-2008 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sources** | ar | %c | ar | %c | ar | %c | ar | %c | ar | %c |
| Labour productivity growth | 1.63 | 100 | 3.09 | 100 | 2.24 | 100 | 0.8 | | 1.30** | 100 |
| Contribution of: | | | | | | | | | | |
| 1 Capital deepening | 0.97 | 59.5 | 1.68 | 54.4 | 1.18 | 52.7 | 1.4 | | 0.57 | 44.2 |
| 1.1 Tangibles | 0.55 | 33.7 | 0.85 | 27.5 | 0.67 | 29.9 | 0.8 | | 0.23 | 17.9 |
| 1.2 Intangibles | 0.43 | 26.4 | 0.84 | 27.2 | 0.51 | 22.8 | 0.6 | | 0.34 | 26.2 |
| 2 Labour composition | 0.25 | 15.3 | 0.33 | 10.7 | 0.16 | 7.1 | 0.3 | | 0.11 | 8.7 |
| 3 Multifactor productivity | 0.41 | 25.2 | 1.08 | 35.0 | 0.9 | 40.2 | -0.8 | | 0.61 | 47.2 |
| Contribution of Intangibles | | | | | | | | | | |
| 1.2 Intangible capital deepening | 0.43 | 100 | 0.84 | 100 | 0.37 | 100 | 0.6 | * | 0.34 | * |
| 1.2.1 Computerized information | 0.12 | 27.9 | 0.27 | 32.1 | 0.1 | 27.0 | 0.1 | 16.7 | 0.06 | 17.6 |
| 1.2.2 Innovative property | 0.13 | 30.2 | 0.22 | 26.2 | 0.09 | 24.3 | 0.2 | 33.3 | 0.15 | 44.1 |
| 1.2.3 Economic competencies | 0.17 | 39.5 | 0.35 | 41.7 | 0.17 | 45.9 | 0.2 | 33.3 | 0.11 | 32.4 |

| | Germany 1995-2006 | | France 1995-2006 | | Italy 1995-2006 | | Spain 1995-2006 | Austria 1995-2006 | | Denmark 1995-2006 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sources** | ar | %c | ar | %c | ar | %c | ar | ar | %c | ar | %c |
| Labour productivity growth | 1.79 | 100 | 2.00 | 100 | 0.29 | | 0.47 | 2.36 | 100 | 2.11 | 100 |
| Contribution of: | | | | | | | | | | | |
| 1 Capital deepening | 1.06 | 59.2 | 0.91 | 45.5 | 0.52 | | 0.8 | 0.79 | 33.5 | 1.4 | 66.4 |
| 1.1 Tangibles | 0.68 | 38.0 | 0.43 | 21.5 | 0.4 | | 0.68 | 0.24 | 10.2 | 0.68 | 32.2 |
| 1.2 Intangibles | 0.38 | 21.2 | 0.48 | 24.0 | 0.12 | | 0.12 | 0.55 | 23.3 | 0.72 | 34.1 |
| 2 Labour composition | -0.15 | -8.4 | 0.4 | 20.0 | 0.22 | | 0.64 | 0.22 | 9.3 | 0.17 | 8.1 |
| 3 Multifactor productivity | 0.88 | 49.2 | 0.69 | 34.5 | -0.45 | | -0.96 | 1.35 | 57.2 | 0.53 | 25.1 |
| Contribution of Intangibles | | | | | | | | | | | |
| 1.2 Intangible capital deepening | 0.38 | 100 | 0.48 | 100 | 0.12 | 100 | 0.12 | 0.55 | 100 | 0.72 | 100 |
| 1.2.1 Computerized information | 0.07 | 18.4 | 0.15 | 31.3 | 0.03 | 25.0 | 0.05 | 0.13 | 23.6 | 0.29 | 40.3 |
| 1.2.2 Innovative property | 0.23 | 60.5 | 0.18 | 37.5 | 0.05 | 41.7 | 0.15 | 0.29 | 52.7 | 0.27 | 37.5 |
| 1.2.3 Economic competencies | 0.07 | 18.4 | 0.15 | 31.3 | 0.04 | 33.3 | -0.08 | 0.13 | 23.6 | 0.17 | 23.6 |

ar average annual rate of change.

%c per cent contribution.

Source: US estimates are from Corrado *et al.* (2009), Canadian estimates are from Baldwin *et al.* (2012), UK estimates are from Haskel *et al.* (2011), Ontario estimates are author's calculations, remaining estimates are from Van Ark *et al.* (2009).

* Detail may not sum to totals due to rounding

** The number appears too high if compared with the data published by Statistics Canada, which can be explained by i) adjustment for intangibles, ii) lack of or limited provincial data on intangibles and its impact on estimates used in growth accounting. The results will be refined when more data is available and estimation approaches are improved

tion contributed the least to labour productivity growth in Ontario – only 0.06 percentage point or 17.6 per cent of the total intangible capital contribution in the 1998-2008 period. At the same time the contribution of computerized information in the province was greater than that in Canada. According to Baldwin *et al.* (2012) computerized information accounted for 16.7 per cent of the total intangible capital contribution to labour productivity growth in Canada (Table 5).

Inclusion of intangible assets in growth accounting did not alter dramatically the estimate of the contribution of MFP to the labour productivity growth. The results show that in the 1998-2008 period MFP accounted for 47.2

**Table 6**
**Percentage Point Contribution of Intangible Capital to Labour Productivity Growth by Source, Ontario**

| Sources | 1998-2008 |
|---|---|
| Total Intangible Capital Contribution | 0.34 |
| 1.1 Software | 0.06 |
| 1.2 Computerized databases | 0.02 |
| 2.1 Business R&D | 0.07 |
| 2.2 Oil, gas and mineral exploration | 0.003 |
| 2.3 New product development costs in the financial industry | 0.008 |
| 2.4 New architectural and engineering design, and 2.5.2 Purchased other science and engineering services | 0.07 |
| 2.5.1 Own account other science and engineering services | 0.004 |
| 3.1 Brand equity | 0.07 |
| 3.3.1 Purchased organizational structure | 0.02 |
| 3.3.2 Own account organizational structure | 0.02 |
| 3.2 Firm-specific human capital | 0.0016 |

Source: Author's calculations. Detail may not sum to totals due to rounding.

per cent of the labour productivity growth. A no-intangibles study of productivity in Ontario, conducted by the CSLS, indicates that in the 1997-2007 period MFP contributed 48.1 per cent to labour productivity growth, which is higher than in our study. This indicates that more research is needed to fully understand MFP and through which channels the technological advances are transmitted into labour productivity growth. This study also shows that when spending on intangible assets is not included in aggregate investment, average annual growth for Ontario's GDP is underestimated by 0.3 percentage point in 1998-2008.

## Conclusion

This study aimed to provide the answers to the following questions:

- How much do Ontario's businesses spend on various categories of intangible assets?
- How big is Ontario's stock of intangible capital and how fast is it growing?
- How important are intangibles as a contributor to the business sector labour productivity growth in Ontario?

In line with existing research on intangible assets in various jurisdictions, the results of this study confirm that intangible assets are a valuable component of business sector output in Ontario. The nominal investment in intangibles has grown from $29 billion in 1998 to almost $52 billion in 2008. As a percentage of business sector output, investment in intangibles increased from 9.2 per cent in 1998 to 10.4 per cent in 2008.

By nature, capital investment is highly volatile and very sensitive to changes in economic conditions. The tides and waves of investment usually follow business cycle expansions and downturns. In Ontario, the growth rate of the business sector's real investment in intangibles oscillated from -0.25 per cent to 5.65 per cent in the 1998-2008 period. However, on average in the same period the growth rate of investment in intangibles exceeded the growth rate of investment in tangibles. In addition, investment in intangibles was not as volatile as investment in tangible capital.

According to this study, real intangible capital stock grew at an average rate of 2.5 per cent from 1998 to 2008 and reached $163 billion in 2008. Computerized databases, although one of the smallest categories of intangibles, was the fastest growing category in 1998-2008. It grew at an average annual rate of 5.8 per cent, followed by business R&D with an average annual growth rate of 4.1 per cent.

The estimates indicate that innovative property contributed the most to labour productivity growth in Ontario in the 1998-2008 period. On average, innovative property contributed 0.15 percentage point to labour productivity growth, which is 44.1 per cent of the total contribution of intangible capital. The contribution of economic competencies was somewhat comparable to that of innovative property. In the 1998-2008 period, economic competencies contributed on average 0.11 percentage point to labour productivity growth or 32.4 per cent of total contribution of intangibles. Computerized information contributed only 0.06 percentage point or 17.6 per cent of the total contribution of intangibles to labour productivity growth. It appears that, in contrast to other jurisdictions, Ontario businesses do not invest significantly in organizational structure, which in turn might explain the low contribution of the computerized information category of intangibles to labour productivity growth. According to Bresnahan *et al.* (2002), organizational change should accompany ICT adoption in order to boost labour productivity growth.

This study is an initial attempt to measure investment in intangible assets, estimate the stock of intangible capital and evaluate the contribution of intangibles to labour productivity growth in Ontario. The study aims to raise awareness of the importance of intangibles to output and productivity growth in the province. Governments around the world provide significant support for innovative activities by businesses. However, they may place a disproportionately greater emphasis on selected categories of intangible assets, such as R&D. R&D has been traditionally viewed as a main driver of innovation and MFP growth. As a result, R&D activities have been encouraged and extensively supported by governments. Theoretical findings and empirical evidence, however, indicate that private R&D stock generally represents no more than 20-25 per cent of total business stock of intangible capital. Therefore, government policies, which predominantly support R&D, may not result in desired or targeted output and productivity growth. Empirical studies of intangible capital indicate that other categories of intangibles, such as brand equity and organizational structure also contribute significantly to productivity growth. This contribution should not be ignored.

Existing government policies that support education, entrepreneurship and R&D, and strengthen intellectual property rights have a positive impact on investment in knowledge-based capital. The recent research and analyses by the Organisation for Economic Co-operation and Development (OECD) (OECD 2013a, 2013b, 2013c, 2013d), however, indicate that existing policy frameworks should be updated to reflect the importance of intangible capital. The accumulation of intagible capital can also be encouraged by product market liberalization; bankruptcy regimes that do not penalize business failures too severely; a focus on broad concepts innovation, and labour market reforms. The OECD also warns that public policy to maximize the growth potential of knowledge-based capital may have ambiguous effects and trade-offs may emerge with other policy goals. Therefore, further research is needed to deepen our understanding of intangibles and their role in the economic activity of the business sector so that governments will have a more complete understanding ofthe state of business investment in intangibles; and whether support measures are needed to encourage and boost such investment.

The next steps for this study are to continue improving the measures of intangible assets in Ontario and refining the estimates of the contribution of intangibles to output and productivity growth in the province.

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## Appendix

| Asset | Description |
|---|---|
| 1 Computerized Information | |
| 1.1 Software | Spending on software has been capitalized in the Canadian System of National Accounts. Statistics Canada publishes provincial software investment data as part of non-residential investment (*CANSIM Table 031-0004*). |
| 1.2 Computerized databases | Expenditure on computerized databases is approximated by the operating revenues of the data processing, hosting and related services industries (NAICS code 51821), which are published by Statistics Canada in the *CANSIM Table 354-0005*. |
| 2 Innovative Property | |
| 2.1 Business R&D | Business spending on R&D has been capitalized in the Canadian System of National Accounts. Statistics Canada publishes provincial R&D investment data as part of non-residential investment (*CANSIM Table 031-0004*). |
| 2.2 Oil, gas and mineral exploration | Spending on oil, gas and mineral exploration has been capitalized in the Canadian System of National Accounts. Statistics Canada publishes provincial oil, gas and mineral exploraton investment data as part of non-residential investment (*CANSIM Table 031-0004*). |
| 2.3 New product development costs in the financial industry | Estimated as 20% of all intermediate purchases of the Financial Services industry (NAICS 521 and 522).<br>Source: Ontario *Input-Output Tables* |
| 2.4 New architectural and engineering design | Estimated as 50% of total expenditure on architectural and engineering services (NAICS 5413). Source: Ontario *Input-Output tables*<br>Note: combined with 2.5.2 to meet confidentiality requirements. |
| 2.5 Other science and engineering services | 2.5.1 plus 2.5.2. |
| 2.5.1 Own account other science and engineering services | Estimated as 20% of labor compensation of scientists and engineers. To avoid double-counting, financial services (NAICS 521) is excluded. Ontario data is not available for NAICS 521, so it was estimated as 1/6 of NAICS 52 (NAICS 52 consists of 6 categories). It is captured in 2.3. Architectural, engineering and related services (NAICS 5413) is also excluded. It is captured in 2.4. Management, scientific and technical consulting services (NAICS 5416) are excluded as well. Captured in 3.3. Scientific research and development services (NAICS 5417) are equally excluded. Captured in 2.1. In addition, advertising and related services (NAICS 5418) and other professional, scientific and technical services (NAICS 5419)are ecluded. Captured in 3.1.1 and 2.1 respectively.<br>Source: Statistics Canada *Customized Tables* (LFS) |
| 2.5.2 Purchased other science and engineering services | Estimated as 50% of total expenditure on royalties and licensing fees.<br>Source: Ontario *Input-Output tables*<br>Note: combined with 2.4 to meet confidentiality requirements. |
| 3 Economic Competencies | |
| 3.1 Brand Equity | 3.1.1 plus 3.1.2. |
| 3.1.1 Advertising expenditure | Estimated as 60% of business sector expenditure on:<br>(1) advertising flyers, catalogs and directories<br>(2) advertising in print media,<br>(3) advertising services, and<br>(4) advertising and promotion<br>Source: Ontario *Input-Output tables* |
| 3.1.2 Market and consumer research | n/a for Ontario |
| 3.2 Firm-specific human capital (training cost) | 3.2.1 plus 3.2.2. |
| 3.2.1 Direct firm expenses | Estimated by using *Conference Board of Canada* data on Canadian business sector direct annual spending per employee and the total number of employees (Statistic Canada)<br>Caveat: data are in constant 2010 dollars only |
| 3.2.2 Indirect expenses | Estimated by using *Conference Board of Canada* data on Canadian business sector indirect direct annual spending per employee and total number of employees (Statistic Canada).<br>Caveat: data are in constant 2010 dollars only. |
| 3.3 Organizational structure | 3.3.1 plus 3.3.2. |
| 3.3.1.Purchased | Approximated as the total operating revenue of the “management consulting services” industry (MAICS 54161), *CANSIM Table 360-0001* |
| 3.3.2 Own account | Estimated as 20% of the labor compensation of total management occupations.<br>Source: Statistics Canada, customized tables |

# The Impact of the Oil Boom on Canada's Labour Productivity Performance, 2000-2012

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Abstract

The objective of this article is to evaluate the impact of the oil and gas industry on labour productivity growth in Canada since 2000 through an exploration of the various channels, both direct and indirect, by which the oil and gas sector affects aggregate productivity. The article sheds light on the paradoxical lack of a direct negative contribution of the oil and gas sector to aggregate labour productivity growth despite the very large fall in productivity experienced by the sector. It highlights the divergent productivity growth paths for the oil and gas sectors in Alberta and Newfoundland and Labrador, which drove the aggregate productivity performance of these two provinces. The article also discusses how developments in the oil and gas industry, notably the increase in the price and production of petroleum, have affected productivity growth in other parts of the economy.

Oil and gas extraction is one of Canada's most important, and controversial, industries. In 2010, it represented 4.8 per cent of nominal GDP, up from 3.0 per cent in 2000, and it accounted for 20 per cent of nominal GDP growth between those two years. As Canada enjoyed a large and increasing trade surplus in hydrocarbons, the rising price of petroleum contributed to improved terms of trade, and during 2000-2012 real gross domestic income (GDI) grew 0.4 percentage points per year faster than real GDP (2.3 per cent versus 1.9 per cent).

But labour productivity growth in the oil and gas sector has been dismal since 2000, as real output – measured by the value added of the industry – has remained weak while employment has surged. Real output per hour worked in oil and gas extraction fell 6.4 per cent per year between 2000 and 2012. Yet, paradoxically, despite this performance, the sector did not make a negative contribution to aggregate labour productivity growth.

The oil and gas sector is particularly important for two provinces – Alberta and Newfoundland and Labrador – yet the overall productivity performance of these provinces has been drastically different. Over the 2000-2012 period, Newfoundland and Labrador enjoyed the most rapid productivity growth in Canada

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(Grand'Maison and Sharpe, 2013), while Alberta experienced the worst. Oil and gas extraction played a key role in the productivity performance of both provinces – positive in the case of Newfoundland and Labrador, and negative in the case of Alberta.

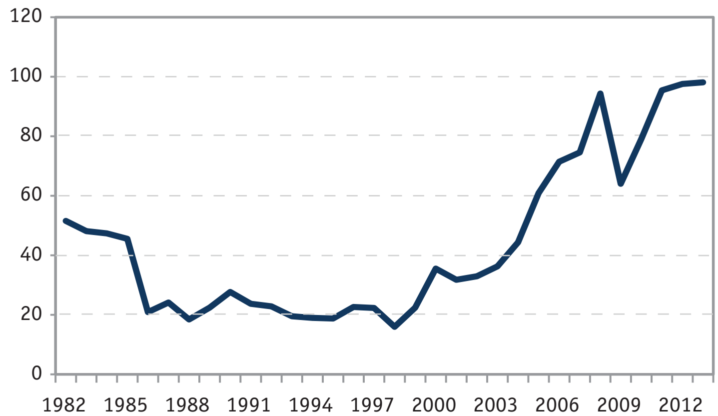
The objective of this article is to increase our understanding of the impact of developments in the oil and gas sector on labour productivity growth in Canada since 2000.[2] The article consists of five main sections. The first section sketches developments in the oil and gas sector, presents data on output, labour input and labour productivity in oil and gas extraction in Canada, Alberta, and Newfoundland and Labrador, and places the industry in the context of the business sector of these jurisdictions. The second section develops a framework for assessing both the direct and indirect impacts of oil and gas extraction on productivity. The third and fourth sections analyze, respectively, the direct and indirect effects of oil and gas extraction on business sector labour productivity growth in Canada, Alberta and Newfoundland and Labrador. A brief conclusion follows.

## The Oil Boom and Productivity in Oil and Gas Extraction

### The Oil Boom

The first decade of the millennium saw a large and sustained increase in the world price of crude oil (Chart 1). From a low of around $20 per barrel from the mid-1980s to the end of the 1990s, the real world price increased to $35 in the year 2000, rose steadily to over $90 in 2008 and climbed to the $100 range more recently.

**Chart 1**
**Real Oil Prices, 1982-2013**
(2005 U.S. dollars per barrel)



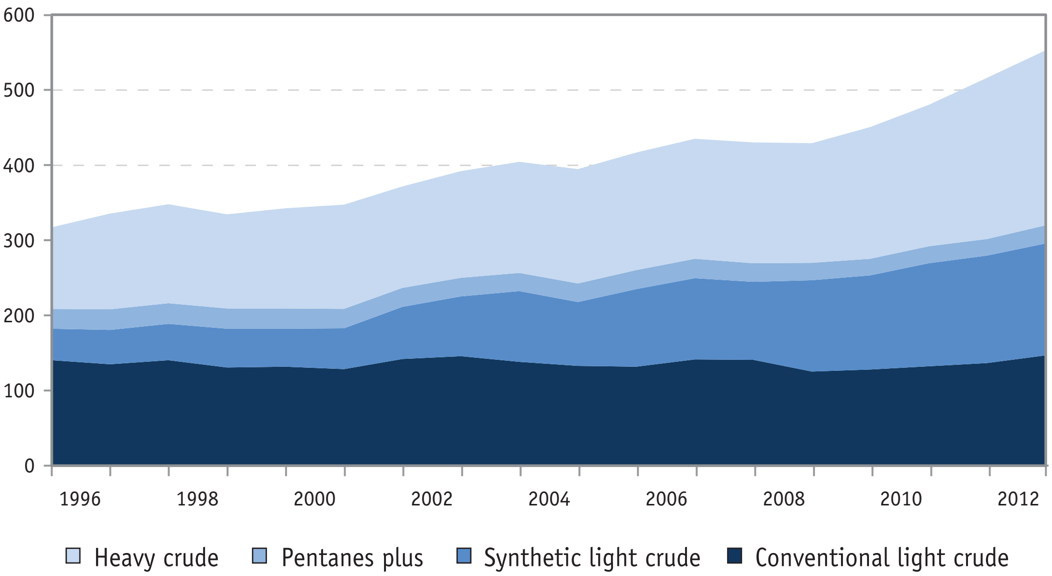

Note: "Real oil prices" are the average spot prices (2010$/bbl) for crude oil based on WTI, Dubai, and Brent.
Source: World Bank, DataBank, Global Economic Monitor (GEM) Commodities.

Canada was poised to take advantage of the opportunity this presented through exploitation of the Alberta oil sands and the offshore reserves of Newfoundland and Labrador. Production of oil expanded from 343 thousand cubic meters per day in 2000 to 516 thousand cubic meters per day in 2012 (Chart 2). While output of conventional light crude oil remained steady, production declined in Alberta, where producing wells reached exhaustion, and increased in Newfoundland and Labrador, where several new offshore platforms began production. Production of both synthetic light crude and heavy crude expanded rapidly. The increase came entirely from the oil sands, as production of conventional heavy crude in Alberta declined.

The bonanza brought about by the high price of oil, of course, mainly took the form of sales outside Canada. The volume of net exports of heavy crude doubled between 1997 and 2012, and that of light crude became positive by the end of the period (Chart 3). This along with the price hike made the trade balance in energy products increase from less

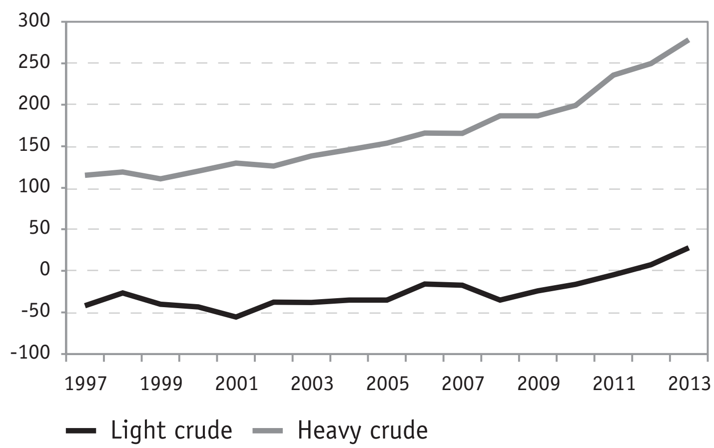
2 The main productivity measured used in this article is value-added labour productivity, defined as real GDP at basic prices per hour worked.

**Chart 2**
**Production of Oil by Type, Canada, 1996-2013**
(thousands of cubic meters per day)




Source: National Energy Board, Statistics, Crude Oil and Petroleum Products Statistics, Disposition of Domestic Crude.

**Chart 3**
**Net Exports of Oil, 1997-2013**
(thousands of cubic meters per day)




Source: National Energy Board, Statistics, Crude Oil and Petroleum Products, Disposition of Domestic Crude Oil and Imports.

than $20 billion before the year 2000 to more than $60 billion by 2008, giving a tremendous boost to the current account balance. Although after the financial crisis of 2008 the current account balance turned sharply negative, net revenues from energy products remained strongly positive through 2013.

While there was a large hike in the price of petroleum coupled with a steady increase in output, the price of natural gas dropped sharply following higher prices in the mid-2000s and output of gas declined steadily after 2007. This pattern gave rise to an increasing share of oil in the gross output of the oil and gas extraction sector, both in nominal and real terms. By 2012, petroleum accounted for 90 per cent of the oil and gas sector's nominal output, up from about 60 per cent in 2002. Similarly, petroleum's share of the oil and gas sector's real output rose from two-thirds to more than three-quarters. The oil and gas extraction industry is treated as a single industry by Statistics Canada (NAICS code 211), and hence in the analysis of output and productivity in this article (Exhibit 1).

## Productivity in Oil and Gas Extraction

### Real GDP

In 2012, real GDP or value added in the oil and gas extraction subsector was $91.3 billion (chained 2007 dollars) in Canada, up from $78.5 billion in 2000, which represents an average annual growth of 1.3 per cent (Table 1). Between 2000 and 2012, real GDP in the oil and gas extraction subsector grew by 2.5 and 0.7 per cent per year, in Newfoundland and Labrador and Alberta, respectively.[3]

Since 2007, Statistics Canada has broken the output of the oil and gas extraction sector into conventional and non-conventional oil extraction (primarily the oil sands in Northern Alberta). Conventional oil and gas extraction output was $58.9 billion 2007 dollars, about two-thirds of total oil and gas production, and down 14.5 per cent from $68.9 billion in 2007 when it represented nearly four-fifths. Non-conventional oil extraction has risen 53 per cent from $19.6 billion 2007 dollars in 2007 to $30.0 billion in 2012 and now accounts for just over one-third of the total real value added in the oil and gas sector.

