Getting Aligned.

How Adopting Standards Affects Canada's Productivity and Growth

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CUSTOM REPORT

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How Adopting Standards Affects Canada's Productivity and Growth

At a Glance

- International studies continue to provide evidence of the link among standardization, labour productivity and economic growth.

- Compatibility of products, quality standards, increased networks and larger, more efficient scales of production are some of the underpinnings that link standardization with a more efficient economy.

- From 1981 to 2014, standardization contributed to 7.8 per cent of the growth rate in real GDP and 16.1 per cent of the growth in labour productivity in Canada. Assuming that the estimated impact of standardization was constant between 1981 and 2014, in 2014, growth in the stock of standards contributed roughly $3 billion of the $39 billion increase in real GDP.

- *If* the stock of standards had not increased between 1981 and 2014, real GDP would have been $91 billion lower in 2014 alone.

Briefing October 2015

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Preface

This report's research was undertaken by The Conference Board of Canada with funding and support from the Standards Council of Canada (SCC). The research was conducted by Natalia Ward, Economist, and Pedro Antunes, Deputy Chief Economist at The Conference Board of Canada.

Many thanks are due to SCC staff for their valuable comments and insights throughout the production of this research report. In keeping with Conference Board guidelines for financed research, the design and method of research, as well as the content of this report, were determined solely by the Conference Board.

This briefing is an update to the Conference Board's July 2007 research report entitled *Economic Value of Standardization*.

About The Conference Board

The Conference Board of Canada is the foremost independent, not-for-profit, applied research organization in Canada. We help build leadership capacity for a better Canada by creating and sharing insights on economic trends, public policy issues, and organizational performance. The Board's Economic Forecasting and Analysis division employs more than 40 professional economists, who combine their knowledge across regions and sectors to producing their forecasts. The forecasting group constructs and maintains econometric models of the national and regional economies and a one-of-a-kind, comprehensive quarterly database of the provincial economies in Canada. The Conference Board of Canada was established in 1954, and is affiliated with the U.S.-based Conference Board, Inc., which serves some 2,000 companies in 60 nations.

Executive Summary

A number of international studies have concluded that standards provide an important contribution to economic growth and efficiency. We apply empirical methods to examine if the link among the stock of standards,[1] economic output and labour productivity holds true for Canada. In an earlier 2007 study produced by the Conference Board, we found a strong link among the stock of standards, labour productivity and real GDP in Canada. This briefing updates our 2007 study.

Economic theory suggests that there are many ways through which the adoption of standards can boost an economy's efficiency and thus its output and labour productivity. These include improved compatibility, the identification of minimum admissible attributes, provision of information and product descriptions, the enabling of economies of scale, the facilitation of international trade, and the promotion of innovation.

While it is important to note that standards do not contribute to economic efficiency independent of other factors, our empirical work demonstrates that standards play an important role in enhancing labour productivity and boosting Canada's productive capacity. We find that a 10 per cent increase in the stock of standards is associated with a 1.6 per cent increase in labour productivity (excluding the influence of declining productivity in the oil and gas extraction sector). Over the study period of 1981 to 2014, standardization contributed 16.1 per cent to the growth in labour productivity. This translates into approximately a 7.8 per cent contribution to the growth in production, or real GDP. The impact, over time, of this positive contribution is substantial. Our estimates suggest that by the end of 2014, real GDP could have been roughly $91 billion lower had there been no growth in the stock of standards over the past three decades.

Assuming that the estimated impact was constant over time, standardization contributed roughly $3 billion of the $39 billion increase in real GDP in 2014. Based on the analysis, a 1 per cent increase in the stock of standards would have added $2.4 billion to real GDP in 2014.

[1] See page 10 for a definition.

What Is a Standard?

Standards are basic infrastructure of the 21st-century knowledge economy. Standards cover a wide spectrum of documents, from definitions, classifications, manufacturing techniques, processes, delivery systems, and beyond. They set out requirements, specifications, guidelines or characteristics that can be consistently applied to ensure that products, materials, processes, and services perform as intended in terms of their quality, safety, and efficiency. Standards are developed by consensus and approved by a recognized body. Hundreds of thousands of international standards, and many thousands more at the national level, underpin the global economy. Put simply, they make things work, help innovations spread, and facilitate trade among provinces, countries, and economic regions.[2]

In Canada, the Standards Council of Canada (SCC) is the federal Crown corporation with the mandate to promote efficient and effective voluntary standardization in Canada. SCC does not develop standards; rather, it accredits Standards Development Organizations (SDOs).[3] In this capacity, SCC leads and facilitates the development and use of national and international voluntary standards and accreditation services in order to enhance Canada's competitiveness and well-being.[4] The development and use of Canadian standards, along with aligning our national standards with international and regional standards, helps reduce technical barriers to trade, internally and internationally, and promote economic growth in our country.

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[2] Source: Standards Council of Canada.

[3] Source: Standards Council of Canada.

