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111 Sparks Street, Suite 500
Ottawa, Ontario K1P 5B5
613-233-8891, Fax 613-233-8250
csls@csls.ca

CENTRE FOR THE STUDY OF LIVING STANDARDS

A DETAILED ANALYSIS OF THE PRODUCTIVITY PERFORMANCE OF OIL AND GAS EXTRACTION IN CANADA

Celeste Bradley and Andrew Sharpe
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A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada

Abstract

In recent years, the productivity performance of oil and gas extraction in Canada has been dismal. Based on official real GDP and labour input estimates from Statistics Canada, labour productivity in oil and gas extraction fell 8.23 per cent per year between the 2000 cyclical peak and 2007, with capital productivity down 5.97 per cent per year over the same period and total factor productivity (TFP) off 6.67 per cent per year between 2000 and 2006. Among the various hypotheses put forward to explain these trends, the most robust seems to be that higher output prices have suppressed productivity growth through two effects: increased exploitation of low-productivity marginal deposits, and business decisions based on profitability rather than productivity. Despite the rapid decline in productivity in oil and gas extraction, it is not necessarily true that Canadians are worse off. In fact, increased output prices and employment shares in the industry, as well as the high productivity level, have resulted in positive contributions to Canada's aggregate labour productivity growth from 2000 to 2006.

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Executive Summary

In recent years, the productivity performance of oil and gas extraction in Canada has been dismal. Based on official real GDP and labour input estimates from Statistics Canada, labour productivity fell by 8.23 per cent per year between the cyclical peaks in 2000 and 2007, with capital productivity down 5.97 per cent per year and total factor productivity (TFP) off 6.67 per cent per year between 2000 and 2006. This situation reflects the faster growth of inputs relative to output. While real GDP in oil and gas extraction increased 14.1 per cent over the 2000-2007 period, hours worked grew 108.0 per cent and the real capital stock grew by 75.4 per cent. Hence, the key to explaining the slump in productivity in oil and gas extraction is to shed light on why inputs are growing so much faster than output.

Oil and gas extraction is relatively less important in the United States than in Canada in terms of both output and employment. In the 1990s labour productivity in oil and gas extraction grew faster in the United States than in the Canada. From 2000 to 2006 labour productivity declined in the United States, but not to the same extent as in Canada. In terms of levels, labour productivity (GDP per worker) in oil and gas extraction in the United States has been lower than in Canada since at least the 1980s. However, the labour productivity gap in oil and gas extraction between Canada and the United States has been narrowing, and the Canadian industry is now only slightly more productive. Capital and total factor productivity exhibited similar trends. In both cases, the United States experienced faster growth than Canada in the 1990s, and less dramatic productivity declines from 2000 to 2006.

Oil and gas extraction accounted for 6.2 per cent of aggregate labour productivity growth in Canada in the 1987-2006 period. While oil and gas extraction is an activity with a high level of labour productivity, over this period its labour productivity declined. In spite of this decline, the contribution of oil and gas extraction to aggregate labour productivity growth was still positive. The reason for this counterintuitive result is that a larger share of the Canadian labour force worked in oil and gas extraction in 2006 than in 1987, and a smaller share worked in other, lower-productivity, activities. As well, relative real oil and gas prices increased significantly over this period.

Canada experienced a significant slowdown in labour productivity growth between the 1996-2000 and 2000-2006 periods, from an average annual rate of growth of 2.35 per cent to 1.12 per cent. Despite rising employment and output prices, oil and gas extraction contributed to the slowdown, because of its dramatic decline in labour productivity growth.

There are a number of possible explanations for the observed declines in all three measures of productivity (labour, capital, and total factor) in oil and gas extraction in Canada: declining capital intensity; higher output prices; lagging innovation and technological progress; deterioration of the average quality of the workforce; greater environmental regulation; deterioration of the average quality of resources exploited independent of price effects; labour relations; and taxation.

Upon examining various hypotheses put forward to explain falling productivity in oil and gas extraction, the strongest seems to be the effect of higher prices on both capital intensity and TFP. When the price of a natural resource increases it becomes profitable to increase extraction rates at existing deposits and to extract from marginal deposits that were previously unprofitable due to high costs of extraction. In the short term, because labour is less rigid than capital, we can expect this adjustment process to translate into a falling capital-labour ratio.