### Labour Input

Employment in the oil and gas extraction subsector in Canada was 65.4 thousand in 2012, up from 26.5 thousand in 2000, an average annual rate of increase of 7.8 per cent (Table 2). Employment growth in the subsector was nearly six times faster than the growth experienced by the overall business sector (1.3 per cent per year), and resulted in the oil and gas extraction subsector more than doubling its share of total business sector employment to 0.47 per cent in 2012 from 0.22 per cent in 2000. Similarly, Newfoundland and Labrador and Alberta experienced employment growth in their oil and gas extraction subsectors of 6.4 and 8.1 per cent per year, respectively, well above total employment growth in both provinces.

Conventional oil and gas extraction employed 49.2 thousand in 2012, accounting for 75 per cent of total oil and gas extraction employment, up from 34.6 thousand in 2007, when it represented 65.0 per cent of total oil and gas employment. Perhaps surprisingly, given the growing importance of oil sands output, employment in non-conventional oil extraction has fallen, from 18.2 thousand in 2007 to 16.3 thousand in 2012, with its employment share down from 35 per cent to 25 per cent. This development may reflect the growing importance of the less labour-intensive steam-assisted gravity drainage (SAGD) technology for the extraction of bitumen from the oil sands.

**Exhibit 1**
**A Breakdown of Mining, Quarrying and Oil and Gas Extraction (NAICS Code 21) by NAICS Code**

| | | |
|---|---|---|
| 21 | Mining, Quarrying and Oil and Gas Extraction | |
| | (Breakdown by NAICS Codes) | |
| 211 | Oil and Gas Extraction | |
| | 211113 | Conventional Oil and Gas Extraction |
| | 211114 | Non-conventional Oil and Gas extraction |
| 212 | Mining and Quarrying (except Oil and Gas) | |
| | 2121 | Coal Mining |
| | 2122 | Metal Ore Mining |
| | 2123 | Non-metallic Mineral Mining and Quarrying |
| 213 | Support Activities for Mining and Oil and Gas Extraction | |
| | Support Activities for Oil and Gas Extraction, combining | |
| | 213111 | Oil and Gas Contract Drilling |
| | 213118 | Services to Oil and Gas Extraction |
| | Support Activities for Mining, combining | |
| | 213117 | Contract Drilling (except Oil and Gas) |
| | 213119 | Other Support Activities for Mining |

Source: Statistics Canada 2012.

3 Throughout this article, estimates for Newfoundland and Labrador's oil and gas extraction subsector refer to estimates for oil and gas extraction plus support activities for mining and oil and gas extraction.

**Table 1**

**Real GDP in Oil and Gas Extraction, Canada, Alberta, and Newfoundland and Labrador, 2000-2012**

| | Canada | | | NFLD | Alberta |
|---|---|---|---|---|---|
| | Total | Conventional | Non-conventional | | |
| | (millions, chained 2007 dollars) | | | | |
| 2000 | 78,504 | .. | .. | 3,733 | 62,253 |
| 2001 | 77,150 | .. | .. | 3,542 | 58,151 |
| 2002 | 82,855 | .. | .. | 7,694 | 59,538 |
| 2003 | 84,251 | .. | .. | 8,767 | 59,581 |
| 2004 | 84,870 | .. | .. | 8,490 | 60,964 |
| 2005 | 84,294 | .. | .. | 8,370 | 59,982 |
| 2006 | 86,498 | .. | .. | 8,180 | 62,101 |
| 2007 | 88,513 | 68,933 | 19,580 | 9,630 | 62,840 |
| 2008 | 85,554 | 65,265 | 20,228 | 9,051 | 60,215 |
| 2009 | 82,053 | 57,987 | 23,278 | 6,988 | 59,821 |
| 2010 | 84,751 | 57,770 | 25,655 | 7,066 | 61,472 |
| 2011 | 87,893 | 58,363 | 27,747 | 6,917 | 63,563 |
| 2012 | 91,285 | 58,946 | 30,048 | 5,015 | 67,712 |
| | **Compound Annual Growth Rates, per cent** | | | | |
| 2000-2012 | 1.3 | .. | .. | 2.5 | 0.7 |
| 2000-2007 | 1.7 | .. | .. | 14.5 | 0.1 |
| 2007-2012 | 0.6 | -3.1 | 8.9 | -12.2 | 1.5 |

Note: Estimates for Newfoundland and Labrador refer to oil and gas extraction plus support activities for mining and oil and gas extraction.

Source: CSLS calculations based on Statistics Canada data.

## Labour Productivity

The labour productivity performance of the oil and gas extraction subsector has been dismal (Table 3). At the national level, the subsector saw a decline in labour productivity of 6.4 per cent per year between 2000 and 2012. This abysmal productivity performance follows from the evolution of real output and labour input growth presented earlier. With a massive increase in labour input between 2000 and 2012 (total hours worked increased by 8.2 per cent per year), and weak output gains (1.3 per cent per year), output per hour worked plummeted sharply.

The decline in labour productivity was particularly sharp in Alberta (-7.1 per cent per year). Newfoundland and Labrador's oil and gas extraction sector saw its productivity decline at a rate of -4.8 per cent per year.

Despite the subsector's negative labour productivity growth, the absolute level of labour productivity in oil and gas extraction remained very high, almost thirteen times the business sector average in 2010. This was true for Canada, Alberta and Newfoundland and Labrador.

The oil and gas extraction industry in Alberta comprises two very different sectors, conventional oil and gas and the oil sands, each with very different productivity performance. Labour productivity in conventional oil and gas extraction fell 10.3 per cent per year during the 2007-2012 period, while in non-conventional oil and gas extraction it increased by 10.7 per cent per year. Thus the fall in labour productivity in oil and gas extraction, at least during the 2007-2012 period, was entirely driven by conventional oil and gas extraction, as employment surged 42 per cent and real output fell 15 per cent.

**Table 2**
**Employment in Oil and Gas Extraction, Canada, Alberta, and Newfoundland and Labrador, 2000-2012**

| | Canada | | | NFLD | Alberta |
|---|---|---|---|---|---|
| | Total | Conventional | Non-conventional | | |
| | (thousands of jobs) | | | | |
| 2000 | 26.5 | | | 1.3 | 22.5 |
| 2001 | 29.7 | | | 0.9 | 25.2 |
| 2002 | 30.0 | | | 1.1 | 25.4 |
| 2003 | 30.9 | | | 1.2 | 26.4 |
| 2004 | 35.2 | | | 1.4 | 30.4 |
| 2005 | 42.7 | | | 1.5 | 36.6 |
| 2006 | 45.9 | | | 2.0 | 39.3 |
| 2007 | 52.8 | 34.6 | 18.2 | 2.0 | 44.4 |
| 2008 | 64.6 | 46.4 | 18.2 | 2.1 | 54.8 |
| 2009 | 61.7 | 42.3 | 19.3 | 1.4 | 54.3 |
| 2010 | 55.3 | 41.4 | 13.9 | 2.1 | 49.5 |
| 2011 | 62.8 | 47.1 | 15.7 | 2.8 | 55.7 |
| 2012 | 65.4 | 49.1 | 16.3 | 3.1 | 57.3 |
| | Compound Annual Growth Rates, per cent | | | | |
| 2000-2012 | 7.8 | .. | .. | 6.4 | 8.1 |
| 2000-2007 | 10.3 | .. | .. | 9.1 | 10.2 |
| 2007-2012 | 4.4 | 7.3 | -2.2 | 7.5 | 5.2 |

Note: Estimates for Newfoundland and Labrador refer to oil and gas extraction plus support activities for mining and oil and gas extraction.
Source: CSLS calculations based on Statistics Canada data.

Two factors are at play in the collapse of labour productivity in conventional oil and gas since 2007. First, yields are decreasing in the exploitation of conventional oil and gas deposits in Western Canada as the easily accessed reserves and basins have been increasingly exploited. Second, high oil prices have made it profitable to exploit lower quality, and hence higher cost, oil and gas deposits.

The robust labour productivity growth in non-conventional oil production, a very promising and little known development, likely reflects two factors. First, the increasing importance of stream-assisted gravity drainage (SAGD) technology for extraction of bitumen, which is less labour intensive than mining of the oil sands, has likely reduced labour requirements per unit of output. Second, given that the oil sands have now been in production for a number of decades, the industry is benefiting from process improvements through learning-by-doing.

### Business Sector Productivity

During the 2000-2012 period Alberta had the slowest business sector labour productivity growth of all provinces (0.45 per cent per year), while Newfoundland and Labrador had the fastest (1.66 per cent per year) (Chart 4). How do we explain the very different productivity growth performance of the two major oil-producing provinces? Oil and gas extraction, which plays a major role in both economies, experienced a drastic decline in labour productivity in both economies. Nonetheless, business sector labour productivity growth was weak in Alberta and quite strong in Newfoundland and Labrador; this disparity is related to differences in the contribution of

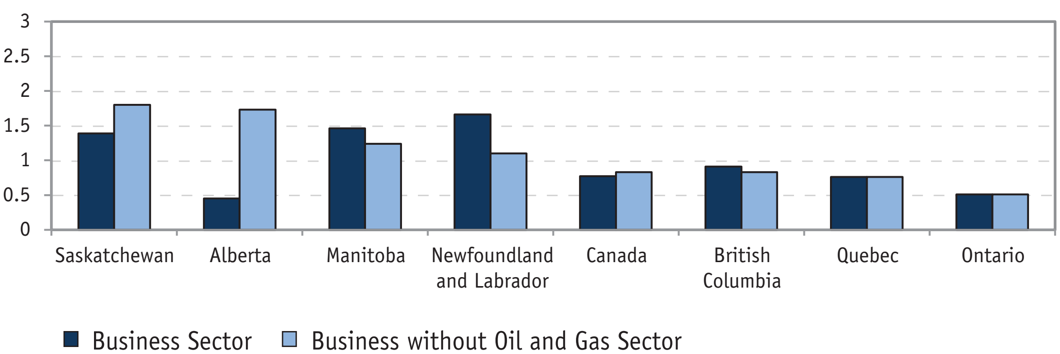
## Table 3
## Labour Productivity in Oil and Gas Extraction, Canada, Alberta, and Newfoundland and Labrador, 2000-2012

| | Canada | | | NFLD | Alberta |
|---|---|---|---|---|---|
| | Total | Conventional | Non-conventional | | |
| | (chained 2007 dollars per hour worked) | | | | |
| 2000 | 1,419.14 | .. | .. | 1,185.29 | 1,320.39 |
| 2001 | 1,209.10 | .. | .. | 1,570.23 | 1,065.56 |
| 2002 | 1,309.83 | .. | .. | 3,002.05 | 1,107.13 |
| 2003 | 1,271.71 | .. | .. | 3,413.18 | 1,045.65 |
| 2004 | 1,125.37 | .. | .. | 2,507.79 | 934.88 |
| 2005 | 887.85 | .. | .. | 2,244.96 | 731.54 |
| 2006 | 870.84 | .. | .. | 1,608.71 | 733.01 |
| 2007 | 797.16 | 946.54 | 512.43 | 1,910.69 | 676.39 |
| 2008 | 613.89 | 648.74 | 521.88 | 1,700.43 | 517.60 |
| 2009 | 642.24 | 659.46 | 584.45 | 1,967.78 | 534.47 |
| 2010 | 713.95 | 649.66 | 861.43 | 1,377.66 | 583.85 |
| 2011 | 654.51 | 579.53 | 826.27 | 985.78 | 538.86 |
| 2012 | 639.48 | 548.80 | 850.21 | 654.04 | 545.29 |
| | Compound Annual Growth Rates, per cent | | | | |
| 2000-2012 | -6.4 | .. | .. | -4.8 | -7.1 |
| 2000-2007 | -7.9 | .. | .. | 7.1 | -9.1 |
| 2007-2012 | -4.3 | -10.3 | 10.7 | -19.3 | -4.2 |

Note: Estimates for Newfoundland and Labrador refer to oil and gas extraction plus support activities for mining and oil and gas extraction.

Source: CSLS calculations based on Statistics Canada data.

## Chart 4
## Labour Productivity Growth in Canada and the Provinces, Business Sector and Business Sector excluding Oil and Gas Extraction Activities, 2000-2012
(per cent)

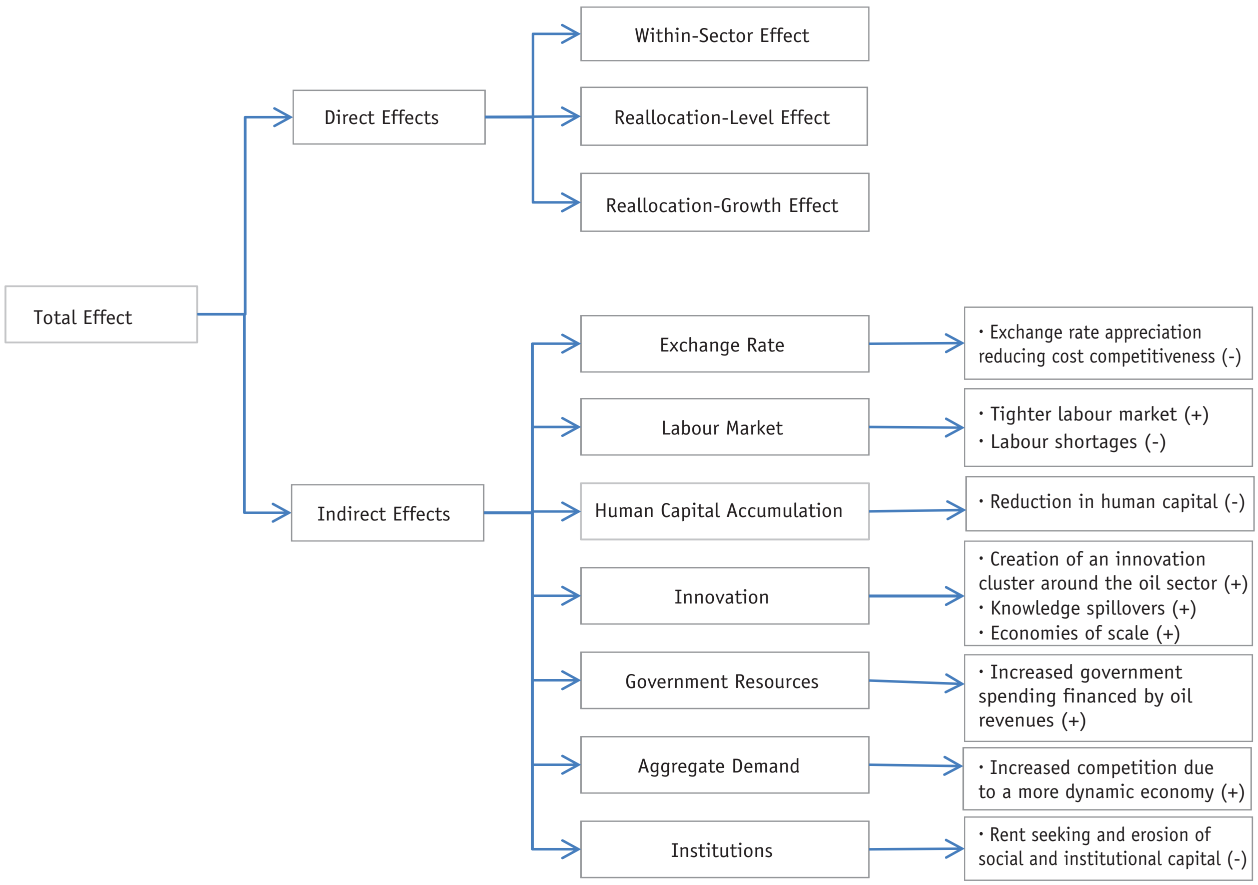



Source: CSLS calculations based on Statistics Canada data.

oil and gas extraction to aggregate labour productivity growth between the two provinces. The contribution of the oil and gas extraction subsector to business sector labour productivity growth was *positive* in Newfoundland and Labrador while it was *negative* in Alberta. These matters are explored in the following sections.

**Exhibit 2**

**The Effect of Oil and Gas Extraction on Aggregate Productivity Growth in Canada**




## A Framework for Analyzing the Impact of Oil and Gas Extraction on Canadian Productivity Growth

Exhibit 2 provides a schema for identifying and quantifying the different ways in which developments in and arising from the oil and gas industry impact, both directly and indirectly, aggregate productivity growth. This is the framework used to identify the direct contribution and the indirect effects of the oil and gas sector on productivity growth.

The next section provides empirical estimates of the direct contribution, and the section following discusses and presents evidence regarding the indirect effects, both for Canada as a whole and for Alberta and Newfoundland and Labrador, the two provinces where the oil and gas sector is most important.

## Assessing the Direct Contribution of Oil and Gas Extraction to Business Sector Labour Productivity Growth

The contribution of the oil and gas extraction subsector to business sector labour productivity growth is broken down into three components using labour productivity growth decomposition formulas.[4] The three components of the direct contribution of a sector to productivity growth are:

- The **within-sector effect (WSE)** is the labour productivity growth rate of the sector, scaled to reflect the share of the sector in the aggregate.

**Table 4**

**CSLS Labour Productivity Growth Decomposition for Canada, 2000-2012**

A) Two-digit NAICS Decomposition

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Business Sector Industries | 0.61 | 0.49 | -0.29 | 0.77 |
| Mining and Oil and Gas Extraction | -0.32 | 0.45 | -0.18 | -0.06 |
| All Other Industries Combined | 0.94 | 0.04 | -0.10 | 0.88 |

B) Three-digit Breakdown of Mining and Oil and Gas Extraction

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Mining and Oil and Gas Extraction | -0.44 | 0.88 | -0.50 | -0.05 |
| Oil and Gas Extraction | -0.37 | 0.85 | -0.48 | 0.00 |
| Mining and Quarrying (except oil and gas) | -0.07 | 0.04 | -0.02 | -0.05 |
| Support Activities for Mining and Oil and Gas Extraction | 0.00 | 0.00 | 0.00 | 0.00 |

Note: Contributions do not add up exactly to business sector labour productivity due to the use of chained dollar estimates instead of constant dollar estimates.

Source: CSLS calculations based on Statistics Canada data.

- The **reallocation-level effect (RLE)** measures the effect of a shift of resources in or out of a sector whose productivity level differs from the average.
- The **reallocation-growth effect (RGE)** measures the effect of a shift of resources into a sector that has a rate of productivity growth that differs from the aggregate rate of productivity growth.

## Canada

Business sector output per hour in Canada grew at a 0.77 per cent average annual rate from 2000 to 2012 (Table 4, Panel A). In contrast, labour productivity in the mining and oil and gas extraction industry fell at a 3.51 per cent average annual rate. The level of real GDP per hour worked in mining and oil and gas in 2012 was $233 (chained 2007 dollars), 4.9 times the business sector average. Between 2000 and 2012, the share of hours worked of the mining and oil and gas sector rose 0.8 percentage points from 1.4 per cent to 2.2 per cent of total business sector hours worked. The combination of the high labour productivity level and significant change in the hours share means that the mining and oil and gas sector had important effects on aggregate productivity growth.

The decomposition formula reveals that despite the strong negative within-sector contribution from mining and oil and gas extraction (-0.32 percentage points), the sector only made a relatively small negative contribution to overall business sector labour productivity growth (-0.06 percentage points). This result was due to the very large positive reallocation level effect (0.45 percentage points), reflecting the large influx of workers into this very high productivity level sector. This very important positive reallocation effect of the oil and gas sector on productivity is seldom recognized.

4 This article presents estimates calculated using the CSLS formula, while the unabridged version of this article uses two formulas: one developed by CSLS, and the Generalized Exactly Additive Decomposition (GEAD) formula. Further information on these formulas can be found in Sharpe and Waslander (2014), de Avillez (2012), Reinsdorf (2014), and Tang and Wang (2012).

### Table 5

**CSLS Contributions from Conventional and Non-conventional Oil and Gas Extraction to Labour Productivity Growth in Canada, 2007-2012**

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Business Sector | 0.05 | 0.78 | -0.38 | 0.49 |
| Oil and Gas Extraction | -0.29 | 0.50 | -0.26 | -0.04 |
| Conventional Oil and Gas Extraction | -0.52 | 0.53 | -0.24 | -0.22 |
| Non-conventional Oil and Gas Extraction | 0.23 | -0.03 | -0.02 | 0.18 |
| | (per cent contribution to aggregate labour productivity growth) | | | |
| Business Sector | 10.6 | 158.0 | -77.4 | 100.0 |
| Oil and Gas Extraction | -58.1 | 102.3 | -51.9 | -7.7 |
| Conventional Oil and Gas Extraction | -104.9 | 108.0 | -47.9 | -44.7 |
| Non-conventional Oil and Gas Extraction | 46.7 | -5.6 | -4.1 | 37.0 |

Source: CSLS calculations based on Statistics Canada data.

Because of the negative productivity growth within the mining and oil and gas sector, there was a negative reallocation growth effect (-0.18 percentage points). Consequently, the net reallocation effect of 0.27 percentage points (0.45 - 0.18 = 0.27) was less than the reallocation level effect, but still large enough to offset most of the negative contribution of the within-sector productivity growth (-0.32 percentage points).

Breaking down mining and oil and gas extraction into its three subsectors (Table 4, Panel B), it is interesting to note that although the overall contribution of the sector remains the same (-0.05 percentage points), the greater level of disaggregation captures within-sector and reallocation effects that were not captured at the two-digit level. In particular, oil and gas extraction experienced a massive reallocation level effect (0.88 percentage points). This effect was completely offset by the negative within-sector and reallocation growth effects (-0.37 and -0.48 percentage points, respectively), resulting in an overall contribution of zero to business sector labour productivity growth. In other words, oil and gas extraction – despite experiencing negative productivity growth during the period – did not make a negative contribution to aggregate labour productivity growth.

A breakdown of labour productivity growth of the oil and gas extraction into conventional and non-conventional oil and gas extraction is only available for the 2007-2012 period (Table 5). But a decomposition of oil and gas extraction productivity for this period provides fascinating insights into recent developments in the sector. It shows that conventional oil and gas extraction has made a significant negative contribution to labour productivity growth in the business sector (-0.22 points), while the oil sands have made a positive contribution (0.18 points). This result derives from the very large negative contribution of the within-sector effect in conventional oil and gas extraction (-0.52 points), following from the sector's very large fall in labour productivity. In contrast, the oil sands made a large positive within-sector contribution to business sector labour productivity growth (0.23 points) because of the sector's robust labour productivity growth.

### Alberta

Business sector output per hour in Alberta grew at a 0.45 per cent average annual rate from 2000

**Table 6**

**CSLS Labour Productivity Growth Decomposition for Alberta, 2000-2012**

A) Two-digit NAICS Decomposition

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Business Sector Industries | -0.25 | 1.21 | -0.61 | 0.45 |
| Mining and Oil and Gas Extraction | -1.32 | 1.00 | -0.48 | -0.79 |

B) Three-digit Breakdown of Mining and Oil and Gas Extraction

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Mining and Oil and Gas Extraction | -1.83 | 2.84 | -1.77 | -0.75 |
| Oil and Gas Extraction | -1.81 | 2.86 | -1.77 | -0.72 |
| Mining and Quarrying (except oil and gas) | -0.02 | -0.01 | 0.01 | -0.02 |
| Support Activities for Mining and Oil and Gas Extraction | 0.01 | -0.01 | 0.00 | -0.01 |

Source: CSLS calculations based on Statistics Canada data.

to 2012 (Table 6). In contrast, labour productivity in the mining and oil and gas extraction fell at a 4.02 per cent average annual rate. Alberta's level of real GDP per hour worked in mining and oil and gas extraction in 2012 was $246 (chained 2007 dollars), 3.6 times the business sector average. Between 2000 and 2012, the share of hours worked of the mining and oil and gas sector rose 2.3 percentage points from 6.8 per cent to 9.1 per cent of total business sector hours worked.

The decomposition formula reveals that the strong reallocation level effect (with a contribution of 1.00 percentage points) was not enough to offset the negative within-sector effect (-1.32 percentage points) and the negative reallocation growth effect (-0.48 percentage points). This resulted in a strongly negative contribution of mining and oil and gas extraction to labour productivity growth in Alberta's business sector (-0.79 percentage points or -176.1 per cent ). The sector's overall reallocation effect was positive (1.00 - 0.48 = 0.52), reflecting once again the large influx of workers into this high-productivity sector.