[4] Standards Council of Canada. "Mandate, Mission and Vision."

The National Standards of Canada Development Process

Standards Development Organizations (SDOs) convene technical committees—consensus-based bodies of individuals representing a mix of interests, expertise and jurisdictions—from industry, consumer groups, regulatory bodies and other stakeholders. In drafting standards, committee members ensure that standards meet relevant technical specifications and perform as required. Draft standards are publicly posted for 60 days and comments received are used to refine the documents. The development process can be lengthy, taking from nine months to several years, depending on a standard's complexity and contentiousness.

To obtain the National Standards of Canada (NSC) designations, an accredited SDO must substantiate that SCC development requirements have been met. If approved, the SDO is notified it may publish the standard as an NSC. Approval indicates that a standard has been: developed through a consensus-based process involving a balanced committee of stakeholders; subjected to public scrutiny; published in both official languages; drafted to be consistent with or incorporate existing international or relevant foreign standards; and determined not to be a barrier to trade.

NSCs continually evolve, subject to ongoing and often close scrutiny that may lead to reaffirmation, revision, or withdrawal. All standards must undergo at least one formal review within five years of publication. This review and revision cycle ensures standards are in step with changes in technology, health and safety regulations, and markets, and continue to comply with international norms and World Trade Organization practice.

Source: Standards Council of Canada.

The Impact of Standards on Economic Growth and Productivity

Economic theory and empirical studies[5] provide evidence that standardization has economic benefits. Globalization and the heightened need to develop compatible

[5] BSI, 2015, DTI, 2005, DIN, 2000, AFNOR, 2009 and others.

networks have increased the potential economic benefits of standardization, while the development of data on standards has made it possible to measure their benefits.

In theory, compatibility emerges as one of the most significant reasons for the evolution of standardization.[6] Clearly, compatible products, processes, and measurement systems should result in efficiency gains. To make the case, we can imagine a world where railway tracks change width as they cross borders, or where brands determine the design of electric sockets—perhaps an inefficiency that those who have travelled internationally can relate to. The keyboard's *QWERTY* key placement is another clear example of compatibility;[7] it is obviously much more efficient for everyone to work with the same standard. That said, standardization can, in some instances, hinder change to more efficient systems. The keys' placement was originally intended to slow typing in order to prevent keys in mechanical typewriters from getting stuck. Today more efficient computer keyboard designs are available, but how to make the switch?

A second rationale for the existence of standards is to provide minimum admissible attributes, for example, safety standards or minimum quality standards. Standards contribute to building trust and reducing risks among producers and consumers; this is largely accomplished through the use of third-party conformity assessments. Another reason for the development of standards is to reduce variety, which enables organizations to take advantage of economies of scale. And internationalized standards can potentially boost international trade by improving compatibility, product information and measurement—not to mention getting merchandise across borders without having to unload and reload railway cars.

In our 2007 study, a number of interviews with executives of companies, SDOs, trade associations and government departments in Canada provided qualitative evidence of the benefits of standardization. Interviewees were vocal about the benefits of participating in the standards development process. Interview results suggest that standardization is the basis for continuous improvement, innovation and new product development; that it helps to establish a level playing field and bolster consumer confidence and trust in the products. Respondents also suggested that standards play

[6] David, P. and Greenstein, S. (1990).

[7] David (1985).

an important role in improving productivity, facilitating trade and new market development as well as contributing to improved public safety.

Recent empirical studies have concluded that standards have had a positive impact on the economy and contribute to improving labour productivity.[8] The first comprehensive studies[9] in this area were performed by Jungmittag, Blind, and Grupp (1999) using German data from 1961 to 1996, and the British Department of Trade and Industry (DTI [2005]) using British data from 1948 to 2002. Both of these studies begin with the premise that standards may be an important factor in determining aggregate economic activity and, as a result, productivity growth.[10] The Jungmittag, Blind, and Grupp (1999) study finds that the collection of standards has played an important role in explaining long-run movements in economic output of the German business sector. The DTI (2005) study finds that the collection of standards played an important role in explaining long-run movements in British labour productivity (output per hour worked).

The authors, however, urge caution in interpreting the results, since standardization does not act independently of other factors. Standardization acts in combination with other factors such as research and development (R&D) to catalyze innovative activity and generate gains in productivity. As already noted, the link between standards and innovation is tenuous as there is some evidence that standardization can both encourage and hinder innovation.[11]

Methodology

To estimate the economic impact of standards on labour productivity, we used an empirical model similar to what we developed for our 2007 study. The model is based on the assumption that the economy can be represented by an *aggregate production function*, much like that of an individual firm. Economic output (or real GDP) can be

[8] BSI (2015), DTI (2005), DIN (2000), AFNOR (2009), and others.

[9] Both studies have since had follow-up estimations confirming their original results (while extending their sample sizes).

[10] Haimowitz and Warren (2007).