Another seemingly robust explanation is that profitability trumps productivity as an objective for firms. While the objectives of productivity and profitability normally coincide, they diverge when commodity prices are extremely high. As a result, the productivity growth of an industry, measured in constant prices, may suffer due to greater inefficiency in operations. This would be reflected in a fall in TFP growth. Data on TFP and capital intensity suggest that falling capital intensity growth rates can explain a large part of the productivity slowdown in oil and gas extraction between the 1996-2000 and 2000-2006 periods. Yet, it also suggests that the decline in labour productivity in oil and gas extraction is also due to sustained declines in TFP. These findings reinforce the idea that higher prices were the main driver of both the post-2000 labour productivity slowdown and the negative productivity growth in oil and gas extraction.

Since productivity growth is the key driver of increases in living standards, the deceleration in labour productivity growth in Canada after 2000 implies a slower rate of increase in living standards. But improving terms of trade are also a source of real income increases. The higher commodity prices that Canada has enjoyed in recent years, in addition to the negative effect on oil and gas extraction productivity, have boosted the real income of Canadians.

To improve productivity growth in oil and gas extraction, this report does not recommend any industry-specific policies above and beyond general policies aimed at facilitating economy-wide productivity growth. Despite the decline in productivity in this industry, it is not true that Canadians are worse off. In fact, the increases in prices and in employment, together with the high productivity level of oil and gas extraction, have resulted in a positive contribution (albeit shrinking compared to the 1996-2000 period) to aggregate labour productivity growth over the 2000-2006 period.

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A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada[1]

I. Introduction

A. Motivation

In recent years, the productivity performance of oil and gas extraction in Canada has been dismal. According to official real GDP and labour input estimates from Statistics Canada, labour productivity in oil and gas extraction fell 7.74 per cent per year between the 2000 cyclical peak and 2007, with capital productivity down 5.97 per cent per year and total factor productivity (TFP) off 6.67 per cent per year.[2] The three questions that this report seeks to answer are

- Why has productivity in oil and gas extraction fallen?
- What has been the effect of this poor performance on aggregate labour productivity growth? and,
- What, if anything, should be done about falling productivity?

Oil and gas extraction is a sector that has received much attention in recent years. There are a number of reasons for this interest including the dramatic increase in oil prices and the effect of oil prices on the Canadian dollar, the environmental impact of the development of the oil sands (Sharpe *et al.*, 2008), and the inter-regional re-alignment of the Canadian economy in response to the growth of oil and gas extraction. This realignment has had, and will continue to have, important political and social, as well as economic, implications.

B. Organization of the Report

This report is divided into eight major parts. After the introduction, definitions, data sources, concepts, and measurement issues relevant to the analysis of productivity in oil and gas extraction are discussed. The third part of the report reviews trends in indicators related to oil and gas extraction productivity in Canada, both at the national and provincial levels. Trends in real GDP, hours worked, capital stock, labour

[1] The authors would like to thank Industry Canada for financial support and Jianmin Tang from Industry Canada for useful comments and suggestions. We would also like to thank officials from Natural Resources Canada for their comments, as well as Souleima El-Achkar, Jean-François Arsenault, Peter Harrison, Alexander Murray, and Christopher Ross for assistance.

[2] All data used in the report can be found in the extensive set of Appendix Tables posted alongside this report on the CSLS website (www.csls.ca). In general, the report will make direct reference to the relevant appendix table when discussing specific trends or results. The set of Appendix Tables covers both the oil and gas extraction and the mining sub-sectors. For an analysis of the mining sub-sector, see Bradley and Sharpe (2009).

productivity, capital productivity, and total factor productivity (TFP) are analyzed. The fourth part of the report reviews trends in productivity in the United States. The fifth part assesses the contribution of changes in labour productivity in oil and gas extraction to aggregate labour productivity growth in Canada. The contribution of oil and gas extraction to the overall productivity slowdown that occurred between the periods 1996-2000 and 2000-2006 is assessed. The sixth part presents hypotheses for the observed decline in productivity in oil and gas extraction since 2000. Hypotheses examined are changing capital intensity; higher prices for energy and materials; lagging innovation and technological progress; deterioration in the average quality of the workforce; greater environmental regulation; deterioration in the average quality of resources independent of price effects; labour relations; and taxation. The seventh part assesses the implications of falling productivity in oil and gas extraction for the Canadian economy. The eighth and final part summarizes the findings of the report and concludes.