Breaking down mining and oil and gas extraction into its three subsectors (Table 6, Panel B), it is interesting to note (once again) that the overall contribution of the sector remains (roughly) the same, but the greater level of disaggregation captures within-sector and reallocation effects that were not captured at the two-digit level. In particular, oil and gas extraction experienced a massive reallocation level effect (2.86 percentage points). This effect was completely offset by the negative within-sector and reallocation growth effects (-1.81 and -1.77 percentage points, respectively), resulting in an overall contribution of -0.72 percentage points to business sector labour productivity growth.

### Newfoundland and Labrador

Business sector output per hour in Newfoundland and Labrador grew at a 1.66 per cent average annual rate from 2000 to 2012 (Table 7). In contrast, labour productivity in mining and oil and gas extraction fell at a 3.36 per cent average annual rate. The level of real GDP per hour worked in mining and oil and gas extraction in the province in 2012 was $429 (chained 2007 dollars), 6.3 times the business sector average. Between 2000 and 2012, the share of hours worked of the mining and oil and gas sector rose

**Table 7**
**CSLS Labour Productivity Growth Decomposition for Newfoundland and Labrador, 2000-2012**
A) Two-digit NAICS Decomposition

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Business Sector Industries | 0.63 | 2.79 | -1.17 | 1.66 |
| Mining and Oil and Gas Extraction | -0.89 | 2.70 | -1.05 | 0.77 |

B) Three-digit Breakdown of Mining and Oil and Gas Extraction

| | WSE | RLE | RGE | Total |
|---|---|---|---|---|
| | (percentage point contribution to aggregate labour productivity growth) | | | |
| Mining and Oil and Gas Extraction | -0.89 | 2.70 | -1.05 | 0.77 |
| Oil and Gas Extraction | -0.89 | 2.24 | -1.08 | 0.27 |
| Mining and Quarrying (except oil and gas) | 0.02 | 0.50 | -0.01 | 0.50 |

Note: Estimates for Newfoundland and Labrador refer to oil and gas extraction plus support activities for mining and oil and gas extraction.
Source: CSLS calculations based on Statistics Canada data.

3.3 percentage points from 3.0 per cent to 6.3 per cent of total business sector hours worked.

The decomposition formula reveals that despite the strong negative within-sector labour productivity growth in mining and oil and gas (-0.89 percentage points), the sector actually made a significant positive contribution (0.77 percentage points). This result was due to the extremely large positive reallocation level effect (2.70 percentage points), which was more than enough to offset both the negative within-sector effect and the negative reallocation growth effect (-1.05 percentage points). The positive combined reallocation effect (2.70 - 1.05 = 1.65) reflected the large influx of workers into this very high productivity sector.

Contribution estimates for Newfoundland and Labrador's oil and gas extraction subsector could not be calculated due to data confidentiality issues. The CSLS, however, was able to compute contribution estimates for oil and gas extraction plus support activities for mining and quarrying and oil and gas extraction (Table 7, Panel B). These show that the very strong reallocation level effect of the mining and oil and gas sector is largely due to the oil and gas extraction subsector. However, the mining subsector also makes a contribution (0.50 percentage point), as it has a higher than average productivity level and increased its share of hours worked.

## Assessing the Indirect Effects of Oil and Gas Extraction on Business Sector Labour Productivity Growth

This section investigates the indirect effects of oil and gas extraction on the aggregate productivity performance of Canada, Alberta, and Newfoundland and Labrador during the 2000-2012 period. These effects are: 1) the exchange rate effect; 2) the effect on the labour market; 3) the impact on human capital accumulation; 4) the effect on innovation; 5) the effect on government resources, which interacts with the other effects; and 6) the effect on aggregate demand.

### Exchange Rate Effects: the Dutch Disease

Canada exported $73 billion nominal dollars worth of crude oil and crude bitumen in 2012, up from $19 billion in 2000. The massive increase in both the volume and the price of oil exported put upward pressure on the exchange rate, which rose from $0.73 U.S. in 2000 to $1.04 U.S. in 2012. This appreciation has had important implications for the productivity performance of the non-oil and gas sector, as discussed in this section.

There is an extensive literature on the effects of resource sectors on national and regional economies. The term "Dutch Disease", named after the experience of the Netherlands following discovery of an enormous natural gas field in 1961, is commonly used to describe this effect. The Dutch Disease focuses on the effect a resource price boom or exploitation of rich deposits may have, primarily through the exchange rate, on the manufacturing sector, which many regard as vital for economic development. In other words, newfound resource riches may damage the engine of long-term growth of the economy.

Resource riches can be disastrous but also quite beneficial. Much depends on the general setting, on institutions and policies. It is important to be cautious when attributing developments in the economy at large to a resource boom, as adverse developments outside the oil and gas sector may be due to factors unrelated to natural resources and resource development may lead to positive spin-offs in manufacturing instead of displacing the industry.

### The Canadian Experience

Labour productivity in manufacturing advanced at only 0.7 per cent per year on average between 2000 and 2012 in Canada, down from 2.9 per cent per year between 1981 and 2000. This development reflected a decline in real output in manufacturing at a rate of 1.2 per cent per year in 2000-2012, down from growth of 3.3 per cent per year in 1981-2000. In 2000-2012, employment in manufacturing fell by 1.9 per cent per year. A fall in demand and hence output, either in the growth rate or in absolute terms, has negative short- and long-term implications for productivity growth. Short-term effects include less spreading of overhead costs, greater labour hoarding, less learning by doing and fewer economies of scale. Long-term effects include less investment in human capital, R&D, and physical capital (Spiro, 2013; Rao and Li, 2013).

The cause of the lack of output growth is to be sought at least in part in the appreciation of the exchange rate, and this in turn is associated with oil and gas. There are three links in the nexus between oil and gas and manufacturing that need to be investigated:

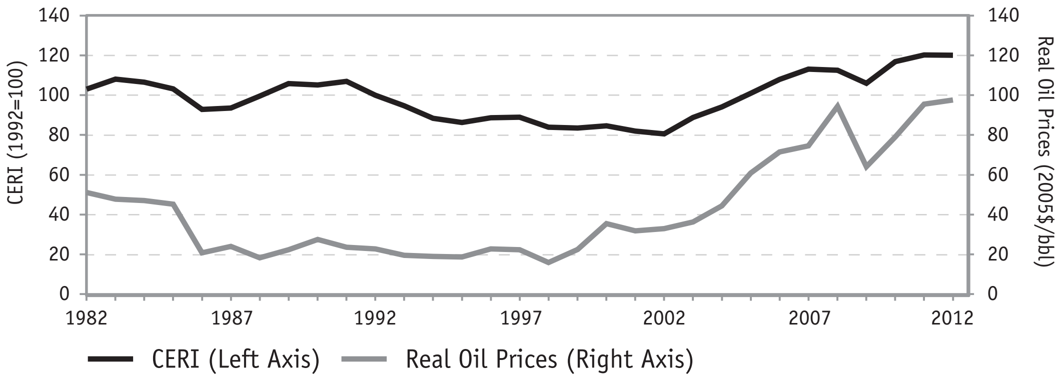
- The degree to which the appreciation of the exchange rate is due to the price of and external trade in oil;
- The degree to which the deterioration of the cost competitiveness of the manufacturing sector is driven by the exchange rate; and
- The degree to which the loss of cost competitiveness in manufacturing affects output and productivity.

As regards the first linkage, the appreciation of the Canadian dollar effective exchange rate after 2002 coincided with and follows the same pattern as the rise in real oil prices (Chart 5). The effective exchange rate appreciated 39.7 per cent between 2002 and 2008, driven by a 186.4 per cent increase in real oil prices. Both indicators declined in 2008-2009 as the great world recession set in, but recovered fully in the next two years. Similarly, using quarterly data for 1994-2013, Courchene (2014) found a positive correlation of 0.94 between the price of crude oil and the Canada-U.S. exchange rate. This suggests that the Canadian dollar has increasingly become a petro currency.

While this evidence is suggestive, it is not definitive, and it does not show what part of the appreciation is due to oil. Beine *et al.*

**Chart 5**

**Canadian Dollar Effective Exchange Rate Index (CERI) (1992=100) and Real Oil Prices (2005 U.S. Dollars per Barrel), 1982-2012**




Note: "Real oil prices" are the average spot prices (2005$/bbl) for crude oil based on WTI, Dubai, and Brent.
Source: World Bank, DataBank, Global Economic Monitor (GEM) Commodities; and the Bank of Canada.

(2012) argues that much of the appreciation in the Canadian dollar between 2002 and 2008 was due the weakness in the U.S. dollar that was unrelated to changes in energy and commodity prices. They estimate that 58 per cent of the appreciation of the Canada-U.S. bilateral exchange rate between 2002 and 2008 was due to the weakness of the U.S. component, while only 42 per cent was due to the strength of the Canadian component, which they regard as being related to energy price movements. Similarly, Carney (2012), former Governor of the Bank of Canada, estimated that half of the appreciation of the Canada-U.S. exchange rate was due to the rise of global commodity prices, and about 40 per cent was due to the depreciation of the U.S. dollar against other major currencies.

As regards the second linkage in the chain of causation from oil and gas to productivity in manufacturing, unit labour cost in manufacturing expressed in U.S. dollars is a key metric of the cost competitiveness of the Canadian economy. Unit labour costs in U.S. dollars in Canada rose 80 per cent between 2000 and 2012 in Canada but declined by 20 per cent in the United States. This represented a massive deterioration in Canada's cost competitiveness.

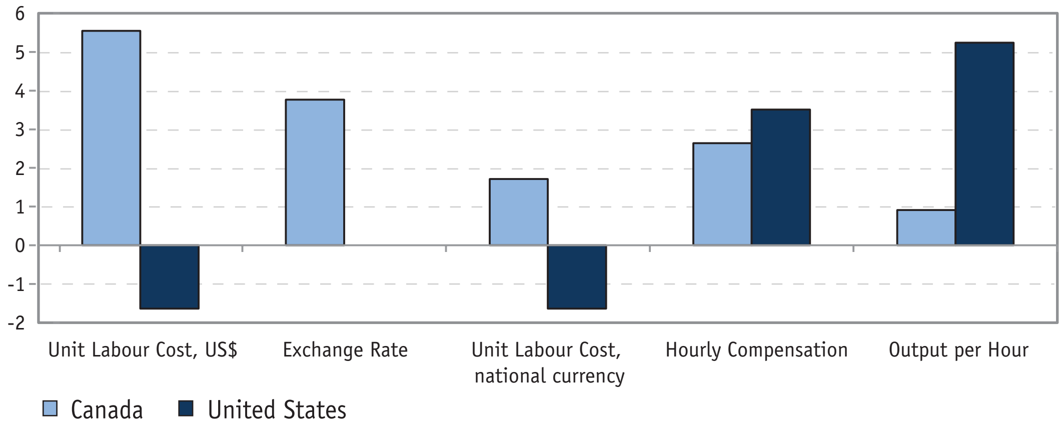
Changes in unit labour costs in U.S. dollars reflect changes in the three factors: nominal labour costs, labour productivity, and the exchange rate. Chart 6 shows developments in these variables for Canada and the United States for the 2000-2012 period. Unit labour cost grew 5.5 per cent per year over the period in Canada, compared to a decline of 1.6 per cent in the United States, for a difference of 7.1 per cent per year. Just over one half of this decline is due to the 3.8 per cent average annual appreciation of the Canadian dollar. The difference in labour productivity growth (0.9 per cent vs. 5.2 per cent) contributed even more to the loss in Canada's cost competitiveness. The slower rate of hourly compensation increases in Canada (2.6 per cent vs. 3.5 per cent) offset the two negative developments only in small part.

It should be noted that the contribution of productivity performance to the fall in cost competitiveness is likely overestimated, as productivity growth is endogenous to demand conditions. To the degree that productivity growth is a function of output growth, the weak productivity growth

**Chart 6**

**Unit Labour Cost in the Manufacturing Sector (US$), Canada-U.S. Comparison, 2000-2011**

(compound annual growth rates, per cent)




Source: U.S. Bureau of Labor Statistics, International Labor Comparisons.

reflects the fall in output growth, which was in part caused by the appreciation of the Canadian dollar. It is well-known that changes in output are reflected in productivity performance; this is known as the Verdoorn Law.

One would expect that the U.S. and Canadian manufacturing sectors experienced the same structural phenomena in recent years. In principle, these structural phenomena – most importantly, the shift of low-skill manufacturing activities to emerging markets – should have affected the U.S. and Canadian manufacturing sectors roughly equally, *ceteris paribus*. However, Chart 7 evidences the divergence between the United States and Canada in terms of value added in the manufacturing sector. In particular, real GDP in the U.S. manufacturing sector was 20.7 per cent above its 2000 level in 2013, while real GDP in Canada's manufacturing sector was 14.0 per cent below its 2000 level in 2013. Coinciding with Canada's oil boom, much of the divergence between Canada and the United States occurred in 2002-2007, with real GDP in U.S. manufacturing rising dramatically and falling in Canada.

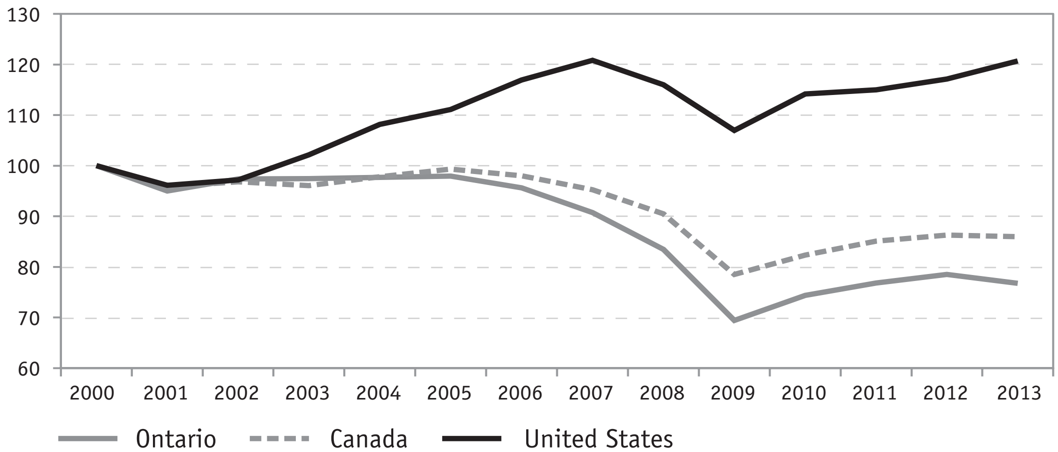
As regards the third issue, the appreciation of the Canadian dollar and loss of cost competitiveness was, of course, not the only factor leading to a fall in foreign demand for Canadian manufactured products. Weak economic growth in the United States, our major market, as well as the emergence of low-cost producers of manufactured goods, especially China, also played a role. These developments have been highlighted by Shakeri, Gray and Leonard (2012).

To sum up, there exists a causal link between the price and export of oil and output in manufacturing but it explains only a part of what happened to the latter industry. The appreciation of the Canadian dollar was quite large but also reflects a weakening of the U.S. dollar that was unrelated to oil. Both factors have been more or less equally responsible for the appreciation. The appreciation in turn accounts for a substantial part, but not the entire dramatic increase in relative unit labour cost in manufacturing. Some part of the increase in Canada's relative unit labour cost is due to the Canadian industry's failure to keep up with the rapid rate of increase in out-

**Chart 7**

**Index of Real GDP in Manufacturing, Canada, Ontario and the United States, 2000-2013**

(Index, 2000 = 100)




Source: Statistics Canada, CANSIM Tables 379-0030/31. BEA, GDP by Industry.

Note: Real GDP for the US is in 2009 Chained Dollars. Real GDP for Canada and Ontario is in 2007 Chained Dollars.

put per hour worked in the United States. Taken together, these two observations mean that a significant part, but less than one-half, of the decline of manufacturing output relative to that in the U.S. could be attributed to the effect of the oil boom on the Canadian exchange rate.

### Labour Market Effects

In this section, we examine whether the oil and gas subsectors in Alberta and Newfoundland and Labrador are tightening labour market and affecting wages in these provinces.

According to Statistics Canada, Alberta had a job vacancy rate of 3.1 per cent in 2012, the highest in Canada and well above the national average of 1.7 per cent. The unemployment rate in Alberta was 4.6 per cent, the lowest in Canada and well below the national average of 7.3 per cent. The ratio of the unemployment rate to the job vacancy rate in Alberta was 1.48, also the lowest in Canada. These three measures of labour market conditions indicate that in 2012 Alberta had the tightest labour market of all provinces.

Between 2001 and 2012, average weekly earnings for the industrial aggregate grew at a 4.3 per cent average annual rate in Alberta, compared to 2.9 per cent in Canada. This trend resulted in a growing gap in wages between Alberta and Canada, with wages in Alberta rising from 102.8 per cent of the national average in 2001 to 119.6 per cent in 2012. All of Alberta's sectors have shown wage growth in excess of the national average. However, in certain sectors the difference has been small. Both vacancy rates and wages indicate that the labour market in Alberta was rather tight.

The oil and gas boom in Newfoundland and Labrador also has greatly tightened labour market conditions in the province, with potential effects on productivity. The unemployment rate plummeted from 18.1 per cent in 1997 to 12.5 per cent in 2012, while in St. John's it fell from 13.5 per cent in 1997 to 7.7 per cent in 2010. The tighter labour market in both provinces would have led to higher wages and skill shortages, giving producers a greater incentive to substitute capital for labour, boosting labour productivity.

## Table 8
### Summary of Absolute and Relative Rates of Educational Attainment

| | Canada | | | Newfoundland and Labrador | | | Alberta | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2012 | Change 00-12 | 2000 | 2012 | Change 00-12 | 2000 | 2012 | Change 00-12 |
| High School Non-Completion Rate Ages 15-24 | | | | | | | | | |
| Absolute | 41.2 | 34.1 | -7.1 | 42.3 | 35.8 | -6.5 | 42.8 | 36.7 | -6.1 |
| Relative to Canada (%) | .. | .. | .. | 102.7 | 105.0 | 2.3 | 103.9 | 107.6 | 3.7 |
| Post-Secondary Enrolment Rate for Under 25 Year Olds | | | | | | | | | |
| Absolute | 28.5 | 39.1 | 10.7 | 24.2 | 38.4 | 14.2 | 24.5 | 30.3 | 5.8 |
| Relative to Canada (%) | .. | .. | .. | 84.9 | 98.2 | 13.3 | 86.0 | 77.5 | -8.5 |
| Average Years of Schooling for Ages 15 and Over | | | | | | | | | |
| Absolute | 13.5 | 14.0 | 0.5 | 13.3 | 13.8 | 0.5 | 13.4 | 13.8 | 0.4 |
| Relative to Canada (%) | .. | .. | .. | 98.5 | 98.6 | 0.1 | 99.3 | 98.6 | -0.7 |

In all, this evidence indicates a possible positive effect on labour productvity. One caveat needs consideration: If the labour market becomes too tight, skills shortages and production bottlenecks could appear, and these can be detrimental to productivity. However, there appers to be ample supply of labour available to Alberta's employers through interprovincial migration and immigration, while outmigration did continue in Newfoundland and Labrador. There have been no indications of a general labour shortage or widespread skill shortages in either province. Accordingly, we conclude as follows: Labour market tightening in Alberta and (to a lesser extent) Newfoundland and Labrador is likely to have had a positive effect on labour productivity in various sectors in these provinces through the greater incentives to substitute capital for labour.

### Human Capital Accumulation Effects

Accumulation of human capital is vital for the productivity growth of a nation in the long run. The oil and gas sector may influence productivity growth if it impacts on educational attainment, positively or negatively.

The oil and gas sector and its support activities create low-skill jobs with high wages which can attract youth away from schooling. This increases the opportunity cost of post-secondary education. There are two possible scenarios for the long-term effects. In the first scenario, the high wages are permanently attracting youths away from pursuing higher education. In the second scenario, the high wages are temporarily attracting youths from pursuing higher education. This temporary attraction allows youths to accumulate savings to fund their higher education. There may also be a positive effect if the emergence of a thriving oil and gas sector creates employment opportunities that require a high level of education where such jobs used to be scarce.

This section presents evidence regarding trends in educational attainment in Alberta and Newfoundland and Labrador between 2000 and 2012 and contrasts this with the experience in Canada generally.

Since 2000, there has been a significant fall in high school non-completion in all three jurisdictions, a positive factor for the overall quality of the labour force. However, it appears that the rate of decline in high school non-completion was somewhat slower in the two oil producing provinces than at the national level. The relative high school non-completion rates in these provinces rose slightly, from 102.6 per cent of the national level for Newfoundland and Labrador in 2000 to 105.0 per cent in 2012 and from 103.7 per cent of the national level in Alberta in 2000 to 107.8 per cent in 2012. This suggests that the relatively tight labour market in Alberta and the greatly improved labour market in Newfoundland and Labrador may have enticed some young persons to take jobs rather than complete high school.

There has also been a significant upward trend in the post-secondary enrolment rate in all three jurisdictions since 2000, again a positive factor for the overall quality of the labour force. The rate of increase in the post-secondary enrolment rate was well above the national average in Newfoundland and Labrador, and well below in Alberta. Consequently, the relative enrolment rate in Newfoundland and Labrador rose significantly from 84.9 per cent of the national level in 2000 to 98.2 per cent in 2012. In contrast, the relative enrolment rate fell in Alberta from 86.0 per cent of the national average in 2000 to 77.3 per cent in 2012. It is quite surprising that Alberta has only around three students enroled in post-secondary education for every four students enrolled at the national level. The ample and well-paying employment opportunities in Alberta appear to lead to the postponement or the abandonment of post-secondary studies for many young people in the province.

Consistent with the other two education metrics discussed above, since 2000 there has been an upward trend in educational attainment in all three jurisdictions, again a positive factor for the overall quality of the labour force. In Canada, the average number of years of schooling has risen from 13.5 years in 2000 to 14.0 years in 2012. Alberta also saw a similar increase (from 13.4 years to 13.8 years), as did Newfoundland and Labrador (from 13.3 years to 13.8 years). The average number of years of schooling for both oil producing provinces remained below but close to that of Canada. Educational attainment is a measure of the stock rather than the flow of education. It cannot change very rapidly, and is affected by interprovincial migration as well as school completion in a province. It is therefore not a very sensitive measure for the question at issue in this section.

The strongest evidence of an effect of oil and gas on human capital accumulation is the increase in post-secondary enrollment in Newfoundland and Labrador, where the rate came very close to the national rate from a much lower level in the year 2000. It seems likely that the oil and gas sector is at the root of this development, not just for the employment opportunities it created and was expected to create, but also through its effect on the economy of the province and on government revenues.

For Alberta, the evidence suggests a negative effect on human capital accumulation of young people. While there has been continued progress in reducing the high school non-completion rate and in increasing post-secondary enrolment rates, the gains in human capital have been smaller than at the national level. This development was also found by Morissette, Chan and Lu (2013), which found that wage growth induced by increases in world oil prices reduced full-time university enrolment among young men in oil-producing provinces.

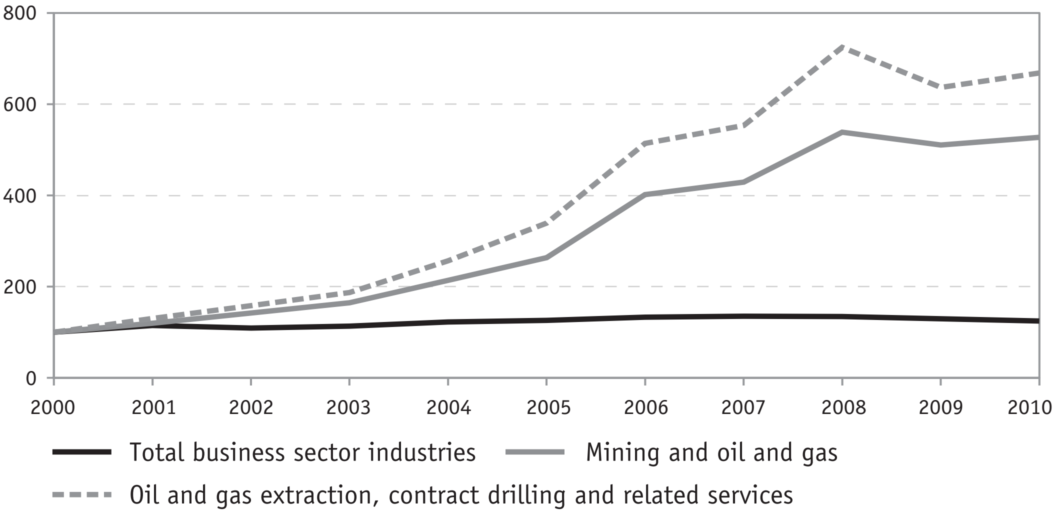
### Innovation Effects: Business Expenditures on Research and Development

Productivity growth is driven by innovation, and innovation in turn is spurred by competition. There are several channels by which the rapid development of the oil and gas sector can foster innovation in the sector itself and in other sectors. First, the high profits arising from eco-

**Chart 8**

**Trends in Nominal BERD Expenditures for Total Economy, Mining and Oil and Gas, and Oil and Gas Extraction, 2000-2010**

(Index, 2000 = 100)




Sources: Statistics Canada, CANSIM Tables 358-0161 and 358-0024.

nomic rents in the oil and gas sector give firms the resources to undertake R&D. Second, technologies developed in the oil and gas sector can have spillover effects on other sectors. Third, a robust oil and gas sector can create greater opportunities throughout the economy, leading to more firms entering the market and fostering competition, spurring the adoption of best practices because of the increased competitive intensity. This section examines the first of these effects, using information about business expenditures on research and development (BERD).