[11] Blind K. (2013).

explained by the stock of productive capital, the amount of available labour and the efficiency with which these factors of production generate output. The measure of efficiency is referred to as multifactor productivity. The purpose of the research was to assess whether the stock of standards has an impact on the efficiency (multifactor productivity) of the economy. And if so, what is the contribution of this gain in efficiency to economic output and to labour productivity (or output per hour worked). Gains in productivity are essential to helping an economy grow its income and wealth and allow Canadian firms to remain competitive in a global market.

The data on the number of standards over time was provided by the Standards Council of Canada in cooperation with four of the eight SCC-accredited Standards Development Organizations (SDOs):[12] Bureau de normalisation du Québec (BNQ), Canadian General Standards Board (CGSB), CSA Group and ULC Standards. The four SDOs not included in this study were accredited in 2013 and 2014.[13] These newly accredited SDOs have not published standards under SCC's accreditation in the period examined in this study.

It is important to note that in Canada, SDOs do not solicit development opportunities nor determine what standards should be developed. Consumer organizations, trade, and industry associations, government departments or others, who see a need for a standard, submit a proposal to whichever organization has the most expertise in a relevant product, process or service area. SDO staff sort the level of interest in the subject area, and determine whether other organizations are working on such items already, the extent of support, and where a new standard might fit in their enterprise's catalogue. Technical committees then decide if a standard should be developed and proceed accordingly. Therefore, the stock of standards developed by SCC-accredited SDOs reflects the demand for standards solutions.[14] Consequently, the stock of standards is used as a proxy to represent the activities in the standardization system.

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[12] In addition to the NSCs and consensus SDO standards used in this study, Canadian industry and regulators use standards developed by other organizations in other countries along with those developed by international standard development organizations.

[13] The newly SCC-accredited SDOs are Air-Conditioning, Heating & Refrigeration Institute, Underwriters' Laboratories Inc., and ASTM International accredited in 2013, and NSF International accredited in 2014.

[14] Standards Council of Canada.

In this study, we include the following documents as part of the stock of standards: new standards, new editions of standards, adoptions of international standards, and Other Recognized Documents (ORDs). "An ORD is defined as a document developed by a certification body, in the absence of a recognized Canadian standard, in order to establish safety and performance criteria for a new product. The ORD is intended to provide Regulatory Authorities and industry associations with assurance that a level of safety or performance, which is equal to that of existing standards for similar functions, is being maintained. An ORD must be accepted by the applicable Regulatory Authority or appropriate industry association(s) in order to gain validity."[15] ORDs are an important part of the Canadian standardization system as they are often created to respond to an emerging need when a standard does not exist.

We determined the number of standards in existence in any one year as follows:

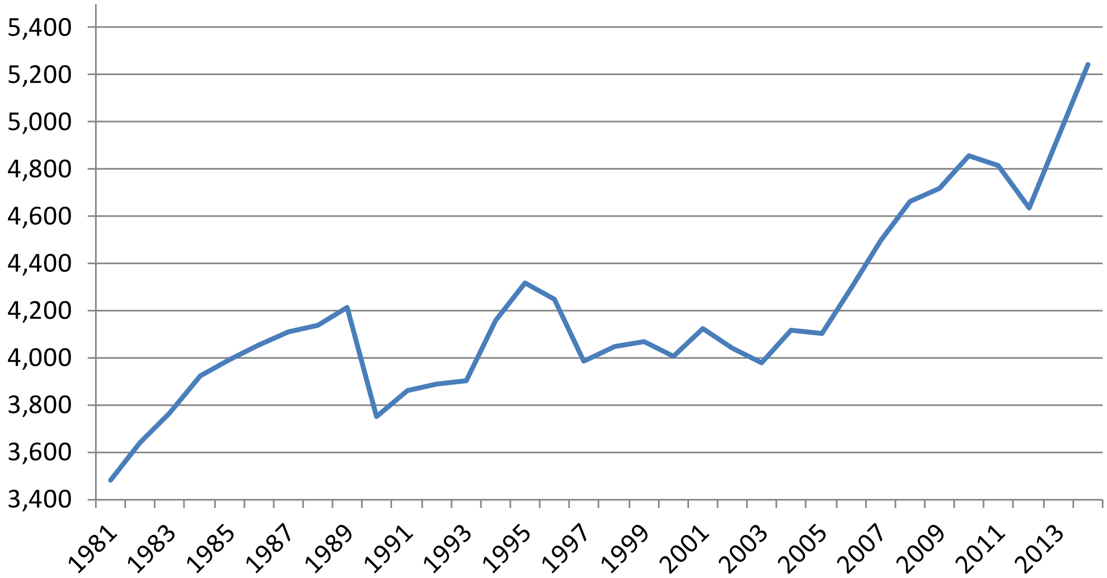
$$\begin{pmatrix} Stock \\ of \\ standards \end{pmatrix} = \begin{pmatrix} Number\ of \\ standards \\ in \\ the\ previous\ year \end{pmatrix} + \begin{pmatrix} Number \\ of \\ new\ standards \\ introduced \end{pmatrix} - \begin{pmatrix} Number \\ of \\ standards \\ withdrawn \end{pmatrix}$$

The data provided by the SCC allowed for constructing data on the stock of standards over time, from 1981 to 2014. (See Chart 1.)