II. Definitions, Data Sources, Concepts, and Measurement Issues

This section discusses definitions, data sources, and productivity measurement issues.

A. Definitions

Statistics Canada classifies establishments[3] according to the North American Industry Classification System (NAICS, pronounced "nakes"). NAICS groups establishments into sectors based on the similarity of their production processes. NAICS has a hierarchical structure which divides the economy into 20 sectors, identified by two-digit codes. Below the sector level, establishments are classified into three-digit sub-sectors, four-digit industry groups, and five- and six-digit industries. At all levels, the first two digits always indicate the sector, the third digit the sub-sector, the fourth digit the industry group, and the fifth digit the industry. The oil and gas extraction sub-sector is part of the mining and oil and gas extraction sector, NAICS code 21.

Oil and gas extraction (NAICS code 211)[4] is a sub-sector composed of establishments primarily engaged in operating oil and gas field properties. Such activities may include exploration for crude petroleum and natural gas; drilling, completing and equipping wells; operating separators, emulsion breakers, desilting equipment and field gathering lines for crude petroleum; and all other activities in the preparation of oil and gas up to the point of shipment from the producing property. This sub-sector includes the production of oil, the mining and extraction of oil from oil shale and oil sands, and the production of gas and hydrocarbon liquids, through gasification, liquefaction and pyrolysis of coal at the mine site.

Oil and gas extraction consists of two industries. Conventional oil and gas extraction (NAICS 211113) includes establishments primarily engaged in the exploration for and/or production of, petroleum or natural gas from well in which the hydrocarbons will initially flow or can be produced using normal techniques. Non-conventional oil extraction (211114) includes establishments primarily engaged in producing crude oil from surface shales or tar sands or from reservoirs in which the hydrocarbons are semisolids and conventional production methods are not possible. Unfortunately, data are not available for these industries, only at the aggregate level of the oil and gas extraction sub-sector.

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[3] "The establishment is the level at which all accounting data required to measure production are available. The establishment, as a statistical unit, is defined as the most homogeneous unit of production for which the business maintains accounting records from which it is possible to assemble all the data elements required to compile the full structure of the gross value of production (total sales or shipments, and inventories), the cost of materials and services, and labour and capital used in production. Provided that the necessary accounts are available, the statistical structure replicates the operating structure of the business. In delineating the establishment, however, producing units may be grouped. An establishment comprises at least one location but it can also be composed of many. Establishments may also be referred to as profit centres." (Statistics Canada, 2007)

[4] This paragraph and the next are drawn from the official NAICS handbook (Statistics Canada, 2007). See the Appendix for a complete description of the industries that make up the oil and gas extraction sub-sector.

It is worth noting that the analysis in this report excludes two industries. In both cases the exclusion is the result of the absence of data. This report does not analyze productivity in the "oil and gas contract drilling" industry (NAICS code 213111), because data were not available. This industry includes establishments primarily engaged in drilling wells for oil or gas field operations, for others, on a contract or fee basis. Another exclusion is the "services to oil and gas extraction" industry (NAICS code 213118) which includes establishments primarily engaged in performing oil and gas field services, except contract drilling, for others, on a contract or fee basis. These two industries are part of the support activities for mining and oil and gas extraction sub-sector (213) and not the oil and gas extraction sub-sector (211).[5]

Another potentially important exclusion is construction. The building of structures may be an important part of the value chain in the oil and gas business, but building is a construction sector activity, not a mining and oil and gas extraction activity. Due to the lack of data, this report does not attempt to assess the importance of this exclusion.