Profits in oil and gas extraction and support activities in Canada were strong in the 2000s, rising from around $20 billion in 2000 to a peak of $37 billion in 2008 before plummeting with the financial crisis and fall in oil prices. Although oil prices have rebounded significantly since 2009, the weakness of natural gas prices has meant that total profits in the oil and gas sector had not regained their 2000 level by 2011. For much of the 2000s, the profit margin of the oil and gas sector was double that of the industrial aggregate. The high profits of the oil and gas sector between 2000 and 2008 meant that resources were available to expand R&D.

Indeed, increasing profits in the oil and gas sector led to a marked increase in its business expenditures for research and development (BERD) for both Canada and Alberta. Between 2000 and 2007, BERD expenditures grew in all industries, at 4.4 per cent annually for Canada. The oil and gas extraction, contract drilling and related services sub-sector charted impressive annual growth in R&D, at 27.7 per cent nationwide. Since 2007, however, BERD spending overall gradually declined. Canadian total industry spending fell 1.0 per cent per year, and in Newfoundland and Labrador it fell by 5.8 per cent per year.

Chart 8 shows BERD expenditure for the mining and oil and gas sectors as well as for the total economy. While total industry BERD has increased moderately since 2000, total expenditure within oil and gas extraction soared from \$129 million in 2000 to \$839 million in 2010. As a result, BERD expenditure of Canada's oil and gas extraction sector increased as a proportion of total BERD spending for all industries, from 1 per cent to over 5 per cent.

In Alberta, virtually all mining and oil and gas business sector R&D spending falls within the oil and gas extraction, contract drilling and related services sector. Alberta itself accounts for most national BERD spending within the oil and gas extraction sector, at \$478 million out of \$821 million dollars in 2011 (58 per cent).

Between 2000 and 2007, BERD expenditures grew sharply in all Albertan industries, at 13.9 per cent per year, and a large part of this growth was contributed by the oil and gas contract extraction, contract drilling and related services subsector, where spending grew at an annual rate of 24.1 per cent. Since 2007, however, BERD spending has gradually declined, at an average annual rate of 1.6 per cent for Alberta, though only at 0.2 per cent for the mining and oil and gas extraction sector.

As for Newfoundland and Labrador, business sector R&D expenditures grew by 13.4 per cent per year, \$20 million in 2000 to \$72 million in 2010. This was a faster rate than in Canada and than what the province experienced during the 1987-1997 period, when it grew 7.12 per cent per year. Lack of detail makes it impossible to determine if this increase came from the oil and gas sector or from other parts of the business sector.

## Effects on Government Spending

A key characteristic of the oil and gas sector is that when prices are high, substantial rents are accrued to governments, who benefit from corporate and income taxes, as well as taxes and royalties from the resources themselves.[5] High government revenues permit increased expenditures, which can be allocated to productivity-enhancing investments such as postsecondary education or R&D. In this way, the oil and gas boom may indirectly improve productivity within the Canadian economy through increased government spending.

### Total Revenues and Spending per Capita

In the recent period of rapid growth in Canada's oil and gas extraction industry, the provincial governments of Alberta and Newfoundland and Labrador have enjoyed fast-growing revenues. Since 1997, per capita government revenues have increased annually for these two provinces at 6.5 per cent and 4.8 per cent respectively, compared to 4.3 per cent for the provincial average. In 2009, per capita government revenues in Newfoundland and Labrador were 48 per cent greater than the average of the 10 provinces.

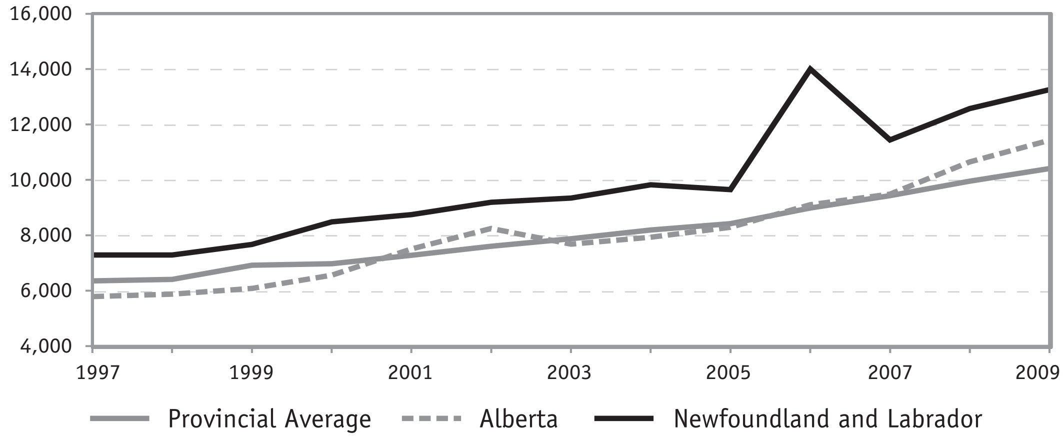
Increased revenues permit increased expenditures, including investments in productivity-enhancing activities. In the past 25 years, Alberta and Newfoundland and Labrador have both, on average, spent more per capita than the other provinces, and this remains true as of 2009 (Chart 9). While average expenditure per capita within the provinces grew annually at 4.2 per cent between 1997 and 2009; the growth rate for Alberta was 5.8 per cent per year, and 5.1 in Newfoundland and Labrador. As of 2009, provincial government spending in these provinces was 10 per cent and 27 per cent greater than the provincial average, respectively.

### Expenditures on Post-secondary Education

Spending on postsecondary education is one of the principal ways in which governments may

5 A Conference Board of Canada (2012) study estimates that oil sands investment will generate \$45.3 billion in federal revenues and \$34.1 billion in provincial revenues between 2012 and 2035 on an inflation-adjusted basis.

**Chart 9**
**Government Expenditure per Capita in Alberta and Newfoundland and Labrador, 1997-2009**
(current dollars)




Source: Statistics Canada. CANSIM Table 385-0001.

attempt to boost productivity in the long run. Provincial responses in terms of this type of expenditure vary according to province. Post-secondary education spending per capita in Newfoundland and Labrador has consistently hovered around the provincial average since 1997, and as of 2009 had even fallen slightly, with postsecondary expenditure growing at just 4.9 per cent per year, compared to 5.6 per cent for all provinces. Alberta, on the other hand, has invested more aggressively in postsecondary education, with per capita expenditures growing at 7.0 per cent annually since 1997, and by 2009 was spending 22 per cent more than the provincial average (approximately $1,380 per person versus $1,130).

### Support for R&D

Funding research and development is another channel by which governments may improve long-term productivity. This funding may be for government R&D, support for higher education or for business R&D. Newfoundland and Labrador and Alberta are among the top three provinces where government funding for R&D has grown the fastest, at 11.7 and 8.4 per cent annually, compared with a (weighted) provincial average of 6.7 per cent per year. This indicates that these two provinces are using the additional government revenues arising from oil and gas exploitation for productivity enhancement.

## Demand Effects

The development of the oil and gas sector has important effects on others sectors of the economy, both in the province of production and in other provinces. The oil and gas sector purchases intermediate inputs and capital equipment from other sectors and the incomes generated in the oil and gas sectors are in turn spent on goods and services. Such effects boost demand for goods and services, which affects capacity utilization, a key determinant of productivity growth. Unfortunately, estimates of capacity utilization rates are not available by province, so the impact of the oil and gas sector on capacity utilization in Alberta and Newfoundland and Labrador cannot be assessed.

Investment in the oil and gas sector increased from $21 billion in 2000 to $41 billion by 2005 and $59 billion in 2012. The Conference Board of Canada (2012), in a study of the economic benefits of oil sands investment for Canada's regions, estimated the supply chain effects of the oil sands. The study found that between 2012 and 2035 the expected investment of $364 billion on oil sand development is expected to generate 1.45 million person years of employment through supply chain effects that will be felt across a wide range of industries. While around two-thirds of the benefits will accrue to Alberta, Ontario will receive 14.8 per cent, British Columbia 6.7 per cent and Quebec 3.9 per cent. This increased demand will have positive implication for productivity growth through increased rates of capacity utilization and economies of scale and scope.

The oil boom generated large amounts of income. Governments claimed a large share of the natural resource rents, and spent some of this on R&D and education, as discussed earlier. A good part of the natural resource rents, however, is collected by the industry as profits and remuneration of employees. These incomes are in turn spent on goods and services, boosting output, capacity utilization and productivity.

## Conclusion

The article has five main conclusions. First, the oil and gas sector did indeed experience a major fall in labour productivity growth since 2000, -6.4 per cent per year between 2000 and 2012. This development is largely explained by high oil prices which made it profitable to develop reserves where more labour was needed to extract a barrel of oil, including both conventional deposits and the oil sands.

Second, despite the negative within-sector labour productivity growth in the oil and gas sector, the overall contribution of the sector to business sector labour productivity was small. This was because of a large positive reallocation effect. In 2010, the average labour productivity in the sector was 10 times the all-industry average. This meant that the rise in the share of total business sector hours worked in the oil and gas sector from 0.4 per cent in 2000 to 0.8 per cent in 2010 offset the negative within sector productivity effect.

Third, the oil and gas sector did have a negative effect on manufacturing productivity and hence on business sector labour productivity growth through its effect on the value of the Canadian dollar, a phenomenon known as Dutch Disease. It is estimated that around one half of the appreciation of the exchange rate was due to domestic factors, especially commodity price increases, mostly oil and gas prices. This development in turn led to a major decline in Canada's international cost competitiveness, resulting in a fall in exports of manufactured products.

Falls in output growth in manufacturing are closely associated with falls in productivity. Manufacturing output growth in Canada fell from 3.3 per cent per year in the 1981-2000 period to -1.2 per cent in the 2000-2012 period while output per hour growth in the sector fell from 2.9 to 0.7 per cent per year. With only 15 per cent of total hours worked in 2012, manufacturing accounted for 40 per cent of the post-2000 fall-off in business sector labour productivity growth.

Fourth, the oil and gas sector was found to have positive productivity impacts though various mechanisms. The increased economic activity related to the oil and gas sector boosted wages, which would lead to greater substitution of capital for labour, increasing labour productivity. The increased profits of oil firms boosted R&D spending. Higher government revenues from the oil and gas sector lead to greater spending on education and R&D. However, because the oil and gas sector is concentrated in Alberta and Newfoundland and Labrador, these effects were largely regional in nature and had limited effects at the national level. Demand from the industry for inputs and investment goods, and from the personal income of the workforce of the industry has boosted activity throughout the economy and particularly in the major oil-producing provinces, with positive effects on productivity.

Fifth, enrolment in post-secondary education of young people did not keep up with national trends in Alberta because of well-paying employment opportunities for youth. In Newfoundland and Labrador post-secondary enrolment increased to close to the national level.

Sixth, while labour productivity growth in the oil and gas sector was strongly negative over the 2000s, it fell more rapidly in the first half of the decade. Since 2007, the productivity level in the non-conventional sub-sector has increased at a high rate. This bodes well for the future contribution of the sector to aggregate productivity growth as the importance of the oil sands in the overall sector is expected to rise.

To conclude, the oil and gas boom has not been the main cause of the slowdown in labour productivity growth in Canada since 2000. However, it has contributed to this development both directly though the large fall in labour productivity in the sector (although offset by positive reallocation effects), and more importantly, through its effects on the exchange rate and the competiveness of the Canadian manufacturing sector.

Of course, as stressed at the beginning of this article, increases in living standards do not only come from productivity growth, but also from improved terms of trade. The dampening of living standards growth though slower productivity growth arising from the oil boom has been largely offset by this development. Real GDI, which incorporates terms of trade effects, grew 0.4 percentage points faster than real GDP (2.3 per cent versus 1.9 per cent per year) in Canada from 2000 to 2012. In 2012, gross domestic income was 4.7% higher than it would have been without improvement of the terms of trade. From this perspective, the oil boom has contributed significantly to Canadian prosperity.

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# On Productivity: The Influence of Natural Resource Inputs

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Abstract

The production function underlying standard estimates of multifactor productivity (MFP) typically restricts the list of explicitly measured inputs to capital, labour and intermediate inputs (energy, materials and services). These inputs are measured in the national accounts, and in most industries are the most important or significant inputs to production. All other influences on output are captured by the MFP 'residual.'

However in some industries – mining, agriculture, and utilities – output can also depend significantly on unmeasured inputs of natural resources. Rainfall in agriculture is an obvious example, but so too is the issue of mineral resource deposits in the mining sector, particularly where mining is a mature industry and the richest and most accessible deposits have already been developed.

In this article we attribute a substantial part of recent large negative changes in MFP growth in the mining, agriculture and utilities industries in Australia to unmeasured natural resource input changes. As MFP growth estimates derived from the application of the usual production function are generally interpreted as measuring improvements in the 'technology' used to convert standard inputs into output, where there are significant changes in natural resource dependent industries this interpretation of MFP needs to be adjusted.

Multifactor productivity (MFP), which is measured as a residual (the growth in the volume of output not explained by the growth in the volume of labour and capital inputs), reflects other sources of change in the productive capacity of an industry or economy as well as technical change. This article looks at the effect of one of these other possible sources of change, namely natural resource inputs.

Many natural resource inputs are not directly measured in the national accounts, yet changes in their use in production or changes in their quality can affect measured value added and hence MFP estimates. In recent years, there have been sustained periods of strongly negative MFP growth in three important Australian industries – mining, agriculture, forestry and fishing (AFF or agriculture for short), and utilities (electricity, gas, water and waste services) (Chart 1). Changes in natural resource inputs appear to have been a major contributor. This article draws heavily on two research studies undertaken by the Australian Productivity Commission that looked at the productivity performance of the mining industry

1 The authors are economists at the Australian Productivity Commission (APC). An earlier version of this article was released as an APC working paper (Topp and Kulys, 2013). The APC is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. Its role, expressed most simply, is to help governments make better policies, in the long-term interest of the Australian community. The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by concern for the well-being of the community as a whole. Further information is available at www.pc.gov.au. Emails: vtopp@pc.gov.au; tkulys@pc.gov.au.

(Topp *et al.*, 2008) and the utilities industry (Topp and Kulys, 2012).

For natural resource inputs to affect MFP growth in an industry they must be changing, and they must be a significant input for the industry. That is, the production of output must depend on the availability and/or quality of the resource input. The most straightforward example of industry reliance on a natural resource input is rainfall in AFF. Rainfall is *not* included in the measures of inputs to production when MFP is estimated for this industry although changes in rainfall have a direct influence on agricultural output each year. As a result, rainfall variability shows up as variability of output and hence measured MFP, rather than as variability in the total quantity of inputs used. MFP growth in AFF was negative at times during the last decade or so, not because farmers became less *technically efficient*, but because it did not rain as much.

Recent periods of slow or negative MFP growth in all three industries mentioned can be attributed, at least in part, to large reductions in the quantities (or qualities) of natural resource inputs being used in production. If the quality or quantity of unmeasured inputs is declining over time relative to measured inputs, estimates of MFP growth will understate technical progress. Conversely, if the relative quality or quantity of natural resource inputs increases, estimates of MFP growth will overstate technical progress, giving an impression that an industry has achieved greater technical progress than is actually the case.

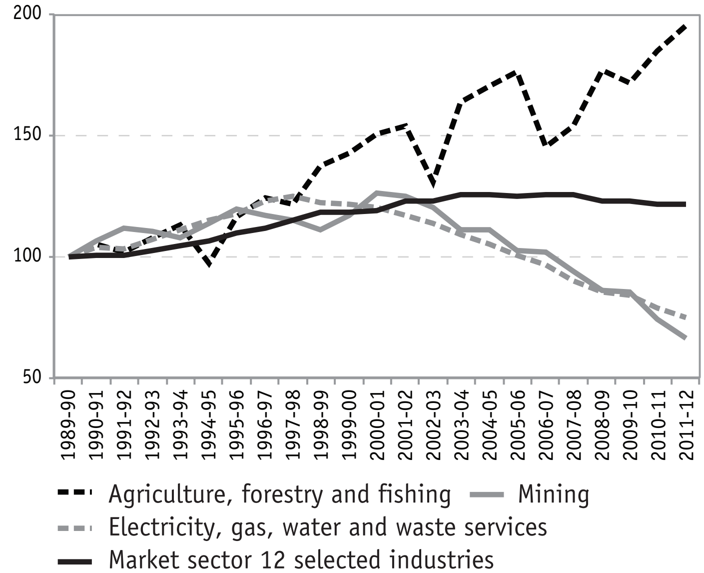
Declines in MFP growth that are the result of a decline in the availability or quality of a natural resource input do, however, reflect a real increase in the costs of production.[2] Hence, while this decline in MFP does not reflect technical regress, it does reflect a decline in the output that can be produced by the economy (all else equal). This can be interpreted as a loss in productivity that is not caused by a loss in productive efficiency. Rather it is caused by a decline in natural resource inputs.

There are three main reasons why the quality or quantity of natural resources available as inputs to production can change: natural variability;[3] depletion through use or natural processes; and diversion to competing uses.

**Chart 1**

**Multifactor Productivity Growth in Australia[a]**

Indexes (1985-86=100)




a The MFP estimates are based on value added rather than gross output (see Box 1). The market sector consists of 12 selected industries (ANZSIC06 Divisions A to K and R).

Source: ABS 2012b.

2 Note that measures of productivity do not provide any information about allocative efficiency – whether the allocation of resources to production is optimal in terms of maximising national income. Productivity focuses only on the supply side – the production of goods and services – and not on whether these are the goods and services that best meet demand. Since welfare depends on price effects as well as volume changes, the use of MFP as an indicator of welfare or broader economic health has obvious limitations.

3 Natural variability is often temporary, but can reflect long-term trends. Moreover variability in unmeasured resource inputs can be positive as well as negative – for example, a sustained period of higher than average rainfall provides an effective increase in the quantity of unmeasured natural resource inputs used in agriculture, and this would generally have a positive effect on conventional measures of MFP for this industry.

## Box 1 Multifactor Productivity Growth Measurement

The Australian Bureau of Statistics (ABS) generates estimates of industry MFP using a conventional growth accounting framework outlined in ABS (2007, 2012a) and Zheng (2005), and recommended by the OECD (2001). Underlying the approach is an assumed production function:

$$Y_t = A_t f(K_t, L_t, I_t) \quad (1)$$

where $Y_t$, $K_t$, $L_t$, and $I_t$ represent output, capital, labour, and intermediate inputs (energy, materials and services inputs) in year *t* respectively, and $A_t$ represents multifactor productivity in year *t*.

After differentiating equation (1) with respect to time and making a number of assumptions regarding the underlying production function, $f$, the ABS derives an index of MFP growth that is calculated from the equation:

$$ln\left(\frac{A_t}{A_{t-1}}\right) = ln\left(\frac{Y_t}{Y_{t-1}}\right) - S_K ln\left(\frac{K_t}{K_{t-1}}\right) - S_L ln\left(\frac{L_t}{L_{t-1}}\right) - S_I ln\left(\frac{I_t}{I_{t-1}}\right) \quad (2)$$

where $Y$, $K$, $L$ and $I$ are as above, and $S_K$, $S_L$, and $S_I$ are weights used for each input type reflecting their contributions to total industry income (and which collectively sum to 1).

MFP growth is thereby calculated as a residual, and reflects that part of the change in output from one year to the next that cannot be explained by the observed change in inputs.

When MFP growth is negative, it implies a decline in the efficiency of production – that is, an increase in the overall quantity of inputs is required to produce each unit of output – and vice versa.

The ABS also produces an alternative measure of MFP which uses real value added (real gross output minus real intermediate inputs) as the output variable, with only labour and capital inputs appearing explicitly in the production function as inputs. The findings reported in this article are general and applicable to both measures of MFP.

Whether any of these have a material impact on MFP estimates is dependent on the particular situation. The three industries provide some good examples of the contingent nature of this issue.

This article explores these issues in more detail, beginning with why, when there are significant natural resource inputs, the methodology used by the Australian Bureau of Statistics (ABS) to estimate MFP growth can be an inaccurate measure of technical progress. The following sections examine the role of natural resource inputs in the three industries and why they are changing, and the effect that these changes have had on measured productivity growth in these industries. The final section explores possible implications for productivity measurement.

## How MFP is Measured

The ABS uses what is commonly known as the 'growth-accounting' approach to derive estimates of MFP. Under this approach, the annual rate of MFP growth is measured as a residual — that is, it is the difference between the growth rate of output and the growth rate of (measured) inputs. Both output and inputs are measured in volume or quantity terms, and are represented using index numbers. (Box 1 contains more information on the growth accounting approach.)

The standard interpretation of MFP growth is that it captures *disembodied technological progress*, such as improvements in the way businesses organize their production processes that allow them to reduce input requirements per unit of output, or to produce a greater quantity of output from a given quantity of inputs (ABS 2012a:429). In practice, however, the conventional growth accounting estimates of MFP reflect the combined influence of any number of factors that might lead to a difference between measured output growth and measured input growth during a particular year or period. According to the OECD, many factors other than technology are reflected in the MFP residual, including adjustment costs, scale and cyclical effects, pure changes in efficiency, and measurement errors (OECD 2001:20).

## The Problem of Unmeasured Inputs When Measuring Technical Progress

To the extent that some important natural resource inputs are either mismeasured or not measured at all before estimates of MFP growth are calculated, greater caution is needed in interpreting changes in MFP as measuring 'technical progress'.

In this case, better estimates of technical progress could be obtained by directly accounting for any changes in the quantities of natural resource inputs used in production before the productivity residual is calculated. This would remove the influence of fluctuations in these inputs from the residual so that it would better reflect technical change (although other sources of change would still be reflected in the residual). A more formal description of such a process is outlined in Box 2.

An adjustment such as this would make the resulting MFP estimates better indicators of technical progress, but the trade-off would be that they no longer accurately reflect 'real costs.' That is, they would no longer indicate changes in the average quantities of *purchased* inputs (capital, labour and intermediate inputs) used to produce each unit of industry output.

## The Scope of the Effect

As mentioned, natural resource input quantity and/or quality can change through natural variability, depletion through use or natural processes, and diversion to competing uses. Both non-renewable resources (such a mineral deposits) and renewable natural resources (such as fisheries) can have natural variability. Both can also be depleted by use, but for renewable resources this can be prevented if the resource is used at sustainable levels. Non-renewable resources, on the other hand, by definition will be depleted, although the impact on the quantity and quality of remaining resources available to industry will depend on the rate of discovery relative to use.

Regardless of whether a resource is renewable or not, the use by industry can be restricted if the resource is diverted to other uses. At an economy-wide level this affects productivity mainly if it reduces their use in the market economy.[4] Where there are competing non-market uses of the inputs, the main source of change is when governments introduce (or increase) restrictions on the use of the resource by industry.

Examples of the natural resource inputs that are important to production in each of the three industries are provided below. While all of these inputs are similar in the sense that they are 'unmeasured' inputs to production in the respective industries, they are quite different in regard to the reasons why their use in production can change over time.

### Agriculture, Forestry and Fishing

Rainfall is an important unmeasured input to production for most, if not all, activities in this industry. Although rainfall is a renewable input, its quality or effectiveness as an input

4 If a resource is diverted to another industry, then one industry's loss is another's gain and productivity is only affected to the extent that the use of the resource in the industries makes a different contribution to the overall volume of production.