[15] Standards Council of Canada.

Chart 1: Total Stock of Standards

(Total stock of standards, 1981-2014)



Sources: Standards Council of Canada; The Conference Board of Canada.

The aggregate production function allows us to derive the two sources that contribute to overall labour productivity growth. Essentially these are growth in multifactor productivity and capital deepening. Capital deepening is arguably easier to understand as it represents an increase in the amount of productive capital per worker. On the other hand, multifactor productivity represents how efficient we are in combining labour and capital to produce output. Because multifactor productivity is so important in determining long-term economic growth, volumes of literature examine what factors may affect it.

Multifactor productivity is itself divided into two parts: knowledge and efficiency. Standards play a role in both these parts. Together with factors such as patents, research and development, and imports of foreign technology, standards might have an impact on levels of knowledge or technological capacity. Standards, along with improvements in physical infrastructure and structural shifts in the economy such as labour mobility between industries, are an integral part of Canada's ability to produce goods and services.

This research examined various empirical relationships to establish whether the stock of Canadian standards, as reported by the SCC-accredited SDOs, has had an impact on Canada's multifactor productivity. The analysis can be done directly on our estimates of multifactor productivity or, as in much of the literature, indirectly on labour productivity, which is more measurable.[16] Since labour productivity is defined by multifactor productivity and capital deepening, we can test, empirically, the relationship among labour productivity, the stock of standards, and the ratio of the productive capital stock in the economy to employment. In addition, other variables, including a time trend, can help to control for other determinants of multifactor productivity.

The macroeconomic data used in the analysis comes from Statistics Canada.[17] We calculated the measure of labour productivity used as a ratio of total real GDP to the total number of hours worked. To create the capital-to-labour ratio, we divided a measure of the capital stock by a measure of the quantity of labour. We used the hyperbolic end-of-year net stock of non-residential capital[18] for all industries measured in chained 2007 dollars as a measure for capital stock. The quantity of labour variable used was total hours worked by all persons 15 years and over in all industries.

[16] Multifactor productivity is not directly observable; it has to be estimated based on a fixed (but unknown) representation of the aggregate production function. As such, studies tend to focus on the link between standards and labour productivity, which, along with capital deepening, are directly observable.

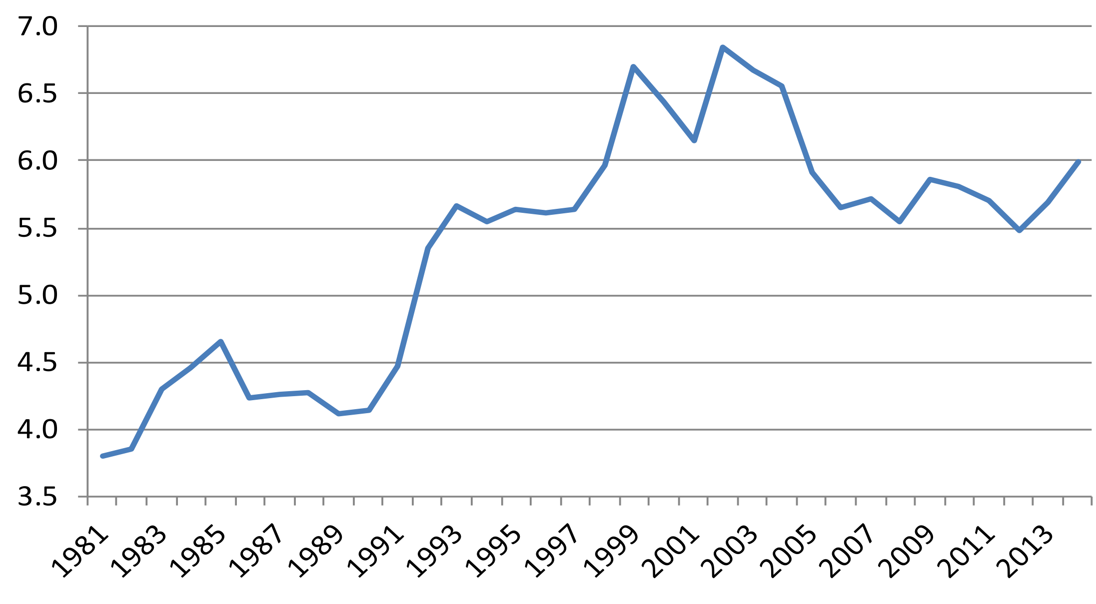
[17] Statistics Canada, Tables 282-0019, Table 282-0028, Table 031-0002, Table 379-0031, Table 380-0064 (accessed in September, 2015). Data for real GDP by industry at basic prices from Table 379-0031 is available from 1997 on; previous to 1997 the data were grown back using growth by industry from Table 379-0018 (from 1981 to 1996).

[18] Hyperbolic end-of-year net stock was chosen because we feel it best represents the productive capacity of assets. Hyperbolic depreciation takes the greatest amount of value from an asset nearer to the end of its useful life. Capital stock data for 2014 were projected based on real private and public investment data from Statistic Canada's National Income and Expenditure accounts, Table 380-0064. Capital stock in 2014 was assumed to equal capital stock in 2013, plus new investment, less depreciation. Depreciation was determined as the implicit average historical depreciation over the previous 5 years (2009-2013), applied to the stock of capital in 2013.

Our methodology looked at both the impact of standards on the total economy, as well as on the Canadian economy excluding the oil and gas extraction sector. We exclude oil and gas extraction because productivity in this sector is being affected by a unique set of circumstances leading to the maturing conventional oil and gas industry and the transformation to non-conventional extraction.[19] The share of non-conventional oil and gas production increased from 22 per cent in 2007 to 34 per cent in 2014.[20] This transformation has resulted in a substantial decline in productivity in oil and gas extraction that could be independent from the growth in the stock of standards that applies to this industry. Labour productivity (output per hours worked) in oil and gas extraction increased on average 3.2 per cent compounded annually over 1981–1999; however, labour productivity in oil and gas extraction fell on average 0.5 per cent compounded annually over 2000–2014. (See Chart 2.)

Chart 2: Labour Productivity in Oil and Gas Extraction: Uneven Trend

(Labour productivity in oil and gas extraction, millions $2007 per total hours worked, 1981–2014)



Sources: Statistics Canada Tables 379-0031, 379-0018 and 282-0028; The Conference Board of Canada.

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[19] Natural Resources Canada.

[20] Statistics Canada, Table 379-0031.

In addition, the oil and gas extraction industry is influenced largely by North American standards often developed in the United States.[21] A 2013 SCC study of the sector concluded that approximately only 3 per cent of the standards developed by SCC-accredited organizations affect this sector.[22] As such, the relationship we are testing is consistent in that it largely excludes oil and gas standards in the measure of the stock of standards and it excludes oil and gas production, labour and capital in the aggregate production function.

Findings

Over the 1981 to 2014 time period, the number of standards rose on average 1.2 per cent per year in comparison to real GDP growth that averaged 2.5 per cent annually.

As a first step, we examined the relationship between the stock of standards and the economy as a whole. The estimation results for the coefficients in the labour productivity equation show that the elasticity of labour productivity with respect to the stock of standards equals 0.048 and is found to be statistically significant.[23] (See Appendix A, Table 1.) This suggests that a 10 per cent increase in the number of standards would lead to a 0.48 per cent increase in labour productivity (output per hour worked) and that standards play an important role in enhancing labour productivity in Canada.

We then repeated the analysis excluding the oil and gas sector from GDP, employment, the capital stock and labour productivity. As expected, this estimation provided more robust results.[24] In this case, the elasticity of labour productivity with respect to the

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[21] In Canada, CSA is the leading SDO contributing to standard development in the oil and gas sector. Outside of Canada, the American Petroleum Institute (API), followed by ASTM International, are two key contributors to standard development in the oil and gas sector. (See page 8). Standards Council of Canada (2013).

[22] Standards Council of Canada (2013).

[23] This compares to 0.356 in our previous study. The extension of the data from 2004 to 2014 affects results. As discussed, we believe that the oil and gas extraction sector, which suffered a rapid decline in productivity over the past decade, is significantly influencing results over the period analyzed.

[24] Appendix A discusses detailed results.

stock of standards is 0.158 and is found to be statistically significant. This suggests that a 10 per cent increase in the number of standards results in a 1.58 per cent increase in labour productivity in the economy, excluding oil and gas extraction. Assuming that the estimated impact is constant over time, standardization contributed $3 billion to real GDP in 2014. (See Appendix A, Table 2.) Table 1 presents abbreviated estimation results for the two parts of the study, comparing estimated elasticity for the economy as a whole and excluding oil and gas extraction as well as our previous study (2007). (See Table 1 and Table 2.)[25]

Table 1: Estimated Elasticity of Labour Productivity: Economy as a Whole (All Industries), Economy Excluding Oil and Gas, Conference Board 2007 Study (Economy, All Industries)

	All industries	Excluding oil and gas extraction	2007 study (all industries)
Elasticity with respect to Stock of Standards	0.048	0.158	0.356
Capital-to-Labour Ratio	0.163	0.212	0.550

Sources: Statistics Canada; The Conference Board of Canada.

Table 2: Average Contribution of Standards to Growth in Labour Productivity and Real GDP: Percentage Points Contribution

	All industries	Excluding oil and gas extraction	2007 study (all industries)
Average GDP and labour productivity contribution (percentage points)	0.060	0.210	0.246

Sources: Statistics Canada; The Conference Board of Canada.