**Box 2 MFP Growth Estimates When Resource Inputs are Significant**

For industries that use significant quantities of natural resource inputs in production a more realistic production function would be:

$$Y_t = A_t f(K_t, L_t, I_t, R_t) \quad (3)$$

where $Y_t$, $K_t$, $L_t$, $I_t$ and $A_t$ are as defined in Box 1, and $R$ represents the volume of inputs of natural resources and/or environmental services used in production. An index of MFP growth would be derived as:

$$ln\left(\frac{A_t}{A_{t-1}}\right) = ln\left(\frac{Y_t}{Y_{t-1}}\right) - S_K ln\left(\frac{K_t}{K_{t-1}}\right) - S_L ln\left(\frac{L_t}{L_{t-1}}\right) - S_I ln\left(\frac{I_t}{I_{t-1}}\right) - S_R ln\left(\frac{R_t}{R_{t-1}}\right) \quad (4)$$

where $Y$, $K$, $L$, $I$ and $S_K$, $S_L$, and $S_I$ are as defined in Box 1, and $S_R$ is a weight commensurate to the contribution of these inputs to total industry income.

In principle, the MFP growth estimates derived from equation 4 would better reflect "true" technical progress in industries where inputs of $R$ make up a significant share of total inputs, compared with the estimates from equation 2 in Box 1.

Note that the measurement issue of concern is not just whether inputs of $R$ are large relative to conventionally measured inputs, but whether they are both large and changing over time relative to aggregate inputs of $K$, $L$ and $I$. If inputs of $R$ are constant over time as a share of total inputs, then omitting $R$ from the production function will not influence the estimated growth rate of MFP. In this case, there are no implications for the measurement and interpretation of MFP growth. However, when quantities of R are changing over time relative to conventionally measured inputs, the MFP growth estimates derived from equation (4) will differ from those derived from equation (2) in Box 1. In this case, equation (4) is a better estimate of technical progress than equation (2).

Note also that measuring the quantity of natural resource inputs, $R_t$, used in production (and the associated weight, $S_R$) is likely to be a non-trivial exercise. Diewert (2001), for example, listed the problem of accounting for natural resource inputs as one of a number of challenges for productivity measurement and interpretation that is still to be resolved.

A simple illustrative example of how the quantity of natural resource inputs might be measured in practice is to consider the case of agriculture, where $R_t$ might be proxied by annual rainfall (noting that variability in other seasonal conditions also influences annual variability in production). Estimating the corresponding contribution of rainfall to industry income ($S_R$) is more complicated and is not attempted here. We note, however, that in the standard growth accounting model $S_R$ is effectively captured within $S_K$, as the latter is derived as a residual and thereby reflects the (percentage) contribution to industry income of all inputs to production other than $L$ and $I$, including any non-measured natural resource inputs. In general, introducing natural resource inputs to the model should reduce $S_K$, but leave $S_L$ unchanged.

fluctuates over time due to natural variations in its quantity. Too little rainfall is usually the more serious concern, but too much rainfall leading to flooding or water-logging, or rain at the wrong time, can also reduce industry output with adverse implications for MFP.[5]

5 Major adverse weather events also affect other industries, such as the impact of the 2011 floods on coal mines in Queensland. As large water users, industries like mining and utilities can also be adversely affected by prolonged droughts, either because of reduced output growth (for example, reduced hydro-electricity production), or because of higher costs associated with the need to buy water.

Note that rainfall is not the only natural resource input that is important to production in AFF. For example, the weather more generally, including cyclones, heatwaves and frosts, contributes to volatility in the effective contribution of natural resource inputs to production.

Other natural resource inputs are also important in AFF. For example, land/soil is a critical natural resource input, although the quantity of services it provides over time is likely to be much less variable than that provided by rainfall. Underlying fish and forestry stocks are also key determinants of production in these sub-sectors. Studies of productivity growth in fisheries often include estimates of fish stocks directly into the underlying production function in recognition of the role they play in explaining changes in output over time (see for example, Fox *et al.*, 2003).

Ultimately, variations in the services provided by any of these *unmeasured* inputs will be reflected in the estimates of MFP growth in AFF.

### Mining

In the case of mining, the key unmeasured natural resource inputs used in production are the underlying deposits of mineral and energy resources being mined. Examples include coal seams, oil and gas fields, and deposits of metal-ores and raw minerals. No amount of conventionally measured inputs – labour, capital, materials, etc. – can produce a ton of coal or a barrel of oil without a coal seam or an oil deposit from which to extract it. These 'environmental goods' are therefore essential inputs to production, and are non-renewable in nature.[6]

Importantly, the average quality of mineral and energy deposits being exploited is not constant over time, but tends to decline with cumulative extraction.[7] In general, better quality resource deposits, such as those that are more accessible, of higher quality or grade, or closer to markets and existing infrastructure, are exploited first (as they generate higher profits), before miners move on to the next best quality deposits. Box 3 explains the quality attributes of resource deposits in more detail.

In the productivity measurement framework, any change in the quality of an input is synonymous with a change in the quantity of the input. Hence, a decline in the average quality of resource deposits being mined should be considered to be a reduction in the average quantity of inputs these deposits are providing.

Absent true improvements in mining technology, the general decline in the quality (cost characteristics) of resource deposits being exploited over time places upward pressure on the quantities of conventionally measured inputs needed to produce each unit of output. This has adverse effects on mining MFP growth.

The negative influence on mining MFP of declining resource quality is likely to be more pronounced during periods of higher output prices, as it becomes economical to mine less-productive (higher unit-cost) deposits. This is an important point to consider in interpreting the current decline in measured productivity in the Australian mining industry. The opposite is also true: if commodity prices drop sharply, mining firms are likely to cut back on production costs by closing or reducing output at less productive (and hence less profitable) mines and deposits, and this would have a positive effect on MFP growth.

### Utilities

In the case of utilities, the unmeasured natural resource inputs used in production largely come

6 New deposits of mineral and energy commodities occur naturally, but at a time scale (millions of years) that is too slow to consider these resources 'renewable'.

7 The discovery of large, high-quality deposits could temporarily increase the average quality of mines in production. Ultimately however, it is more likely that new discoveries will attenuate but not eliminate the long-term decline in the average quality of mineral and energy deposits being mined.

**Box 3 Quality Attributes of Mines and Mineral, Oil and Gas Deposits**

The quality attributes of mines and resource deposits that influence measured production costs (and hence MFP) include:

- the remoteness of deposits, including their distance from infrastructure and markets for inputs and outputs;
- the depth of oil and gas fields below the surface, whether onshore or offshore;
- the depth and nature of overburden above coal and other mineral deposits;
- quality parameters including grades, milling or processing characteristics, and the extent of any impurities;
- the flow rates of oil and gas fields; and
- the complexity of surrounding terrain.

Ultimately, these factors play a large part in determining the quantities of labour, capital, and intermediate inputs needed to produce each unit of industry output.

Source: Topp *et al.* (2008).

in the form of renewable environmental services inputs. There are three main types:

- Water catchments and their associated creeks and rivers provide inputs to production in the water industry through their role as sites for the capture, storage, and delivery of urban drinking water and rural irrigation water.
- Waterways and oceans provide inputs to the water industry through their use as sinks for the disposal of waste-water. Note that the more polluted the waste-water being discharged, the greater will be the effective quantity of inputs (in the form of waste assimilation services) provided by the environment.
- The electricity supply industry derives inputs to production from the atmosphere (air) by using it as a sink for the disposal of waste products, most notably carbon dioxide. Again, the more polluted the waste material, the greater the effective quantity of inputs (in the form of waste assimilation services) provided by the environment.

Although not as straightforward to conceptualize as 'inputs' compared with the examples of rainfall in agriculture, forestry and fishing or coal deposits in mining, the three environmental services listed above are just as important to production in the utilities industry as conventional inputs. Without these inputs, production would either be impossible – no dam site, no reliable water supply for example – or would require businesses to incur significant additional costs. For example, if CO2 could no longer be discharged directly into the atmosphere, fossil-fuel based electricity generators would require some other means of disposal, such as a carbon capture and storage facility. The latter would almost certainly come at a much greater cost (in terms of conventionally-measured inputs) compared with simply releasing waste material directly into the atmosphere. (In some productivity studies, the issue of pollution is viewed as an unmeasured negative output, rather than an unmeasured input of waste assimilation services by the environment. Both approaches lead to the same conclusion regarding the interpretation of conventional MFP estimates. See Box 4).

### Drivers of change in the use or availability of environmental inputs

There are a number of reasons why the quantity (or quality) of natural resource inputs being

### Box 4 How to Treat the Issue of Pollution?

In some studies of productivity growth in the water and electricity sectors, the issue of pollution is viewed as an unmeasured 'quality of output' issue, rather than as an unmeasured 'quantity of inputs' issue (see, for example, Murtough *et al.*, 2001). In the former approach, pollution is treated as a negative output, so that a reduction in pollution is treated as an increase in the volume of industry output, and vice versa.

Characterizing the use of the environment to dispose waste material as an unmeasured inputs issue (rather than an unmeasured quality of output issue) permits the use of the same conceptual framework – the introduction of a single new input term $R$ to the production function, as described in Box 2 – for all three industries. The alternative would be to add an adjusted output term to equation (3) in Box 2 to account for changes in the amount of pollution being generated in the utilities industry, and to limit the $R$ term to covering the examples of rainfall in agriculture, forestry and fishing, and resource deposits in mining.

Whatever the treatment, the implications for MFP are the same: conventional estimates of MFP growth will be negatively biased indicators of true technology change if pollution is reduced, and vice versa. This is because, depending on how the issue is viewed, either input growth is overstated (because the reduction in the use of environmental inputs is ignored, while any increase in the use of conventional inputs is counted), or because output growth is understated (because the reduction in a negative output is not counted).

used in utilities production might decline over time relative to the quantity of conventionally measured inputs. In relation to unmeasured waste-assimilation services provided by the environment, there are limits to the maximum quantity of waste material that can be safely assimilated on a renewable basis. Once these limits are reached, producers will need to find alternate ways to process and dispose of waste material. To the extent that these alternatives require greater inputs of capital and labour inputs the consequence is lower measured MFP than would otherwise be the case.[8]

In relation to the inputs to production that are provided by dam sites, there are two issues that have implications for conventionally measured productivity. First, the addition of new dams will tend to be adverse for MFP growth on the basis that the quality (cost characteristics) of dam sites is not distributed uniformly, and the best sites tend to be developed first.[9] Absent true technical progress in dam construction and operation, the conventionally measured costs of supplying water from dams will tend to increase over time because new dam sites will be less 'productive' (on average) than those that have already been developed.

Second, because there are natural or physical limits on the number of sites that are suitable for the construction of new dams, once *all* such sites have been developed it will only be possible to

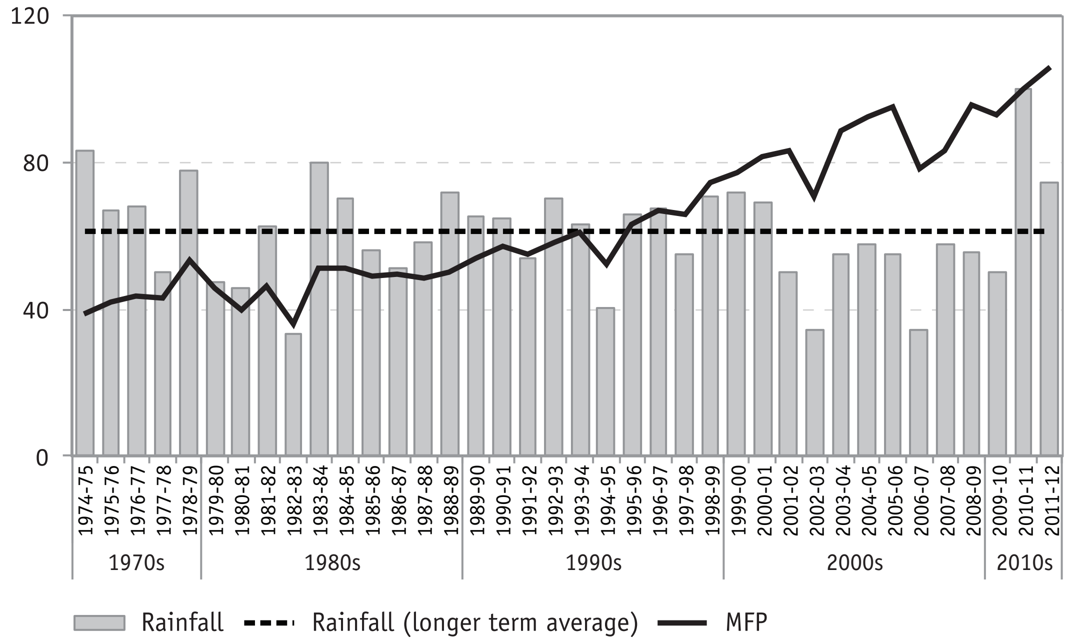
8 Note that exceeding the maximum sustainable capacity of the environment to assimilate waste might jeopardise the ability of the environment to provide a given quantity of waste-assimilation services on a renewable basis. This is similar in principle to the maximum sustainable yield concept in fisheries, whereby overfishing can cause a collapse in the fishery. It is also similar to the issue of land degradation, whereby excessive or inappropriate use of land ultimately causes yields to fall substantially, rather than being sustainable.

9 This is similar to the resource depletion argument in mining, except that individual dam sites provide renewable inputs to production (as long as it rains and river health is not compromised), whereas individual mineral and energy deposits are eventually exhausted. The key point is that new dams tend to be of lesser quality compared with pre-existing dams, in the same way that new resource deposits in the mining industry tend to be of lower quality than previously exploited deposits.

**Chart 2**

**Rainfall in the Murray-Darling Basin and MFP in Agriculture, Foresty and Fishing[a]**

Index 2010-11=100




a MFP is measured on a financial year basis (1 July to 30 June), while rainfall is measured on a calendar year basis. For comparison, rainfall in calendar 1974 is labelled 1974-75 and so on.

Data source: ABS 2012b; APC estimates; and Bureau of Meteorology, (http://www.bom.gov.au/web01/ncc/www/cli_chg/timeseries/rain/0112/mdb/latest.txt)

increase industry output by switching to alternate supply technologies. To the extent that the latter require greater quantities of *measured* inputs per unit of water supplied, any shift to non-dam sources of supply will be adverse for conventionally measured MFP growth.[10]

### Policy and/or regulatory changes can also influence the use of natural resources in production

Apart from natural or biological limits, the quantity of natural resources used as inputs to production in utilities is influenced by policy or regulatory changes that alter the conditions of access to environmental services. A good example is the adoption of stricter pollution standards, which effectively reduce the extent to which utilities businesses can utilize the capacity of the environment to assimilate waste material. To the extent that any changes to policy or regulatory settings ultimately require businesses in utilities to adopt production technologies that are higher-cost (in terms of conventionally measured inputs) and less intensive in the use of 'unmeasured' natural resource inputs, the impact on measured MFP will be negative.[11]

10 At least until such time as non-dam sources have become the dominant sources of water supply. At this point, MFP growth in the water supply sector should more closely reflect any 'true' efficiency improvements in the dominant supply technologies of the time – desalination or water recycling, for example.

11 Reducing the use of the environment as an input to production (such as by ceasing to dump waste material in rivers and waterways, or cutting emissions of CO2 to the atmosphere) may, of course, be highly desirable from a social welfare point of view if the gain to the community from this outcome exceeds the cost (part of which is reflected in the decline in measured industry productivity).

## The Scale of the Effect

Some recent research provides quantitative and qualitative evidence that the problem of unmeasured changes to the quantity and/or quality of natural resource inputs being used in production has played a major role in explaining recent periods of negative MFP growth in agriculture, foresty and fishing (AFF), mining and utilities. Each industry is considered in turn.

### Agriculture, forestry and fishing

In the case of agriculture, forestry and fishing, changes in rainfall inputs can be substantial from year to year, although there is less variability over the long term. The implication is that the impact of changes in rainfall on industry output will usually be observed in short-term (1-2 years) estimates of MFP growth, but will have less of an impact on the average rate of growth over a longer period.

The link between annual changes in rainfall and annual changes in MFP is quite strong. In Chart 2, average annual rainfall in the Murray-Darling Basin (MDB) is used as a proxy for aggregate or nationwide rainfall on the basis that the basin is a large and important agricultural region that accounts for just under one half of total industry output (around 40 per cent of total agricultural income and over 50 per cent of the total value of cereals grown for grain).[12]

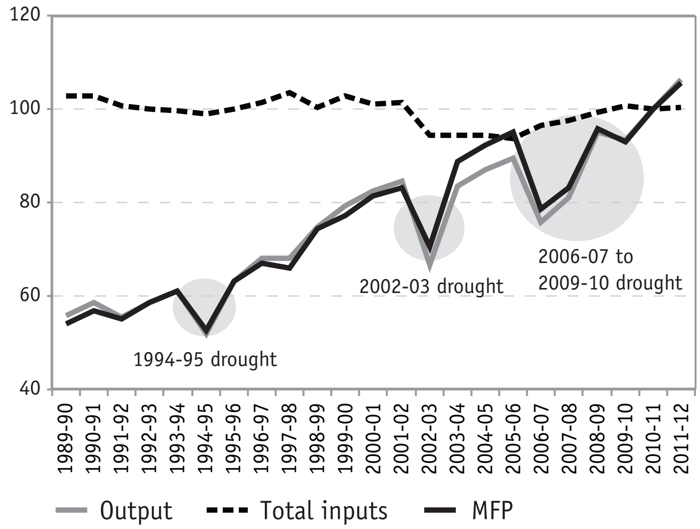
In years when there are widespread and significant declines in average annual rainfall (major droughts), aggregate agricultural output in Australia typically falls sharply, dragging down MFP (Chart 3). While conventionally measured inputs like capital and labour can also fall during major drought years, they do not generally fall by as much as the reductions in output.

Widespread droughts in Australia often last just one year however, and MFP generally recovers all of its 'losses' in the subsequent year. Examples for the 1994-95 and 2002-03 droughts

**Chart 3**

**Inputs, Output and MFP in Agriculture, Forestry and Fishing[a]**

Indexes 2009-10=100




a Note that the MFP series in this figure is value added based MFP, where *output* is real gross value added, and is defined as real gross output (production) less real intermediate inputs, and *total inputs* is defined as the cost-share weighted average of labour and capital inputs, also measured in volume terms.

Data source: ABS 2012b.

are highlighted in Chart 3. Estimates of annual MFP growth are negative in drought years, and rise above trend in drought recovery years.

Because these 'annual' events in agriculture, foresty and fishing tend not to coincide with the beginning or end years of the market sector productivity 'cycles' (which are chosen to help smooth out the adverse influence of fluctuations in the business cycle on the utilization of capital and labour inputs), they usually do not affect the economy-wide MFP results over the productivity cycle.[13]

However, the extended period of below-average rainfall from 2006-07 to 2009-10 kept strong downward pressure on agricultural MFP over multiple years, and ultimately contributed to the below average MFP result for the market

12 See Murray-Darling Basin Authority (http://www.mdba.gov.au/explore-the-basin/about-the-basin).

**Table 1**
**Estimates of the Impact on Mining MFP of Resource Depletion**
(Average annual growth rates)

| Study | Time period covered | ABS estimate of MFP<br>% pa | MFP adjusted for resource depletion: (proxy for the rate of technical progress)<br>% pa |
|---|---|---|---|
| Topp, Soames, Parham and Bloch (2008) | 1974-75 to 2006-07 | 0.01 | 2.50 |
| Zheng (2010) | 1974-75 to 2006-07 | 0.01 | 1.15 |
| Loughton (2011) | 1985-86 to 2009-10 | -0.15 | 2.05 |

sector as a whole during the most recently completed productivity cycle – that is, the cycle which ran from 2003-04 to 2007-08. In this case the influence of rainfall on measured productivity in agriculture, forestry and fishing was more pervasive.

### Mining

In the case of mining, recent research suggests that the ABS estimates of industry MFP are strongly influenced by unmeasured changes in natural resource inputs (see Topp *et al.*, 2008; Bloch and Zheng, 2010 and Loughton, 2011). Although the papers use different approaches to quantify the size of the effect, the results are consistent and unambiguous: a decline in the average quality of resource inputs into mining is responsible for a large share of the poor MFP growth in the industry. In this situation the ABS estimates of MFP in the mining industry are strongly negatively biased indicators of technical progress when viewed over the longer term (Table 1).

Importantly, the influence of resource depletion on the ABS estimates of MFP need to be adjusted for temporal changes in the average quality of deposits being mined *if* they are to be used as indicators of technical progress in this industry. The studies noted above provide alternative approaches to making such adjustments.

### Utilities

Major policy and preference shifts during the last 10 to 15 years have combined with the natural pressures arising from a rapidly growing population to substantially reduce the quantity of environmental services available to this industry. As a result there has been an increase in the rate of growth in conventionally measured inputs (labour, capital, and intermediate inputs) per unit of industry output (see Box 5).

A recent staff working paper published by the Australian Productivity Commission found that these developments contributed to strongly negative MFP growth in utilities between 1997-98 and 2009-10 (Topp and Kulys, 2012). In the water sector, the data showed strong growth in investment in tertiary waste-water treatment plants over the period, as well as the construction of high-cost sources of new water supply.

13 See ABS (2011) for a discussion of how the market-sector productivity cycles are determined. Note that productivity cycles identified specifically for the agriculture industry are generally different from the cycles identified for the market sector as a whole. For more information on industry-specific cycles, see Barnes (2011:XVIII). Despite the variability, Australia includes agriculture, foresty and fishing in its economy-wide estimates of MFP. However, in some countries agriculture is excluded from aggregate productivity statistics due to the impact of climatic variation on annual output.

Box 5 Policy and Preference Shifts in the Utilities Sector

The operating environment of water and electricity businesses has changed in three fundamental ways during the last 10 to 15 years. First, a paradigm change in thinking within the Australian urban water industry led to a cessation in the construction of new urban water dams, and a shift to the construction of manufactured water alternatives, such as desalination and recycled water plants. In effect, the industry moved from having an almost complete dependence on a production technology dependent on natural resource inputs (rain-fed dams), to a much greater reliance on supply technologies that used greater quantities of conventionally measured inputs (desalination and water recycling plants).

The shift to manufactured water technologies was partly in response to an urgent need for new urban water supplies in Australia to meet the demands of a rapidly growing population, and to counteract the adverse effect on existing water supplies of an unexpectedly long period of below-average rainfall. However, it was also a response to growing community opposition to the construction of new dams, largely on the basis that their environmental costs were too high. In some states, natural limits on suitable sites for new dams had also been reached, contributing to the speed and scale of the move to non-dam supply technologies like desalination and recycling.

Second, regulatory changes during the period increased the minimum standards of wastewater treatment in Australia. This led to the construction of new or augmented water treatment plants. As with water supplies, a growing population had increased the demand for wastewater disposal services, and there was growing concern regarding the environmental impact of continuing to rely on conventional treatment methods, particularly the use of coastal outfalls. The shift toward tertiary treatment of urban wastewater reduced the use of the environment as an input to production, but increased requirements of conventionally measured inputs.

Third, changes in energy policies in response to the threat of climate change led to an increase in the share of electricity being supplied via renewable and gas-fired power stations, and a concomitant decrease in the share of output coming from coal-fired power stations. The cut in allowable pollution lowered the use of natural resources (the atmosphere) as an input to production, and increased the average quantity of conventionally measured inputs required per unit of output. Green energy typically requires greater units of conventionally measured inputs per unit of output, compared with coal-fired power.

In all three cases therefore, the reduction in the use of natural resource inputs largely came about as a consequence of policy and/or other decisions that were implemented to address environmental issues, especially water and CO2 emissions. Against the background of rapid population growth, natural limits on the availability of suitable sites for new dams also contributed to the decline in the availability of natural resource inputs, and a large increase in the use of conventionally measured inputs.

Source: Topp and Kulys (2012).

The latter included large-scale desalination plants in five of the six mainland states of Australia.

Topp and Kulys also reported the impact on MFP of the move away from coal-fired electricity generation in Australia between the late 1990s and 2010 due to the higher (conventionally measured) costs of less emissions-intensive power sources. However, unlike mining where some measures of resource quality are available, estimates of the change in these environmental inputs are not available.

The motivations for the shift to higher cost production technologies (in terms of conventional inputs) vary. In the case of the shift to lower carbon emission power generation, Topp and Kulys cite climate-change policies and initiatives. In the water sector, the shift to more labour- and capital-intensive production technologies was necessary to meet 'the requirements of government policies on, among other things, water security, the management of environmental impacts associated with the treatment and disposal of sewage, and the quality of drinking water' (IPART, 2010: 27).