Excluding oil and gas extraction, on average, growth in the number of standards contributed 0.21 percentage points to growth in labour productivity (output per hour worked) and economic output (real GDP, excluding oil and gas sector). Alternatively,

[25] It should be noted that our previous study had a much shorter sample period (1981 to 2004) and as a result did not capture the decline in labour productivity associated with the shift in oil and gas extraction from conventional to non-conventional to the same degree as our current study does.

growth in the number of standards accounted for 15.7 per cent of the growth in labour productivity and about 8.3 per cent of the growth rate in economic output (real GDP), excluding oil and gas extraction, over the 1981 to 2014 period.[26]

To calculate the impacts of the growth in the stock of standards on total GDP and labour productivity the estimation results from the more robust specification (excluding the oil and gas sector) are applied to the overall economy. Over the study period of 1981 to 2014, standardization contributed to 16.1 per cent of the growth of total labour productivity and 7.8 per cent of the growth of real GDP (including all industries). To put it in perspective, our estimates suggest that by the end of 2014, real GDP could have been roughly $91 billion[27] (-5.6 per cent) lower had there been no growth in the stock of standards over the past three decades. Assuming that the estimated impact is constant over time, standardization contributed roughly $3 billion of the $39 billion increase in real GDP in 2014. Alternatively, a 1 per cent increase in the stock of standards would have added $2.4 billion to real GDP in 2014.

Conclusion

Long-term economic growth can be modelled using an aggregate production function in which capital, labour and multifactor productivity determine real GDP. Multifactor productivity is the efficiency in which capital and labour mix to produce output. Many factors are thought to contribute to multifactor productivity including research and development, innovation, adoption of technology and others.

In this study we find empirical evidence of the link between the stock of standards in Canada and multifactor productivity over the 1981 to 2014 period. It may well be that the stock of standards is not independent of other factors that influence efficiency gains in the economy. We do find, as do other international studies, that growth in the stock of standards has been an important contributing factor to labour productivity and total real GDP growth in Canada.

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[26] For impact calculations, please see Appendix A.

[27] We calculated the cumulative monetary impact on total GDP as a difference between real GDP and expected real GDP calculated without the effect of standards. (See Appendix A for detailed calculations.)

Appendix A: Methodology and Detailed Empirical Results

The empirical model used in this analysis is similar to the aggregate model used in our previous study. The model is based on the assumption that aggregate economic output can be represented by a production function that takes the following form:

$$Q_t = A_t K_t^{\alpha} L_t^{(1-\alpha)},$$

Where output for the economy is determined as a (Q_t) a non-linear function of multifactor productivity (A_t), the capital stock (K_t), and the quantity of labour (L_t). In this production function capital and labour inputs are combined to produce output. The ability of capital and labour to produce output is augmented by the level of technology and efficiency in the economy that is captured in the multifactor productivity term. The relationship can be shown in the following equation:

$$\begin{pmatrix} Labour \\ Productivity \end{pmatrix} = \begin{pmatrix} Contribution \\ of \\ Multifactor \\ Productivity \end{pmatrix} + \begin{pmatrix} Contribution \\ of \\ Capital \\ Deepening \end{pmatrix}$$

Capital deepening represents an increase in the amount of capital per worker. Multifactor productivity is itself divided into two parts: knowledge and efficiency. Standards, patents, research and development, and imports of foreign technology are some factors that have an impact on knowledge or technological capacity. Standards, improvements in infrastructure and structural shifts in the economy such as labour mobility among industries are some factors that have an impact on the level of efficiency in the economy. Standards can thus potentially play an important role in enhancing multifactor productivity.

In this study multifactor productivity is modeled as a function of time and the number of standards. Multifactor productivity is assumed to take the functional form:

$$A_t = \exp(\lambda T_t) \times STA_t^{\varepsilon}$$

where T_t is a time trend vector and STA_t is the number of standards in year t.

These assumptions on the production function and multifactor productivity yield the following model for labour productivity:

$$\ln(Q_t / L_t) = \beta + \alpha \ln(K_t / L_t) + \lambda T_t + \varepsilon \ln(STA_t) + u_t$$

(Equation 1)

In this model $\ln(Q_t / L_t)$ is the natural logarithm of labour productivity, $\ln(K_t / L_t)$ is the natural logarithm of capital-to-labour ratio that captures capital deepening, T_t is a time trend vector, STA_t is the number of standards, and u_t is an error term.

The first step in the analysis is to examine the individual variables themselves to determine whether or not they exhibit stochastic (or random) trends. The choice of estimation method depends upon whether or not the variables exhibit stochastic trends. Labour productivity, the capital-to-labour ratio, and the number of standards all exhibit stochastic trends, indicating that the cointegration techniques first developed by Engle and Granger (1987) are the appropriate ones to use for the analysis.[28]

Estimating long-run models such as the one given in Equation 1, where the variables have stochastic trends, may lead to incorrect conclusions about the significance of the relationship among the variables of interest. Engle and Granger (1987) proposed a widely accepted methodology to determine whether the results from estimating a long-run model, in which the variables have stochastic trends, are meaningful. In the first step, a long-run model, such as the one given in Equation 1, is estimated. The residuals or errors from the estimation, in this case u_t, are then tested using an Augmented Dickey-Fuller (ADF) test to see whether they contain stochastic trends. If they do not

[28] Augmented Dickey-Fuller tests were performed on the natural logarithms of labour productivity, the capital-to-labour ratio, and the stock of standards. These tests included a constant and a linear trend. Because of the short length of the time series, a lag length of 1 was chosen. In all cases the tests were unable to reject the null hypothesis of a unit root (i.e., the presence of a stochastic trend) at the 10 per cent level.

contain stochastic trends, then the conclusions based upon the estimation results can be considered meaningful.

The results from estimating Equation 1 are presented in Table 1 below.

Table 1: Estimation Results, Total Industries (in logarithms)

Sample: 1981 to 2014
Method: Least Squares

Variable	Coefficient	Std. Error	T-Statistic	P-Value
LOG (standards)	0.048	0.013	3.741	0.001
LOG (capital-to-labour ratio)	0.163	0.075	2.180	0.038
Time trend	0.011	0.001	8.651	0.000
AR(1)	0.849	0.105	8.076	0.000
Adjusted R-squared				0.993815
Durbin-Watson statistic				1.418785
ADF test of the residual				-4.02873
P-value for the ADF test				0.0174

Notes:
a) Standards errors are White heteroskedasticity-consistent.
b) The P-Value represents the degree of certainty with which we can reject the hypothesis that the variable has no impact on labour productivity.
c) The ADF test of residual included a constant, a trend and lag lengths were chosen using the Schwartz Information Criteria.

Source: The Conference Board of Canada.

The ADF test of the residual reported near the bottom of the table indicates that the residuals from the model do not contain stochastic trends. This suggests that the results obtained from estimating the model are not spurious. Both capital deepening, as measured by the capital-to-labour ratio, and the existing number of standards have a significantly positive impact on labour productivity.

The second part of the study sought to examine whether the same relationship between standards and labour productivity holds once we remove the oil and gas extraction sector. We used the same structure of the equation. However, we calculated real GDP, capital stock and total hours worked as a total less the values for the oil and gas extraction sector for each series. Statistics Canada data on the capital stock in the oil and gas sector extended only to 2013. To extend the sample size to 2014, we grew out the oil and gas extraction sector capital stock with the growth rate of the hyperbolic end-of-year net capital stock of engineering and mining.

To calculate "total hours worked" excluding the oil and gas sector, we used a proxy. Total hours for "other primary" industries (which includes forestry, fishing, mining, quarrying, oil and gas industries) was used as total hours for only the "oil and gas" sector. We derived the proxy as follows:

$$\begin{pmatrix} Total\ Hours \\ Worked \\ Economy\ excluding\ Oil\ and\ Gas \end{pmatrix} = \begin{pmatrix} Total\ Hours \\ Worked \\ All\ Industries \end{pmatrix} - \begin{pmatrix} Total\ Hours \\ Worked\ in \\ \text{Other Primary} \\ Industries \end{pmatrix}$$

The sample period for the resulting series spanned 1987 to 2014. In order to line up the series with other variables, a growth rate from the total hours worked for the entire economy was applied to 1981-1986 to create the total hours worked in the "economy excluding oil and gas" sector for that period of time. In addition, we used a variable representing technology use (calculated as a share of capital stock associated with intellectual property in total capital stock) to estimate impacts in "economy without the oil and gas extraction." Table 2 shows the results.

Table 2: Estimation Results, "Economy Excluding Oil and Gas Sector" (in logarithms)

Sample: 1981 to 2014

Method: Least Squares

Variable	Coefficient	Std. Error	T-statistic	P-Value
LOG (standards)	0.158	0.017	9.50	0.000
LOG (capital-to-labour ratio)	0.219	0.120	1.823	0.077
LOG (IP ratio)	0.258	0.062	4.180	0.000
Time trend	0.0014	0.003	0.496	0.623
Adjusted R-squared				0.987214
Durbin-Watson statistic				1.037327
ADF test of the residual				-4.181071
P-value for the ADF test				0.0147

Notes:
a) Standards errors are White heteroskedasticity-consistent.
b) The P-Value represents the degree of certainty with which we can reject the hypothesis that the

variable has no impact on labour productivity.
c) The ADF test of residual included a constant, and lag lengths were chosen using the Schwartz Information Criteria.

Source: The Conference Board of Canada.

It is important to caution that due to the small sample size (34 observations), estimation results were vulnerable to variations in estimation specification.

The difference in results between *total industries* and *economy excluding oil and gas* suggests that productivity in the oil and gas extraction sector has been strongly affected by factors other than standards, and that once that sector's influence is removed, we can observe a much stronger impact.