While some of the changes in utilities might have been driven by changes in the quantity of natural resources available (such as rainfall and high quality dam sites), others were driven by government decisions. The latter reflected demand from the community for improved environmental outcomes, such as reducing the impact of sewerage outfalls on Sydney beaches, and reducing carbon emissions. Political promises not to build new dams also had an influence, as did commitments to improve the reliability of electricity and water supplies.[14]

Notwithstanding the fact that some investment decisions made in response to regulatory and other market developments could have been more efficient, the broader shift towards supply technologies that use fewer natural resource inputs would appear to be an unavoidable development for the utilities industry. As noted earlier, there are natural or biophysical limits to the maximum quantity of environmental services that can potentially be used each year by utilities, and growing community concern regarding the appropriateness of certain uses of the environment. This means that future output growth is likely to continue to be based on supply technologies that depend more heavily on conventionally measured inputs (labour, capital, and intermediate inputs), rather than on the 'traditional' technologies that used a combination of measured inputs and significant quantities of unmeasured natural resource inputs.[15]

Assuming that businesses in the utilities industry continue to shift towards the use of supply technologies that require greater quantities of measured inputs but fewer units of (unmeasured) natural resource inputs per unit of output, there will be further downward pressure on measured productivity. This should be borne in mind when assessing short- to medium-term developments in utilities MFP, particularly if interested in the rate of technical progress in the industry.

As new technologies that do not rely on natural resource inputs begin to dominate industry production, the contribution to MFP of declining natural resource inputs will dissipate.[16] In

14 Studies of the urban water sector and the electricity distribution sector by the Australian Productivity Commission have criticized recent investment decisions on the basis that there were cheaper or more efficient ways of dealing with growing demand for power and water that should have been adopted first (APC, 2011 and 2012). To the extent that this is true, some part of the recent decline in measured MFP in this industry is excessive and could have been avoided.

15 In contrast to mining, the generation of output in utilities is feasible using technologies that use little or no environmental inputs (or at least not those that are supply constrained). Moreover, it is possible that all three types of natural resource inputs that are currently used by the utilities industry could eventually be replaced by conventionally measured inputs. For example, desalination and water recycling plants could replace dams as the main source of urban water supply; tertiary treatment plants could substantially reduce the use of the environment to assimilate waste-water; and a carbon-free electricity sector could eliminate the use of the atmosphere as a sink for $CO_2$.

16 This will also be the case if natural resource inputs become 'market' inputs, and hence are measured explicitly as inputs. For example, as carbon pricing is introduced, what is effectively a free input becomes a priced input (in the form of a carbon permit), and hence is measured as an input in the conventional MFP framework.

this scenario the MFP estimates for utilities will eventually better reflect the technical progress in the industry.

## Where To From Here?

In AFF, mining, and utilities changes in the quantities of unmeasured natural resource inputs used in production have had a significant impact on industry MFP over the last decade. This effect of declining natural resource inputs is likely to be much smaller, if at all, in other industries simply because no other industries are as reliant on these types of inputs.[17]

The effect of changes in natural resources inputs on value added is captured in the ABS estimates of MFP, along with the contributions to productivity of technical progress and other sources of changes in output other than changes in the inputs of capital and labour. Adjusting for the change in natural resource inputs is useful for estimating the impact that these changes have on productivity. Such an adjustment would also mean that estimates of MFP (adjusted) more closely measure technical progress.

But making such adjustments is easier said than done. Part of the reason is that the inputs in question are, unlike labour, capital and intermediate inputs, not generally traded in markets. This makes it virtually impossible to gather reliable information on their use in production in a way that could be readily incorporated in the standard growth accounting framework. Accordingly, unpacking the broader industry trends in MFP will remain an important means of understanding these sources of changes in productivity.

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# An Analysis of Productivity Trends in the Canadian Forest Products Sector, 2000-2012

Ricardo de Avillez[1]

Abstract

The 2000-2012 period was a difficult time for the Canadian forest products sector. Yet despite an unfavourable environment the sector experienced an above-average productivity performance, driven in particular by the wood product manufacturing subsector. While the forestry and logging subsector has also benefited from strong productivity gains, the productivity performance of the paper manufacturing subsector has been far from impressive, especially in the post-2008 period. This article provides a detailed analysis of output, input and productivity trends in the Canadian forest products sector. It also looks at the key drivers of productivity in the sector, investigating potential barriers to productivity growth and discussing policies that could enable faster growth. Given the increasing role of countries with low-labour costs in several forest product markets, maintaining robust productivity growth is an imperative for the Canadian forest products sector if it wants to remain competitive internationally. In this sense, the article recommends renewed focus on human and physical capital investment, as well as on R&D spending.

Productivity improvements allow firms to produce the same quantity of output by using fewer inputs, which reduces costs.[2] However, the sector's competitiveness depends not only on productivity but also on other factors, such as exchange rates and input costs. The competitiveness of Canada's forest products sector has suffered greatly due to a strong Canadian dollar and high labour costs, which make it harder for the sector to compete internationally with low-wage countries such as Russia, China, and Brazil. In fact, even when compared to other developed countries, Canada's labour costs are quite high.

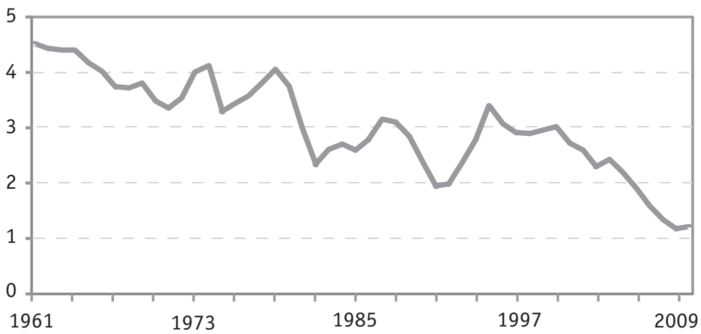
It is unlikely that labour costs in the Canadian forest products sector will experience a significant fall. Aside from nominal (downward) wage rigidities, which are observed in most sectors of the economy, it seems to be a consensus among forest product firms that the sector faces problems related to skill shortages.

Productivity gains can help by reducing the sector's need for labour input, thus reducing

1 Ricardo de Avillez was a senior economist at the Centre for the Study of Living Standards (CSLS) when the research for this project was undertaken. The author would like to thank CSLS Executive Director Andrew Sharpe and Jean-Francois Larue, Chief Economist at the Forest Products Association of Canada (FPAC) for comments. The CSLS would like to thank FPAC for financial support for this research. This article is an abridged version of de Avillez (2014). Email: csls@csls.ca.

2 This article discusses two productivity measures: value-added labour productivity and value-added multifactor productivity.

**Chart 1**
**Nominal GDP in the Forest Products Sector as a Share of Total Economy GDP, 1961-2010**
(per cent)




Source: CSLS calculations based on Statistics Canada data.

**Exhibit 1**
**The Forest Products Sector**
(subsectors and industry groups breakdown by NAICS codes)

113 Forestry and Logging
- 1131 Timber Tract Operations
- 1132 Forest Nurseries and Gathering of Forest Products
- 1133 Logging

321 Wood Product Manufacturing
- 3211 Sawmills and Wood Preservation
- 3212 Veneer, Plywood and Engineered Wood Product Manufacturing
- 3219 Other Wood Product Manufacturing

322 Paper Manufacturing
- 3221 Pulp, Paper and Paperboard Mills
- 3222 Converted Paper Product Manufacturing

Source: Statistics Canada (2012).

production costs. By lowering production costs, productivity gains can help Canadian firms to better compete with international firms, and thus regain some of their lost market share.

Much more effectively than other manufacturing industries, the Canadian forest products sector has managed to soften the blow of rapidly rising unit labour costs with major productivity gains. In order to increase competitiveness, the Canadian forest products sector must maintain high rates of productivity growth.

The objective of this article is to understand these productivity trends in the Canadian forest products sector, emphasizing recent developments in labour and multifactor productivity. The article builds on and expands previous CSLS research on the subject, in particular Harrison and Sharpe (2009) and Sharpe and Long (2012).

This article is organized into four sections. The first section defines the forest products sector and discusses the output and input trends experienced by that sector. The second section details recent productivity developments in the forest products sector. The third section examines the drivers of productivity growth in the forest products sector. The fourth (and final) section concludes.

## An Overview of the Canadian Forest Products Sector[3]

### The Forest Products Sector

The forest products sector, as it is defined in this article, is not identified by a single two-digit NAICS sector or by a single three-digit NAICS subsector; rather, it encompasses three NAICS subsectors, each of which includes different activities related to forest products: forestry and logging; wood product manufacturing; and paper manufacturing. A more detailed breakdown of all the activities included in the forest products sector can be seen in Exhibit 1.

### Output

#### Nominal GDP

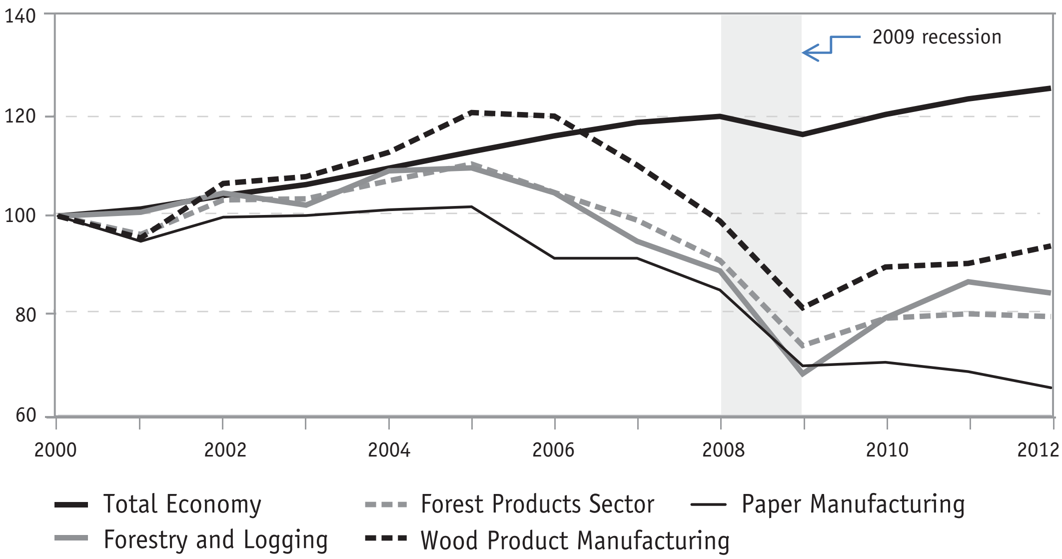
The Canadian forest products sector generated $18,752 million in nominal value added in 2010, accounting for 1.2 per cent of Canada's GDP. Of its three subsectors, paper manufacturing was the largest, responsible for $8,519 million or 45.4 per cent of the value added of the forest products sector. The subsector with the

3 This article makes extensive use of official productivity estimates from Statistics Canada's Canadian Productivity Accounts (CPA). The CSLS has made small adjustments to the official data, which are highlighted in the unabridged version of the article. A database containing the underlying data used in this article is posted at www.csls.ca/res_reports.asp

**Chart 2**

**Real GDP in the Forest Products Sector, 2000-2012**

(index, 2000=100)




Source: CSLS calculations based on Statistics Canada data.

second largest value-added share was wood product manufacturing ($6,809 million or 36.3 per cent), followed by forestry and logging ($3,424 million or 18.3 per cent).

Three provinces accounted for 80 per cent of the nominal value added generated by the forest products sector in 2009: Quebec (31.2 per cent), British Columbia (25.5 per cent), and Ontario (24.1 per cent). In addition, the province of Alberta was responsible for 9.3 per cent of the forest products sector's nominal value added.

During the 2000-2008 period, while Canada's economy grew 5.3 per cent per year in nominal terms, nominal value added in the forest products sector fell 4.8 per cent per year. This fall was largely caused by wood products and paper manufacturing, both of which saw a decline of 5.4 per cent per year in nominal output.

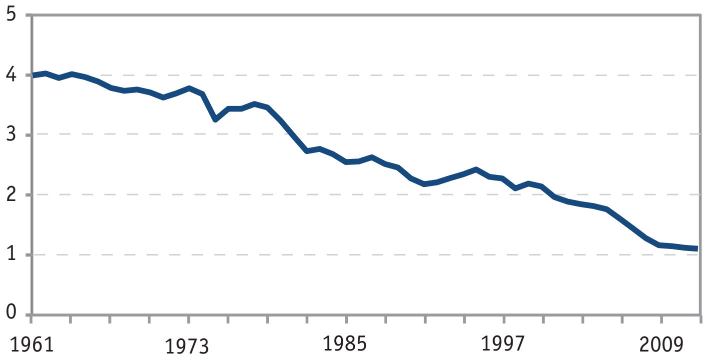
As Chart 1 dramatically illustrates, the nominal value-added share of the forest products sector in Canada's economy has reached its lowest value in 50 years, 1.1 per cent in 2009, down 3.2 percentage points from 4.4 per cent in 1961.

## Real GDP

Real GDP in the forest products sector declined during the 2000-2008 period at a rate of 1.2 per cent per year. During this period, real output in forestry and logging and paper manufacturing fell by 1.4 and 2.0 per cent per year, respectively, while real output in wood product manufacturing remained practically constant. Comparing the sector's real growth with its nominal growth, it becomes clear that, with the exception of the forestry and logging subsector – where prices remained relatively stable – most of the nominal GDP decline in the two other subsectors and in the forest products sector as a whole came from a fall in prices.[4]

4 Prices fell by 3.2 per cent per year in the total forest products sector between 2000 and 2008. In forestry and logging, they fell 0.2 per cent per year. In wood product manufacturing, the declines were much more substantial, at 4.6 per cent per year. Total paper manufacturing also saw siginifcant declines at 3.2 per cent per year.

**Chart 3**
**Number of Jobs in the Forest Products Sector as a Share of All Industries, 1961-2012**
(per cent)




Note: From 1961 to 1997, employment growth in the forest products sector is assumed to be equal to hours growth. Also, total economy employment growth is assumed to be the same as business sector hours growth.
Source: CSLS calculations based on Statistics Canada data.

Real value added of the forest products sector fell significantly during the 2009 recession and, by 2012, the sector's real output level was still well below its 2008 level (Chart 2). For the forest products sector as a whole, real GDP declined 3.0 per cent per year during the 2008-2012 period, with most of this decline accounted for by the paper manufacturing subsector. Chart 2 clearly shows, however, that real output in the forest products sector peaked in 2005 – which is not surprising, given that this was the peak of the U.S. housing market – and started falling well before the 2009 recession.

As the above analysis shows, the last decade has not been kind to the forest products sector. The difficulties in the sector stem from multiple causes, including (but not limited to):

- Decreased U.S. demand for forest products due to the recent housing crisis and the lacklustre economic recovery in the United States;
- The strong Canadian dollar;
- The ongoing migration of readers from newsprint to electronic media; and
- Increased international competition from countries with lower labour costs.

This list, while not comprehensive, highlights the fact that adverse conditions faced by the forest products sector are a reflection not only of transitory factors – such as the strong Canadian dollar or the weak post-2009 economic recovery in the United States – but also of structural changes in the demand for forest products.

## Labour Input

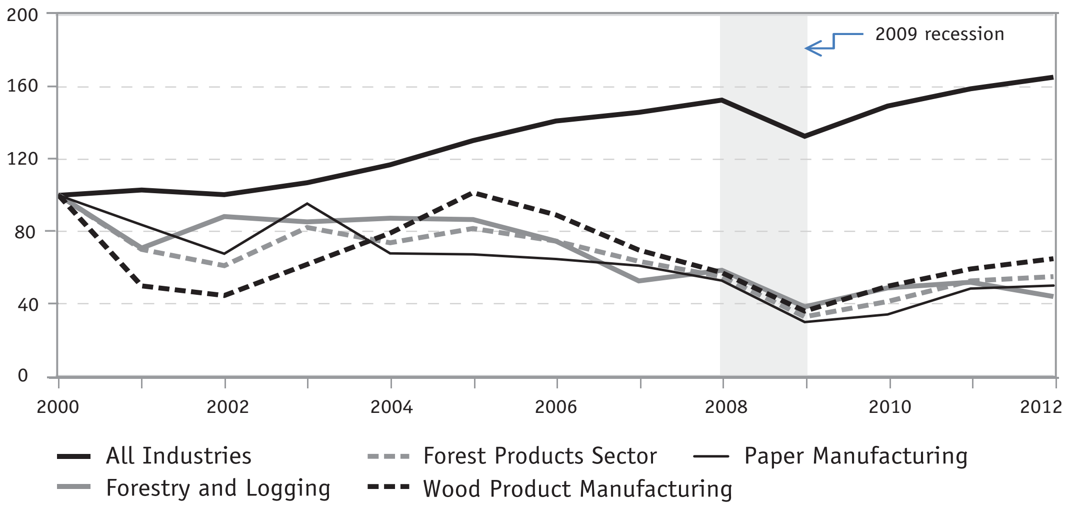
According to Statistics Canada's Canadian Productivity Accounts (CPA) data, there were 199 thousand jobs in the forest products sector in 2012. Wood product manufacturing was the most important subsector in terms of employment, responsible for 97 thousand jobs (or 49 per cent of the total jobs in the forest products sector), followed by paper manufacturing with 68 thousand jobs (34 per cent of the total) and forestry and logging with 35 thousand jobs (17 per cent of the total).

During the 1961-2012 period, the relative importance of the sector in terms of employment fell by three-quarters: it accounted for 4.0 per cent of all jobs in the Canadian economy in 1961, but by 2012 this proportion had fallen to 1.1 per cent (Chart 3).

Employment in the forest products sector declined at a rapid pace of 4.5 per cent per year during the 2000-2008 period, totalling a loss of 101 thousand jobs. In the 2008-2012 period, the rate of job loss fell to 3.0 per cent per year and the sector lost only 26 thousand jobs. Wood product manufacturing and forestry and logging lost jobs at approximately the same rate during the 2000-2012 period, with employment in both subsectors falling by 4.5-4.6 per cent per year, while employment in paper manufacturing fell at a much lower rate of 2.9 per cent per year.

Another point worth highlighting is that the bulk of the job losses observed in the forest

**Chart 4**
**Real Investment in the Forest Products Sector, 2000-2012**
(index, 2000=100)




Source: CSLS calculations based on Statistics Canada.

products sector happened prior to the recession, in the 2005-2008 period. Although employment in the sector lost more ground during the 2009 recession, it became considerably more stable afterwards.

For the purposes of calculating labour productivity, employment is not the best labour input measure available because of changes in average annual hours worked. Table 1 details trends in hours worked in the Canadian forest products sector during the 2000-2012 period. However, over the period, there are few significant differences between the trend industry growth rates for employment and hours worked.

**Table 1**
**Hours Worked in the Forest Products Sector, Detailed Breakdown, 2000-2012**

| | 2000-2012 | 2000-2008 | 2008-2012 |
|---|---|---|---|
| | (CAGR, per cent) | | |
| All Industries | 1.1 | 1.5 | 0.4 |
| Forest Products Sector | -4.2 | -4.6 | -3.3 |
| Forestry and Logging | -4.5 | -4.8 | -3.8 |
| Wood Product Manufacturing | -4.6 | -5.7 | -2.5 |
| Paper Manufacturing | -3.2 | -2.8 | -4.2 |

Source: CSLS calculations based on Statistics Canada data.

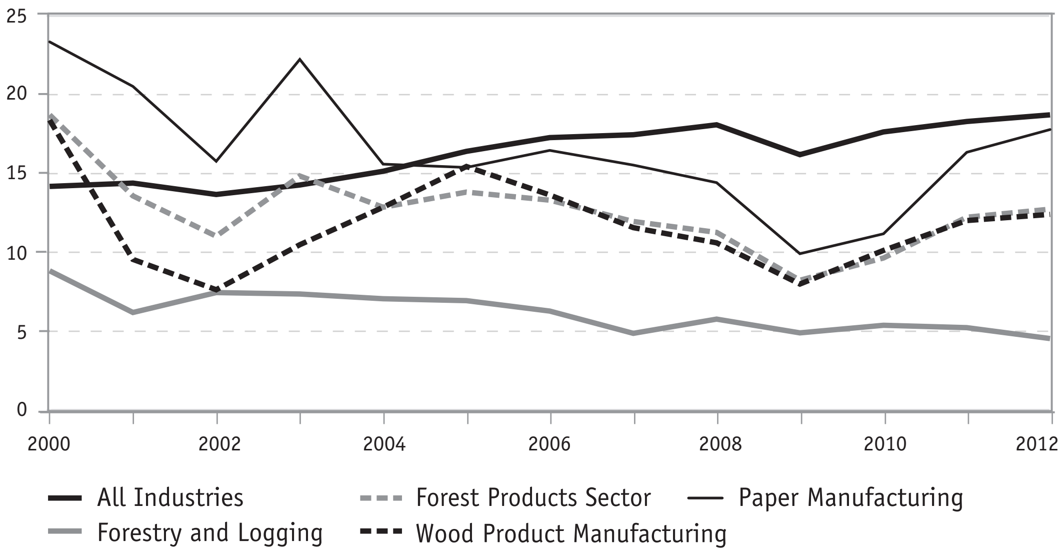
## Capital Input

### Non-Residential Fixed Investment

According to data from Canada's Fixed Capital Flows and Stocks (FCFS) program, real investment (measured in chained 2007 dollars) in the Canadian forest products sector reached $2,395 million in 2012, down 45 per cent from $4,359 million in 2000. The low point of investment in the sector happened in 2009, as a consequence of the recession, with real investment at $1,430 million. By 2012, real investment had already bounced back to its 2008 level (Chart 4). However, real investment only surpassed its pre-recession level in wood product manufacturing. The "sustained" part of the decline in the sector's real investment happened during the 2000-2008 period, a time when total economy investment was growing at a fairly robust pace. In fact, all three subsectors experienced large declines in real investment in the 2000-2008 period.

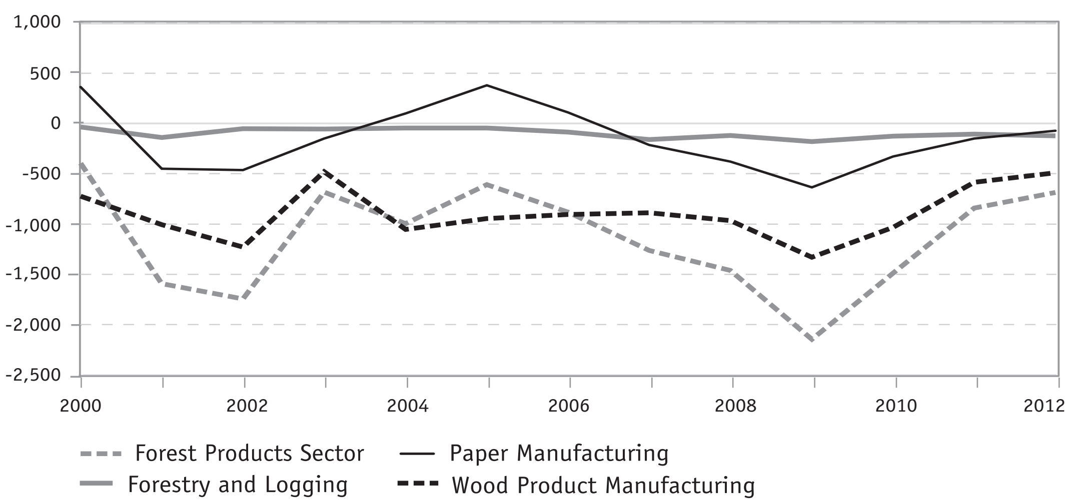
Since GDP in the sector experienced a decline in absolute terms, a fall in real invest-

**Chart 5**
**Real Investment as a Share of GDP in the Forest Products Sector, 2000-2012**
(per cent)




Source: CSLS calculations based on Statistics Canada data.

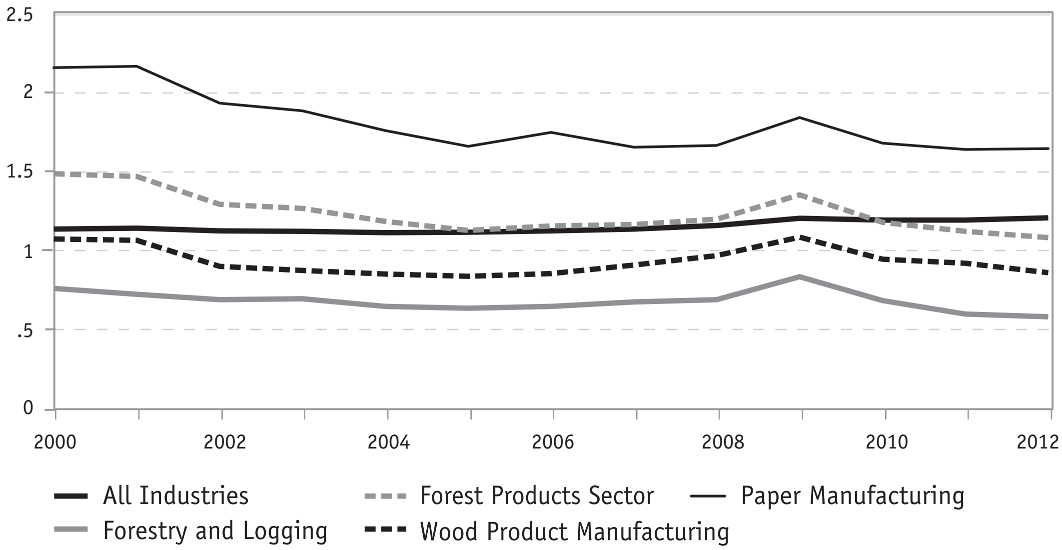
**Chart 6**
**Real Net Investment in the Forest Products Sector, 2000-2012**
(chained 2007 dollars, millions)




Source: CSLS calculations based on Statistics Canada data.

ment would not be unexpected – especially if that fall was approximately proportional to the decline in GDP. The problem, however, is that investment in the forest products sector has fallen considerably more than GDP. As Chart 5 shows, real investment as a share of real GDP in the forest products sector fell 5.9 percentage points during the period, from 18.7 per cent in 2000 to 12.8 per cent in 2012. During the same period, the non-residential

## Chart 7
### Real Capital Stock-to-GDP Ratio in the Forest Products Sector, 2000-2012




Source: Statistics Canada.

fixed investment share of GDP for the total economy actually increased from 14.2 per cent to 18.7 per cent, which highlights the very weak investment performance of the forest products sector in the past decade. These low levels of investment are worrisome, as they suggest that a significant number of firms in the Canadian forest products sector are using outdated capital assets that do not embody the latest technological innovations.

The investment figures discussed so far refer to gross investment. By subtracting depreciation from gross investment, we obtain a measure of net investment, which is investment that increases the overall capital stock. In the case of the Canadian forest products sector, real net investment was negative throughout the 2000-2012 period (Chart 6). In fact, forestry and logging and paper manufacturing had negative net investment during the entire 2000-2012 period, while wood product manufacturing only had positive levels of net investment briefly in 2000 and then in the 2004-2006 period.

### Non-Residential Fixed Capital Stock

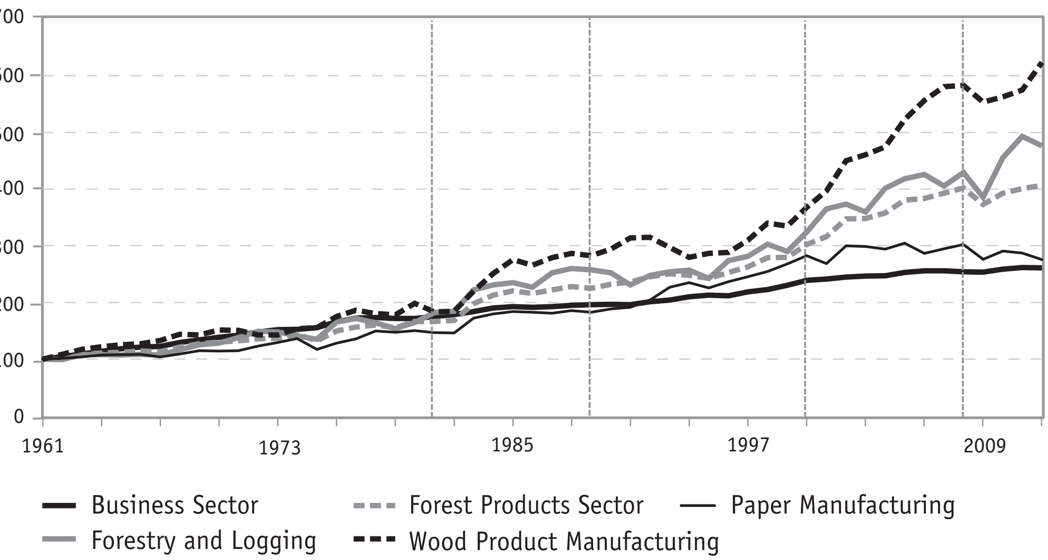
The negative net investment in the forest products sector during the 2000-2012 period led to a marked fall in real capital stock (measured in chained 2007 dollars), which declined at an average rate of 4.4 per cent per year, from $34,685 million in 2000 to $20,299 million in 2012. In recent years, real capital stock in the sector has started to fall at a faster pace (5.5 per cent per year for the 2008-2012 period vs. 3.8 per cent per year for the 2000-2008 period). All three subsectors followed roughly the same trends observed for the forest products sector as a whole, with real capital stock falling during the entire 2000-2012 period, but falling at a faster pace during the 2008-2012 period.

The real capital stock-to-GDP ratio of the forest products sector fell from 1.5 to 1.1 between 2000 and 2012, a period during which the total economy ratio remained fairly stable (Chart 7). Declines in this ratio were observed for all three subsectors: in paper manufacturing, it fell from 2.2 in 2000 to 1.7 in 2012; from 1.1 to 0.9 in wood product manufacturing; and from 0.8 to 0.6 in forestry and logging.

**Chart 8**

**Labour Productivity in the Forest Products Sector, 1961-2012**

(index, 1961=100)




Source: CSLS calculations based on Statistics Canada data.

## Productivity in the Canadian Forest Products Sector

### Labour Productivity[5]

#### Long-Run Labour Productivity Trends

The Canadian forest products sector has had an excellent productivity performance in the last 50 years, outperforming the business sector by far. The sector's labour productivity quadrupled during the 1961-2012 period, while business sector productivity had a much more modest (albeit still significant) 2.5-fold increase (Chart 8).

Between 1961 and 2012, wood product manufacturing saw faster labour productivity growth (3.7 per cent per year) than both forestry and logging (3.1 per cent per year) and paper manufacturing (2.0 per cent per year). During this period, labour productivity in wood product manufacturing and forestry and logging increased (approximately) 6.0 fold and 5.0 fold, respectively. Paper manufacturing, on the other hand, experienced roughly the same labour productivity growth as the business sector, increasing 2.8 fold.

#### Recent Labour Productivity Trends

During the more recent 2000-2008 period, labour productivity increased at an average annual rate of 3.6 per cent per year in the Canadian forest products sector, significantly faster than business sector growth (0.8 per cent) (Table 2).

Labour productivity growth in the forest products sector between 2000 and 2008 was largely driven by wood product manufacturing (5.9 per cent per year), although forestry and logging also benefited from strong productivity gains (3.6 per cent per year). The productivity performance of paper manufacturing, on the other hand, was far from impressive, in line with business sector growth (0.8 per cent per year).

Labour productivity gains in the Canadian forest product sector were negligible in the 2008-2012 period (0.3 vs. 0.7 per cent per year in the

5 Unless noted otherwise, labour productivity is defined here as real GDP (in chained 2007 dollars) per hour worked.

business sector), due largely to productivity losses in paper manufacturing (-2.3 per cent per year). During the period, productivity in wood product manufacturing and forestry and logging continued to improve (1.7 and 2.6 per cent per year, respectively), albeit at a slower pace.

Despite its weak post-2008 labour productivity growth, the Canadian forest products sector had the second highest growth rate for the 2000-2012 period when compared to two-digit NAICS sectors (2.5 per cent per year), only behind agriculture, forestry, fishing and hunting, which experienced an increase of 3.1 per cent per year in labour productivity.

### Provincial and International Comparisons

Driven by its important wood product manufacturing subsector, British Columbia's forest products sector experienced the fastest labour productivity growth among all the provinces for which data were available, at 4.7 per cent per year during the 2000-2012 period, almost double the productivity increase observed by the Canadian forest products sector as a whole. In contrast, Ontario's forest products sector had no labour productivity growth in the period.

The Canadian forest products sector also fared well in international comparisons. Between 2000 and 2007, labour productivity in the forest products sector grew most rapidly in Canada, Finland, Germany and France, at approximately the same rate of 3.8-3.9 per cent per year, in a sample of eight OECD countries (Table 3).

Out of the eight OECD countries, Canada had by far the fastest labour productivity growth in the wood product manufacturing subsector during the 2000-2007 period. The performance of Canada's forestry and logging and paper manufacturing, however, was far from stellar. In the case of forestry and logging, Canada had at most a middling productivity performance, with an average annual growth of 3.2 per cent, well below the growth rates experienced in Germany, Finland, and France. In the case of paper manufacturing, Canada had a subpar productivity performance, experiencing the lowest productivity increases among the eight countries in our sample (0.6 per cent per year).

**Table 2**
**Labour Productivity in the Forest Products Sector, Detailed Breakdown, 2000-2012**

| | 2000-2012 | 2000-2008 | 2008-2012 |
|---|---|---|---|
| | (CAGR, per cent) | | |
| Business Sector | 0.7 | 0.8 | 0.7 |
| Forest Products Sector | 2.5 | 3.6 | 0.3 |
| Forestry and Logging | 3.3 | 3.6 | 2.6 |
| Wood Product Manufacturing | 4.5 | 5.9 | 1.7 |
| Paper Manufacturing | -0.2 | 0.8 | -2.3 |

Source: CSLS calculations based on Statistics Canada data.

## Multifactor Productivity[6]

### Long-Run Multifactor Productivity Trends

Multifactor productivity (MFP) in the forest products sector grew at an average annual rate of 1.4 per cent between 1961 and 2012, seven times the growth rate observed at the business sector level (0.2 per cent per year). In 50 years, MFP in the sector roughly doubled, while business sector MFP increased only around 12 per cent (Chart 9).

Looking at the 1961-2012 period as a whole, MFP in forestry and logging and wood product manufacturing increased practically at the same

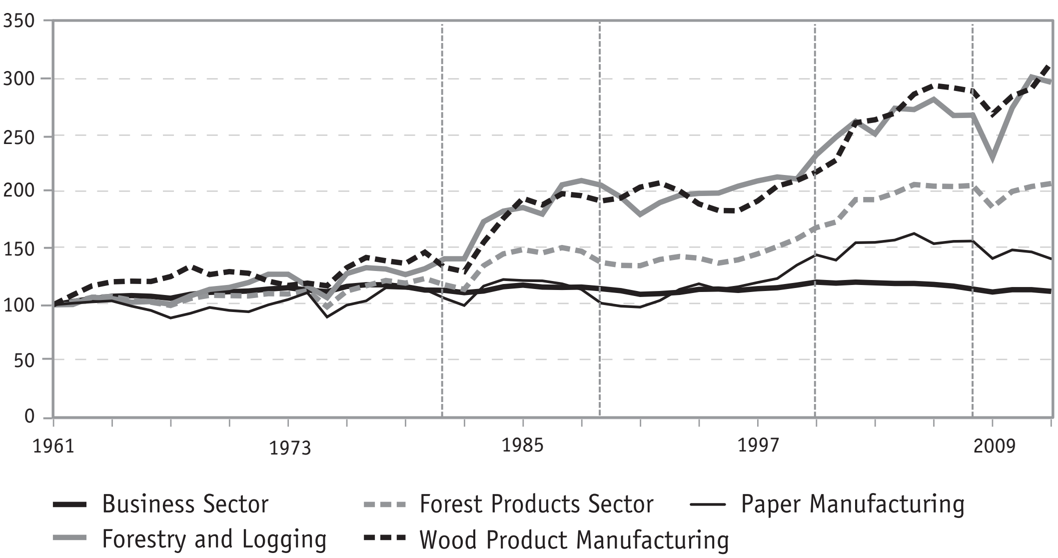
6 There are no official MFP estimates for the three forest products subsectors – and, hence, for the forest products sector as a whole – after 2008. Using Statistics Canada data, the CSLS has constructed MFP estimates for the forest products sector and its subsectors for the 2009-2012 period. The CSLS estimates should be seen as preliminary estimates, and therefore interpreted with caution. More information about of these MFP estimates can be found in the unabridged version of this article.

### Table 3
**Labour Productivity Growth in the Forest Products Sector, Selected OECD Countries, 1989-2007**

| | Canada | Finland | France | Germany | Italy | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| | (compound annual growth rates, per cent) | | | | | | | |
| Forest Products Sector | | | | | | | | |
| 1989-2007 | 3.0 | 5.4 | 1.2 | 4.3 | 3.1 | 1.6 | 1.4 | .. |
| 1989-2000 | 2.8 | 6.3 | -0.6 | 4.6 | 4.5 | 2.6 | 2.1 | .. |
| 2000-2007 | 3.8 | 3.9 | 4.1 | 3.8 | 1.0 | 0.2 | 0.3 | .. |
| Forestry and Logging | | | | | | | | |
| 1989-2007 | 3.2 | 5.4 | -4.9 | 4.6 | 5.2 | 0.3 | 5.4 | .. |
| 1989-2000 | 3.1 | 4.4 | -11.6 | 1.1 | 6.0 | 1.3 | 12.0 | .. |
| 2000-2007 | 3.2 | 7.1 | 6.8 | 10.2 | 3.8 | -1.3 | -4.2 | .. |
| Wood Product Manufacturing | | | | | | | | |
| 1989-2007 | 3.7 | 3.6 | 5.3 | 3.5 | 2.5 | 3.3 | 0.7 | 1.7 |
| 1989-2000 | 3.0 | 5.1 | 5.6 | 3.9 | 3.6 | 2.8 | -0.2 | 0.8 |
| 2000-2007 | 6.8 | 1.3 | 4.7 | 2.8 | 0.8 | 4.0 | 2.0 | 3.1 |
| Paper Manufacturing | | | | | | | | |
| 1989-2007 | 2.6 | 7.1 | 2.9 | 4.2 | 3.2 | 2.5 | 2.0 | 2.2 |
| 1989-2000 | 3.1 | 7.7 | 2.2 | 5.1 | 4.7 | 1.8 | 2.6 | 1.8 |
| 2000-2007 | 0.6 | 6.1 | 4.0 | 2.8 | 0.7 | 3.5 | 1.0 | 2.9 |

Source: Canada data from Statistics Canada; U.S. data from the BLS; for all other countries, data from EU KLEMS.

### Chart 9
**Multifactor Productivity in the Forest Products Sector, 1961-2012**
(index, 1961=100)




Source: CSLS calculations based on Statistics Canada data.

rate (2.2 and 2.3 per cent per year, respectively). MFP growth in paper manufacturing was much more modest (0.7 per cent per year), although still significantly above business sector growth.

### Recent Multifactor Productivity Trends

During the 2000-2008 period, MFP in the forest products sector increased 2.5 per cent per year, by far outperforming the business sector, which experienced negative growth of 0.6 per cent per year (Table 4). Of the three forest products subsectors, wood product manufacturing had the fastest MFP growth (3.6 per cent per year), followed by forestry and logging (1.8 per cent), and paper manufacturing (1.0 per cent).

According to CSLS estimates, MFP growth in the forest products sector suffered a significant slowdown in the 2008-2012 period (0.2 per cent per year), even though the sector still outperformed the business sector (-0.5 per cent per year). This slowdown was not caused by an "across the board" fall in MFP growth; rather, it reflects productivity losses in paper manufacturing (-2.6 per cent per year).

Compared to two-digit NAICS sectors, the Canadian forest products sector ranked second highest in terms of MFP growth during the 2000-2008 period, only behind agriculture, fishing, forestry and hunting, which experienced an increase of 2.6 per cent per year in MFP.

**Table 4**
**Multifactor Productivity Growth in the Forest Products Sector, 2000-2012**

| | 2000-2012 | 2000-2008 | 2008-2012 |
|---|---|---|---|
| | (CAGR, per cent) | | |
| Business Sector | -0.6 | -0.6 | -0.5 |
| Forest Products Sector | 1.7 | 2.5 | 0.2 |
| Forestry and logging | 2.0 | 1.8 | 2.6 |
| Wood product manufacturing | 3.1 | 3.6 | 2.1 |
| Paper manufacturing | -0.2 | 1.0 | -2.6 |

Source: CSLS calculations based on Statistics Canada data.

### International Comparisons[7]

The Canadian forest products sector fared well in international MFP comparisons. Looking specifically at the 2000-2007 period, Canada's wood product manufacturing subsector had the highest MFP growth among the eight countries in our sample, 3.6 per cent per year, but only marginally higher than the MFP growth experienced by France's or Sweden's wood product manufacturing subsectors (3.4-3.5 per cent per year). Canada's paper

**Table 5**
**Multifactor Productivity Growth in the Forest Products Sector, Selected OECD Countries, 1989-2007**

| | Canada | Finland | France | Germany | Italy | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| | (compound annual growth rates, per cent) | | | | | | | |
| Wood Product Manufacturing | | | | | | | | |
| 1989-2007 | 2.4 | 2.3 | 3.5 | 2.5 | 2.1 | 3.4 | -0.6 | -1.0 |
| 1989-2000 | 1.6 | 3.5 | 3.5 | 3.2 | 3.1 | 3.4 | -1.7 | -2.8 |
| 2000-2007 | 3.6 | 0.5 | 3.5 | 1.4 | 0.5 | 3.4 | 1.3 | 2.0 |
| Paper Manufacturing, Printing and Publishing | | | | | | | | |
| 1989-2007 | 0.9 | 3.8 | 0.7 | 0.3 | -0.2 | -0.1 | 0.1 | -1.1 |
| 1989-2000 | 1.0 | 4.2 | 0.1 | 0.9 | 0.3 | -0.7 | -0.5 | -2.0 |
| 2000-2007 | 0.6 | 3.3 | 1.6 | -0.5 | -0.9 | 0.8 | 1.0 | 0.3 |

Source: Canada and U.S. data from World KLEMS; for all other countries, data from EU KLEMS.

7 Multifactor productivity estimates were unavailable for forestry and logging in particular. As a consequence, we cannot calculate MFP growth for the forest products sector as a whole. This part of the article thus focuses on international MFP growth comparisons only for the wood product and paper manufacturing subsectors.

manufacturing subsector, however, had MFP growth of 0.6 per cent per year, making it only the 5th highest of the eight countries studied.

## Productivity Drivers in the Canadian Forest Products Sector

This section seeks to understand the reasons behind the productivity performance of the Canadian forest products sector and its subsectors.

### Growth Accounting

The starting point for any discussion on the dynamics of productivity growth is the standard growth accounting framework used to determine the sources of labour productivity growth in a sector.

During the 1961-2012 period, labour productivity in the Canadian forest products sector grew at a rate of 2.8 per cent per year, almost one percentage point faster than the business sector average of 1.9 per cent per year. The labour productivity differential between the forest products sector and the business sector can be entirely attributed to differences in MFP growth (1.4 vs. 0.2 percentage points, respectively). Overall, the above story is true not only for the forest products sector as a whole, but also for its subsectors.

The labour productivity growth differential between the forest products sector and the business sector has widened in recent years. Between 2000 and 2008, while business sector productivity increased at a rate of only 0.8 per cent per year, labour productivity in the forest products sector grew 3.6 per cent per year. Looking at the forest products sector as a whole, the picture seems very similar to the one we have seen for the overall 1961-2012 period, with MFP growth explaining the lion's share of the labour productivity differential (Table 6, Panel A). However, there were significant differences at the subsector level, particularly between paper manufacturing and the other two forest product subsectors.

In the more recent 2008-2012 period, labour productivity growth in the forest products sector suffered a significant slowdown (falling to 0.3 per cent per year), due largely to the paper manufacturing subsector, while business sector productivity growth remained stable (at 0.7 per cent per year). For the business sector, the sources of labour productivity growth remained largely unchanged from the previous period. For the forest products subsectors, however, there were important changes (Table 6, Panel B). First, capital intensity was either stagnant or fell in all three forest products subsectors. Second, the contribution of MFP growth to labour productivity growth fell in wood product manufacturing and paper manufacturing, while it increased in forestry and logging.

### Human Capital

This subsection looks at human capital indicators in the Canadian forest products sector, and seeks to understand the role of education and training in driving productivity growth in the sector.

#### Average Years of Schooling

Over the past 22 years, the education level of Canadian workers has risen consistently, and workers in the forest products sector are no exception. Average years of schooling increased by almost one full year in the forest products sector, from 12.2 years in 1990 to 13.1 years in 2012, only slightly below the increase of 1.1 years observed for the average Canadian worker (from 12.9 years to 14.0 years). Overall, the education gap (in terms of average years of schooling) between the average Canadian worker and the average worker in the forest products sector remained stable in the 1990-2012 period.

**Table 6**

**Sources of Labour Productivity Growth in the Forest Products Sector, 2000-2012**

A) 2000-2008

| | Business Sector | Forest Products Sector | Forestry and Logging | Wood Product Manufacturing | Paper Manufacturing |
|---|---|---|---|---|---|
| | **(percentage point contributions to labour productivity growth)** | | | | |
| Labour Productivity | 0.8 | 3.6 | 3.6 | 5.9 | 0.8 |
| Contribution of Capital Intensity | 1.1 | 1.0 | 1.9 | 2.3 | -0.7 |
| Capital Stock | 0.7 | 1.8 | 7.3 | 2.0 | -1.0 |
| Capital Composition | 0.4 | -0.8 | -5.4 | 0.3 | 0.3 |
| Contribution of Labour Composition | 0.3 | 0.2 | 0.0 | 0.1 | 0.5 |
| MFP | -0.6 | 2.5 | 1.8 | 3.6 | 1.0 |
| | (per cent contributions to labour productivity growth) | | | | |
| Labour Productivity | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Contribution of Capital Intensity | 145.2 | 26.6 | 53.7 | 39.4 | -85.3 |
| Capital Stock | 95.6 | 48.8 | 205.0 | 34.5 | -117.0 |
| Capital Composition | 49.6 | -22.1 | -151.4 | 4.8 | 31.6 |
| Contribution of Labour Composition | 38.4 | 5.2 | -0.4 | 0.9 | 62.9 |
| MFP | -81.9 | 68.8 | 49.9 | 60.9 | 121.6 |

B) 2008-2012

| | Business Sector | Forest Products Sector | Forestry and Logging | Wood Product Manufacturing | Paper Manufacturing |
|---|---|---|---|---|---|
| | **(percentage point contribution to labour productivity growth)** | | | | |
| Labour Productivity | 0.7 | 0.3 | 2.6 | 1.7 | -2.3 |
| Contribution of Capital Intensity | 0.9 | -0.2 | 0.1 | -0.4 | -0.3 |
| Capital Stock | 0.5 | -0.2 | 0.2 | -0.4 | -0.4 |
| Capital Composition | 0.4 | 0.1 | -0.1 | 0.0 | 0.1 |
| Contribution of Labour Composition | 0.3 | 0.2 | 0.0 | 0.1 | 0.6 |
| MFP | -0.5 | 0.2 | 2.6 | 2.1 | -2.6 |
| | (per cent contribution to labour productivity growth) | | | | |
| Labour Productivity | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Contribution of Capital Intensity | 130.6 | -62.5 | 4.0 | -26.1 | 12.0 |
| Capital Stock | 68.1 | -92.8 | 6.2 | -25.6 | 15.9 |
| Capital Composition | 62.5 | 30.3 | -2.1 | -0.5 | -3.8 |
| Contribution of Labour Composition | 41.7 | 83.9 | -0.5 | 3.9 | -26.9 |
| MFP | -69.9 | 86.4 | 98.3 | 125.0 | 114.1 |

Note: Percentage point contributions may not sum up to labour productivity growth due to rounding.

Source: CSLS calculations based on Statistics Canada data.

### Breakdown of Workforce by Highest Level of Educational Attainment

In 2012, only 9.3 per cent of workers in the forest products sector had a university degree (vs. 26.9 per cent for the Canadian economy as a whole); 38.6 per cent had a non-university post-secondary diploma as their highest educational credential (vs. 35.8 per cent for the Canadian economy); 5.9 per cent had incomplete post-secondary education (vs. 7.3 per cent); 25.4 per cent had only a high-school education (vs. 19.7 per cent); and 20.8 per cent had less than a high-school education (vs. 10.3 per cent).

In a sense, the lower educational attainment levels of workers in the forest products sector are expected. The sector has very specific skill needs that, more often than not, require on-the-job training or non-university post-secondary education (such as a trade certificate) instead of a university education. The (still) high proportion of workers without a high-school diploma – especially in forestry and logging – however, raises legitimate concerns regarding basic literacy and numeracy skills, the lack of which can negatively impact worker productivity.

## Innovation

This subsection looks at innovation indicators in the Canadian forest products sector, and seeks to understand the role of innovation in driving productivity growth in the sector.

### Defining Innovation

Innovation does not result from one particular factor; rather, it is brought about by many different elements, including research and development (R&D), learning-by-doing, monitoring of best practices, etc. As a consequence, there is no single indicator that can summarize the state of innovation in an industry. To deal with the complex nature of innovative activity, a systems approach is recommended. Sharpe and Long (2012) developed an analytical framework for assessing the state of the innovation system in Canada's natural resource industries, which we have adapted for the particularities of the forest products sector (Exhibit 2).