Box: Additional Specification to Control for the Shift in Oil and Gas Extraction from Conventional to Non-Conventional

For the purpose of controlling for the shift from conventional oil and gas extraction to non-conventional and the resulting decline in labour productivity, we estimated a different equation specification. We used two dummy variables to control for the shift, with one variable accounting for the increase in labour productivity up to 1999 (Trend 2) and the second one controlling for the declining productivity from 2000 to 2014 (Trend 1). The estimated elasticity of labour productivity is similar to the estimates excluding the oil and gas sector. However, it is important to note that Trend 1 can be considered statistically significant only at 35.5 per cent and Trend 2 at 21.6 per cent.

Sample: 1981 to 2014
Method: Least Squares

Variable	Coefficient	Std. Error	T-statistic	P-Value
LOG (standards)	0.106	0.053	1.987	0.057
LOG (capital-to-labour ratio)	0.339	0.098	3.461	0.002
Trend 1	-0.552	0.587	-0.940	0.355
Trend 2	-0.580	0.458	-1.266	0.216
AR(1)	0.994	0.030	32.680	0.000
Adjusted R-squared				0.98949714
Durbin-Watson statistic				1.04358527
ADF test of the residual				-4.61630371
P-value for the ADF test				0.00447

Notes:
a) Standards errors are White heteroskedasticity-consistent .
b) The P-Value represents the degree of certainty with which we can reject the hypothesis that the variable has no impact on labour productivity.
c) The ADF test of residual included a constant, and lag lengths were chosen using the Schwartz

Information Criteria.
Source: The Conference Board of Canada.

Over the study period of 1981 to 2014, standardization contributed to 16.1 per cent of the growth rate of total labour productivity and 7.8 per cent of the growth of real GDP. To put it in perspective, our estimates (using elasticity of 0.158 and applying it to the total real GDP) suggest that by the end of 2014, real GDP could have been roughly $91 billion (-5.6 per cent) lower had there been no growth in the stock of standards over the past three decades.

We calculated the contribution to labour productivity and real GDP as follows:

$$\begin{pmatrix} Contribution \\ to \\ GDP \end{pmatrix} = \begin{pmatrix} Average \\ Expected \\ Impact\ on \\ Growth\ Rate \end{pmatrix} / \begin{pmatrix} Average \\ GDP \\ Growth \end{pmatrix}$$

$$\begin{pmatrix} Average \\ Expected \\ Impact\ on \\ Growth\ Rate \end{pmatrix} = \frac{\sum_{t=1}^{33}\left(\begin{pmatrix} Standards \\ Growth \end{pmatrix}_t * \begin{pmatrix} Elasticity \\ w.r.t. \\ Standards \end{pmatrix}\right)}{33}$$

33 is the total number of years available for growth calculation (1981–2014).

$$\begin{pmatrix} Contribution \\ to \\ GDP\ growth \end{pmatrix} = \left[\begin{pmatrix} Growth \\ in \\ Real \\ GDP \\ Including \\ Standards \end{pmatrix} - \begin{pmatrix} Growth \\ in \\ Real \\ GDP \\ Without \\ Standards \end{pmatrix} \right] / \begin{pmatrix} Growth \\ in \\ Real \\ GDP \\ Including \\ Standards \end{pmatrix}$$

$$\begin{pmatrix} Contribution \\ to \\ Labour \\ Productivity \\ Growth \end{pmatrix} = \left[\begin{pmatrix} Growth \\ in \\ Labour \\ Productivity \\ Including \\ Standards \end{pmatrix} - \begin{pmatrix} Growth \\ in \\ Labour \\ Productivity \\ Without \\ Standards \end{pmatrix} \right] / \begin{pmatrix} Growth \\ in \\ Labour \\ Productivity \\ Including \\ Standards \end{pmatrix}$$

Growth rates were calculated over 1981–2014 as average annual compound growth rates.

Assuming that the estimated impact is constant over time, standardization contributed roughly $3 billion of the $39 billion increase in real GDP in 2014. We derived the effect as follows:

$$\begin{pmatrix} Impact \\ on\ Real\ GDP \end{pmatrix}_t = \begin{pmatrix} Contribution\ to \\ GDP\ Growth \end{pmatrix}_t * \begin{pmatrix} Real\ GDP \\ Growth \end{pmatrix}_t$$

where *t* indicates a given year.

Based on the analysis, a 1 per cent increase in the stock of standards would have added $2.4 billion to real GDP in 2014. The value of the impact on real GDP was calculated as follows:

$$\begin{pmatrix} Impact \\ on\ Real\ GDP \\ from \\ 1\%\ increase \\ in \\ Stock\ of\ Standards \end{pmatrix} = \frac{\begin{pmatrix} Estimated \\ Elasticity \\ of \\ Stock\ of\ Standards \end{pmatrix}}{\begin{pmatrix} 100 + Contribution \\ to\ GDP\ Growth \end{pmatrix}} * GDP_t$$

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