### Unique Characteristics of the Forest Products Sector Affect Innovation

Certain characteristics of an industry can influence its ability, as well as its incentives, to innovate. The Canadian forest products sector has a number of characteristics that distinguish it from other sectors in the economy, influencing its innovative performance. Below, we highlight some of these characteristics: [8]

- Homogenous products;
- Highly competitive international markets;
- Price volatility;
- Environmental effects of production;
- The degree of regulation; and
- The degree of vertical linkages in production.

Exhibit 3 summarizes the above discussion by highlighting the general effects each of these unique characteristics of the Canadian forest products sector are expected to have on innovative activities.

### Innovation Indicators

This subsection analyses several different indicators of innovation in the forest products sector, each of which provides a partial picture of the sector's overall innovative capacity.

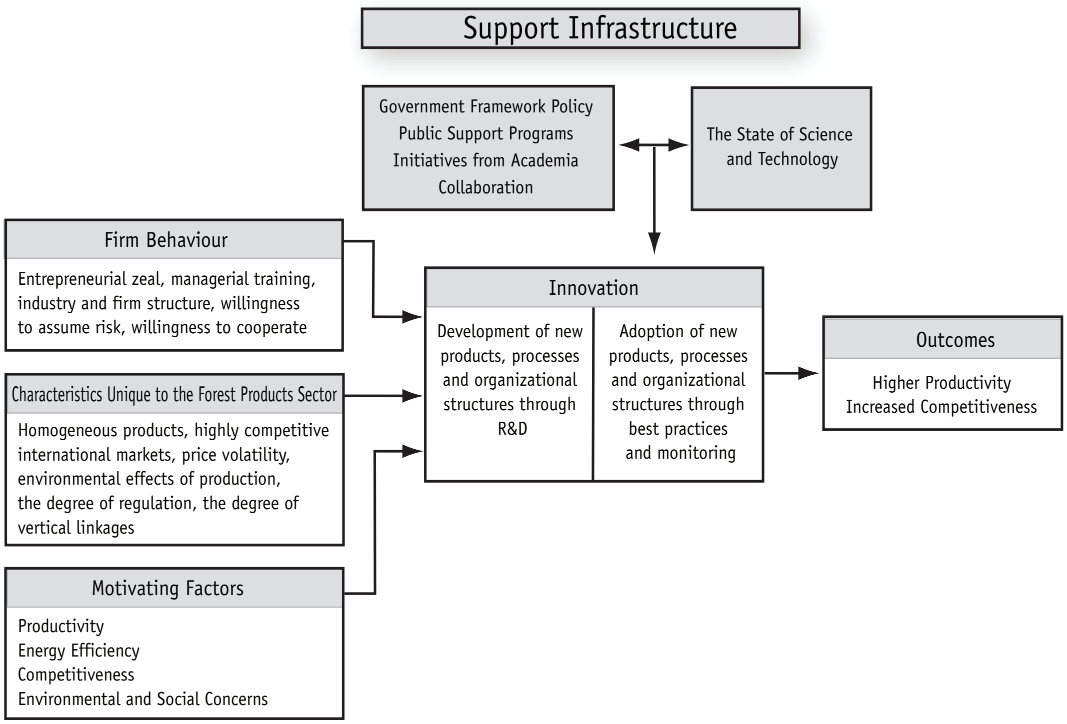
### Technological Prowess and Academic Research

In its 2006 report on the state of science and technology (S&T) in Canada, the Council of Canadian Academies conducted a large-scale online survey of the opinion of Canadian experts, asking them about the overall direction and trend of S&T in a number of different areas. The report rated 16 broad areas of science and technology and 197 more specific sub-areas in terms of their technological standing.

Of the 16 broad areas, energy, mining and forest technologies were deemed to be in a strong technological position relative to other countries by the highest proportion of respondents, at 71 per cent (vs. 55 per cent for all areas). Drilling down to a greater level of detail, two forest products-related S&T sub-areas were within the top-50, with forestry engineering ranked at 35th place (out of 197) and pulp and paper technologies at 50th place. Timber harvesting technologies were also well ranked, coming at 51st place. Despite their high ranking,

8 The unabridged version of the article provides a detailed discussion of the characteristics that distinguish the forest products sector from other sectors in the economy.

**Exhibit 2**
**The Innovation System in the Canadian Forest Products Sector**




Source: Adapted from Sharpe and Long (2012).

a significant number of experts expected the relative strength of forest products S&T sub-areas to either stay stable or decline in coming years.

The Council of Canadian Academies updated and expanded its assessment of the state of S&T in Canada in 2012. The report notes that there has been a decline in the output and impact of Canadian forestry research between the 1999-2004 period and the more recent 2005-2010 period when compared to the rest of the world. It also notes, however, that "Canada's Forestry research was ranked second in the world by top-cited researchers, and Canada accounts for over 10 per cent of the world's papers in this subfield" (Council of Canadian Academies, 2012:164).

### Business Enterprise R&D Expenditures

Economists have found a robust, positive relationship between R&D and productivity growth (see, for instance, Khan, Luintel, and Theodoridis, 2010). Below, we analyze the evolution of business enterprise R&D (BERD) expenditures in the forest products sector and its subsectors during the 2000-2012 period.

During the 2000-2008 period, BERD spending in the forest products sector grew at the same rate as total economy BERD spending (3.8 per cent per year). There were, however, important differences at the subsector level, with wood product manufacturing BERD increasing at a very rapid pace of 22.9 per cent per year, forestry and logging BERD increasing at half the total economy rate (1.9 per cent per year), and paper manufacturing BERD actually declining (-5.1 per cent per year).

With the 2009 recession, BERD spending plummeted in all three forest products subsectors. In the 2009-2012 period, BERD spending

**Exhibit 3**

**The Effect of Unique Characteristics of the Forest Products Sector on Innovation**

| | How Does it Affect Innovation in the Forest Products Sector? | Expected Effect |
|---|---|---|
| Homogeneous Products | • Homogeneous products leave little (or no) room for competition via product differentiation. Since forest-product firms are generally price takers, they must constantly strive for cost effectiveness, which provides an important incentive to engage in process innovation. | + |
| Highly Competitive International Markets | • Canadian forest product industries are more exposed to international competition than the average Canadian firm. Hence, they must innovate if they want to stay in business. | + |
| Price Volatility | • Commodity prices tend to be volatile. As a consequence, forest-product firms have difficulty planning ahead, and tend to be biased towards producing (as opposed to innovating) in periods where prices are high, and hesitant to do anything when prices are low (for fear the trend continues). | - |
| Environmental Effects of Production | • The increasingly competitive international market will reward clusters that enhance energy efficiency and reduce emissions intensity with substantial cost-savings. | + |
| The Degree of Regulation | • In general, regulation is seen as a factor that inhibits innovation;<br>• However, in the forest products sector, regulation can potentially force firms to improve their production processes (Porter hypothesis). | Ambiguous |
| The Degree of Vertical Linkages in Production Processes | • Higher levels of vertical integration can foster innovation since the innovative needs of the sector as a whole are known amongst firms;<br>• Conversely, low vertical integration can hinder innovation because downstream industries will share the benefits, but not the costs, of innovation. | Ambiguous |

Source: Adapted from Sharpe and Long (2012).

started to increase again in forestry and logging and paper manufacturing, growing at rates of 6.9 and 18.1 per cent per year (respectively), but not in the wood product manufacturing subsector, where it declined 5.3 per cent per year. This recovery has been quite timid, however, and BERD expenditures are still well below their pre-recession levels for all three forest products subsectors.

## R&D Intensity

An important indicator of innovation performance is R&D intensity, defined here as BERD expenditures as a share of nominal GDP. Before 2000, R&D intensity in the forest products sector was remarkably stable (0.7-0.8 per cent), slightly below total economy R&D intensity. In the 2000s, however, R&D intensity in the forest products sector rose to above-average levels, peaking at 2.8 per cent in 2006; this increase was caused entirely by the paper manufacturing subsector. In 2009, R&D intensity in the forest products sector had fallen back to the total economy average of 1.1 per cent.

Compared to a group of eleven other OECD countries, Canada had the second highest R&D intensity in wood product manufacturing during the 2000-2008 period (0.9 per cent), only below Norway (1.3 per cent).[9] In the case of paper manufacturing, Canada had the third highest

9 International comparisons are based on data from the OECD's STAN database, which has detailed industry-level R&D intensity estimates for a number of countries for both wood product and paper manufacturing.

**Table 7**
**Business Enterprise Expenditures in Research and Development in the Canadian Forest Products Sector, 2000-2012**

| | 2000 | 2008 | 2012 | 2000-2012 | 2000-2008 | 2008-2012 |
|---|---|---|---|---|---|---|
| | (millions, current dollars) | | | (CAGR, per cent) | | |
| All Industries | 12,395 | 16,644 | 15,493 | 1.9 | 3.8 | -1.8 |
| Forest Products Sector | 290 | 391 | 221 | -2.2 | 3.8 | -13.3 |
| Forestry and logging | 18 | 21 | 14 | -2.1 | 1.9 | -9.6 |
| Wood product manufacturing | 42 | 219 | 85 | 6.1 | 22.9 | -21.1 |
| Paper manufacturing | 230 | 151 | 122 | -5.1 | -5.1 | -5.2 |

Source: Statistics Canada, Research and Development in Canadian Industry, CANSIM Table 358-0024.

R&D intensity (3.4 per cent) out of the 11 countries in our sample. Norway had the highest R&D intensity (4.4 per cent), followed by Sweden (3.7 per cent).

### R&D Personnel Intensity

R&D personnel intensity, defined here as the number of R&D personnel per 1,000 workers is an important indicator of an industry's ability to innovate. In 2010, there were 8.5 R&D personnel per 1,000 workers in the Canadian forest products sector, up almost 50 per cent from 5.7 in 2000, and well above the all-industries average (7.8 R&D personnel per 1,000 workers in 2010). At the subsector level, paper manufacturing accounted for most of the rise in the R&D intensity of the forest products sector during the early 2000s.

Using OECD data, Sharpe and Long (2012:47) calculated R&D personnel intensity for wood product and paper manufacturing in 2008 for 10 OECD countries. In wood product manufacturing, Canada had the second highest R&D personnel intensity among the countries in our sample (8.4 R&D personnel per 1,000 workers), only behind France (16.4 R&D personnel per 1,000). In paper manufacturing, however, Canada's R&D personnel intensity (17.7 R&D personnel per 1,000 workers) was well below Norway's, Finland's, and Sweden's – all of which are countries with well developed forest products sectors.

### M&E Investment Intensity

Although the relatively high levels of R&D investment in the Canadian forest products sector are good news, these indicators represent only one aspect of innovation. In general, a great deal of innovation is related to adopting state-of-the-art capital goods that improve the efficiency of the production process (as innovation tends to be embodied in physical capital).

The low levels of investment in physical capital, especially in the paper manufacturing subsector, suggest that a number of firms in the Canadian forest products sector are using outdated capital assets that do not embody the latest technological innovations. Rheaume and Roberts (2007:20) remark, for instance, that "Canadian pulp and paper mills are significantly smaller and older than those operated by their international competitors". Similarly, Woodbridge Associates (2009:53) support this view, stating that B.C.'s "pulp and paper mills generally are aging, and are not cutting edge."[10]

M&E investment intensity, defined here as real investment in machinery and equipment (M&E) per hour worked, is an important indica-

**Table 8**
**M&E Investment Intensity Growth in the Forest Products Sector, 2000-2012**

| | 2000-2012 | 2000-2008 | 2008-2012 |
|---|---|---|---|
| | (CAGR, per cent) | | |
| All Industries | 2.7 | 4.0 | 0.2 |
| Forest Products Sector | -0.1 | -2.6 | 5.1 |
| Forestry and Logging | 0.4 | 2.7 | -4.2 |
| Wood Product Manufacturing | 1.4 | -2.4 | 9.6 |
| Paper Manufacturing | -2.0 | -4.5 | 3.3 |

Source: CSLS calculations based on Statistics Canada data.

tor of embodied technological change. Between 2000 and 2012, while M&E investment intensity for the Canadian economy as a whole was increasing at an average annual rate of 4.0 per cent, M&E investment intensity in the forest products sector was actually declining 2.6 per cent per year (Table 8).

In the 2008-2012 period, M&E investment intensity in the forest products sector picked up pace, increasing at a rate of 5.1 per cent per year, significantly faster than total economy growth (0.2 per cent per year). Growth in M&E investment intensity was fueled by the wood product manufacturing subsector, which saw M&E investment intensity increase at an average annual rate of 9.6 per cent.

### Foreign Direct Investment

Both foreign investment in the domestic economy and investment of Canadian firms abroad can foster technology diffusion, with firms creating new production processes or adapting established production processes to new realities. According to Statistics Canada estimates, between 2000 and 2012, inward FDI flows declined 48 per cent in the wood product manufacturing subsector and 23 per cent in the paper manufacturing subsector.

### Incidence of Innovation

Innovation at the firm and plant level is also an important indicator. Three occasional Statistics Canada surveys related to innovation provide a variety of insights into what constitutes innovation and how innovation is measured:

- Survey of Innovation;
- Survey of Advanced Technologies, and
- Survey of Innovation and Business Strategy (SIBS).

The Survey of Innovation shows the per cent of innovative plants in the three forest products subsectors during the 2002-2004 period. Compared to total manufacturing (65.0 per cent), the performance of the forest products sector was quite poor, with logging and wood product manufacturing being 47.5 and 7.3 percentage points below the manufacturing total.

According to SIBS, which provides data with additional detail on the type of innovative activity conducted, process innovation clearly plays a larger role in the forest products sector than it does in other industries. More than half of wood product and paper manufacturing firms introduced new methods of manufacturing during the 2007-2009 period (vs. only 17.3 per cent of all firms). In terms of product innovation, wood product and paper manufacturing firms were, in general, more innovative than the average Canadian firm, although they still trailed behind the manufacturing total by a significant margin.

Finally, the Survey of Advanced Technology provides an additional indicator of innovation, inquiring about the percentage of firms in the manufacturing sector that adopted advanced technologies. In fact, 96.9 per cent of wood product manufacturing plants were using at least

10 In general, however, Woodbridge Associates (2009:53) praise the B.C. forest products sector, stating that the "industry is well known for its rapid adoption of state-of-the-art processing technologies," which is consistent with its superior productivity performance. Not surprisingly, B.C. has had by far the best productivity performance in the forest products sector of any province in the 2000-2012 period.

one advanced technology by 2007, above the manufacturing total of 91.5 per cent. Although the proportion of paper manufacturing plants using at least one advanced technology was lower than the manufacturing total (86.0 per cent), paper manufacturing had a higher proportion of plants that used at least five advanced technologies (76.2 vs. 67.7 per cent for the manufacturing total).

## Business Cycle, Returns to Scale, and Other Factors

The standard theoretical framework used to calculate MFP growth relies on some important assumptions, three of which are particularly relevant to us:

- Efficiency;
- Constant returns to scale; and
- Perfect competition.

Needless to say, these can be strong assumptions. In situations where they do not hold, MFP growth – and, as a consequence, sources of labour productivity growth – will be affected. In this subsection, we explore the possibility that part of the MFP growth experienced by the Canadian forest products sector is linked to the factors listed above.

### Business Cycle

In general, productivity exhibits procyclical behaviour, that is, it increases during economic booms and decreases during recessions (Basu and Fernald, 2001). There are many potential reasons for this, but two stand out:

Capacity utilization: During recessions, a significant part of firms' capital stock is idle, causing productivity to fall; inversely, during booms, capital can be over-utilized, causing productivity to rise; and

Labour hoarding: During recessions, firms have a tendency to keep more workers than it would be optimal for a given level of production, driving down productivity.

In forestry and logging, capacity utilization remained relatively high in the 2000-2008 period, ranging from a low of 81.6 per cent in 2001 to a high of 93.6 per cent in 2008. With the recession, capacity utilization dropped 16.3 percentage points to 77.3 per cent, but quickly recovered.

Chart 10 looks at what happens to MFP growth in the forest products sector when we use the capacity-utilization adjusted measure (vs. the baseline measure). During the overall 2000-2012 period, average MFP growth was practically the same, regardless of the measure used (1.6 per cent per year using the capacity utilization-adjusted measure vs. 1.7 per cent per year using the baseline measure). The capacity utilization-adjusted measure (CU-MFP), however, reduced the volatility of MFP growth, making the series more stable.

The effect of labour hoarding on productivity growth is harder to quantify. The unabridged version of this article provides a detailed discussion of this issue.

### Returns to Scale and Firm Size

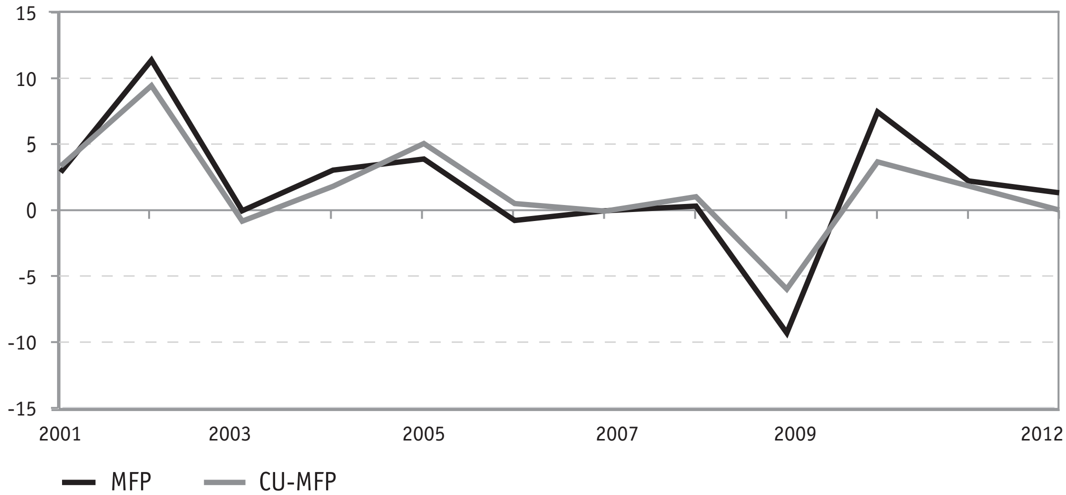
The standard theoretical framework used to compute MFP growth assumes constant returns to scale, that is, a doubling of inputs leads to a doubling of output. Whenever this assumption is violated, productivity gains created by increasing returns to scale (IRS) appear as part of MFP growth.[11] The existing literature highlights the importance of returns to scale in the forest products sector, but does not provide actual estimates of its impact on productivity. Although the econometric estimation of returns to scale is beyond the scope of this article, such estimates can be constructed using the methodology delin-

11 It is interesting to note that the benefits associated with IRS are also linked to the business cycle. In the presence of IRS, economic booms can yield significant productivity gains, since production has to increase to meet the strong demand; conversely, economic downturns lead to productivity losses.

**Chart 10**

**MFP Growth in the Forest Products Sector Adjusted by Changes in Capacity Utilization, 2000-2012**

(per cent)




Source: CSLS calculations based on Statistics Canada data.

eated in Diewert and Fox (2005). It is interesting to note, furthermore, that Diewert and Fox find evidence of the existence of IRS in the U.S. wood product and paper manufacturing subsectors.

### Other Factors

Other factors have influenced productivity growth in the Canadian forest products sector, namely: profits; industrial structure and intersectoral shifts; and the quality and size of Canada's natural resource base.

### Profits

Chart 11 shows operating profits in the Canadian forest products sector during the 2000-2011 period. The level of profits in paper manufacturing peaked in 2000 at $5,080 million and then quickly declined, reaching $848 million in 2011.

Profits can influence productivity growth through three main channels:

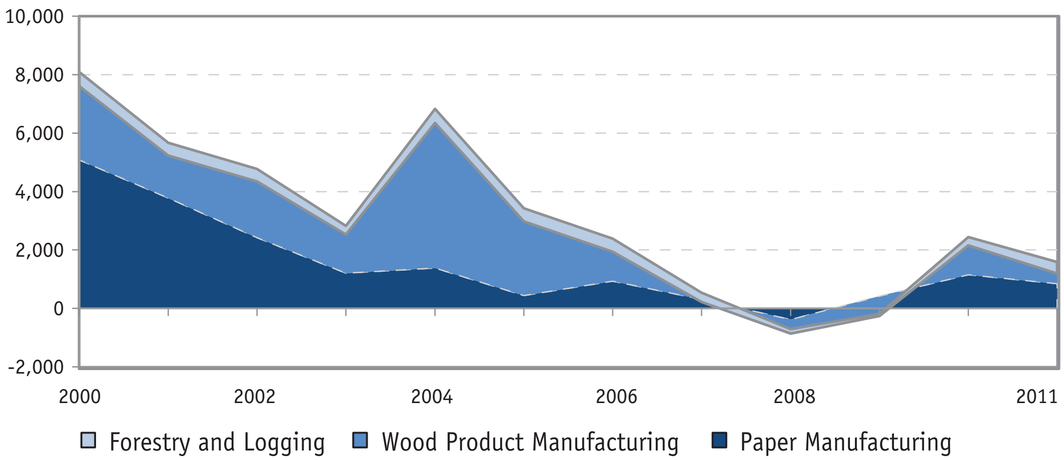
Composition Effect: Low (or negative) profit levels can force low-productivity establishments out of business, raising the average productivity of the sector.

Survival Effect: Falling profits may serve as an incentive for firms to innovate, as they look for ways to cut costs and improve the overall efficiency of their production processes.

Investment Effect: Conversely, falling profits can make it harder for firms to invest in R&D or new capital, slowing down productivity growth.

Although the exact effect profits may have had on productivity growth in the forest products sector is unknown, it is more than likely that falling profits have helped shape a leaner, more efficient sector, despite the falls in investment.

**Chart 11**
**Operating Profits in the Forest Products Sector, 2000-2011**
(current dollars, millions)




Source: Statistics Canada, Financial and Taxation Statistics for Enterprises, CANSIM Table 180-0003.

### Industrial Structure and Intersectoral Shifts

Productivity growth in the forest products sector is a combination of productivity growth in forestry and logging, wood product manufacturing, and paper manufacturing. For each subsector, in turn, productivity growth is the aggregation of productivity growth in more specific activities. Aggregate productivity growth depends not only on how much productivity growth each of these activities experience (pure productivity effect), but also on how important each activity is relative to the total. Shifts towards higher-productivity activities can also cause the overall productivity in the sector to increase (reallocation effect). The reallocation effect in the Canadian forest products sector was quite small during the 2000-2012 period, explaining only 4.6 per cent of average labour productivity growth in the period, with the pure productivity effect accounting for the remaining 95.4 per cent.

### Quality and Size of Canada's Natural Resource Base

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. There is no evidence that this fact played a significant role in influencing productivity in the 2000-2012 period, either positively or negatively.

## Conclusion

Even though global demand for forest products has risen in the past decade, largely reflecting growth in emerging markets, increased international competition has taken its toll on the Canadian forest products sector. Canada's share in world production of all major forest products has fallen, and its share in total world exports of forest products has halved.

The competitiveness of Canada's forest products sector has suffered greatly due to a strong

Canadian dollar and high labour costs, which make it harder for the sector to compete internationally with low-wage countries. By lowering production costs, productivity gains can help Canadian firms to better compete with international firms, and thus regain some of the lost market share.

In fact, much more effectively than other manufacturing subsectors, the Canadian forest products sector has managed to soften the blow of rapidly rising unit labour costs by posting major productivity gains, driven in particular by the wood product manufacturing subsector. In order to regain some of the lost ground and remain competitive, however, Canada's forest products sector must maintain (or even improve) high rates of productivity growth.

Public policies can have a significant impact on productivity growth by affecting the behaviour of firms. Well designed policies can help align incentives, leading to more (and better) investment in human capital, physical capital, and innovation, which usually translates into faster productivity growth. Conversely, poorly designed policies can create perverse incentives, thus hindering productivity growth.[12]

Policies must address two key issues in order to promote productivity growth in the forest products sector. First, the falling levels of investment in physical capital, especially in paper manufacturing, suggest that a number of firms in the sector are using outdated capital assets that do not embody the latest technological innovations. Second, human capital deficiencies in forest products firms can significantly hinder productivity growth if not dealt with properly. In this sense, the article recommends renewed focus on both human and physical capital investment, as well as on R&D spending.

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12 Refer to the unabridged version of the article for a detailed discussion of the effect of various human capital, innovation, taxation and regulation policies on productivity growth in the forest products sector. In addition, refer to FPAC (2014) for a discussion of policies that they recommend to promote productivity growth.