B. Data Sources

This report largely relies on official estimates of real GDP, labour, and capital provided by Statistics Canada. At the time of the writing of this report, official Statistics Canada estimates of productivity in the oil and gas extraction sub-sector were only available for the period 1961-2004. Furthermore, official productivity estimates are only available in index form, which allows for the analysis of growth rates but not of levels. In order to provide more detailed analysis of productivity trends in oil and gas extraction, calculations from the Centre for the Study of Living Standards productivity database are used.[6] These calculations are based on the Statistics Canada data and are provided for the 1987-2007 period (1987-2006 for TFP measures).[7]

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[5] These exclusions are only important to the following analysis if these industries have experienced a different productivity performance than the oil and gas extraction sub-sector, a proposition that is explored herein. In 2007, the support activities for mining and oil and gas sub-sector (NAICS code 213), the lowest level for which data are available, represented approximately 40 per cent of hours worked in the mining and oil and gas sector as a whole (NAICS code 21). Its productivity level, however, was only about one-tenth that of the oil and gas extraction sub-sector. Over the 1987-2007 period, support activities exhibited trends similar to those of the mining and oil and gas sector. In both cases, labour productivity was negative on average over the period (-0.49 per cent per year for the support activities sub-sector and a decline of 0.11 per cent per year for the sector as a whole). Moreover, in both cases labour productivity growth was positive during the 1990s, and then turned negative after 2000. Finally, given that the support activities sub-sector covers activities in both the mining and the oil and gas fields, it is not surprising that its labour productivity growth rate has in general been in-between that of either sub-sectors over the 1987-2007 period and its sub-periods. These trends suggest that the inclusion of the portion of the support activities sub-sector relevant to oil and gas extraction would not alter in any significant way the trends and conclusions discussed in this paper.

[6] The CSLS productivity database used in this report is available online at http://www.csls.ca/data/ptabln.asp. These estimates and Statistics Canada's official estimate for total factor productivity (TFP) are not entirely consistent; TFP estimates between the two sources differ as Statistics Canada uses capital services instead of capital stock when measuring the contribution of capital inputs and also because CSLS estimates do not account for changes in labour composition. The most recent update of the CSLS productivity database provides estimates consistent with those provided by Statistics Canada. It provides estimates of labour, capital and multifactor productivity for Canada and the provinces with estimates for two-digit NAICS sectors (www.csls.ca/data/mfp.asp). No data for sub-sectors (three-digit) are yet available. See Sharpe and Arsenault (2009) for more details on this database.

[7] In general, the sub-periods used in the report to support the analysis are 1989-2000 and 2000-2007. Both these periods are peak-to-peak periods, and as such they are cyclically neutral. While we could have attempted to include 2008 in our

Data on the United States, we use official productivity estimates for oil and gas extraction produced by the Bureau of Labor Statistics, supplemented by productivity estimates constructed from real output and labour and capital input data compiled by the Bureau of Economic Analysis and the Bureau of Labor Statistics.[8]

C. Productivity Concepts[9]

Productivity is the key factor behind growth in living standards. Without increasing the amount each worker can produce there would be no increase in real wages and incomes (CSLS, 2004). It is therefore productivity growth which drives increases in living standards, defined as real GDP per capita. When discussing productivity there are two important factors to consider: whether productivity is measured using partial productivity or total factor productivity, and whether productivity is measured in current or constant dollars.

Productivity can be measured in various ways. There is a fundamental distinction between partial and total factor productivity (TFP).[10] Partial productivity refers to the relationship between output and a single input, such as labour or capital. This report will provide estimates of both labour productivity (the most commonly used measure of productivity) and capital productivity. It is important to note that growth in labour productivity is not attributed solely to changes in labour effort. Other factors that can affect labour productivity include technical change and the amount of capital each worker has to work with. TFP attempts to measure how efficiently all factors are used in the production process. TFP growth is measured as the difference between output growth and combined input growth, and thus captures the effects of all elements of the production process such as skill of the workforce, compositional shifts, improvements in technology and organization, and increasing returns to scale.

In Canada, TFP estimates by industry are limited to the 1961-2004 period. In the United States, the Bureau of Labor Statistics does not provide TFP estimates for oil and gas extraction. The CSLS has therefore calculated its own TFP estimates for the United States based on official labour, capital and value added (GDP) estimates. These indexes are calculated with fixed 1997 factor shares according to a Cobb-Douglas production function that exhibits constant returns to scale (CSLS, 2005). In this framework, if the

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analysis, consistent data on hours worked for the oil and gas extraction sub-sector were not yet available. Moreover, data for 2008 would likely not show any significant change in trend, with the mining and oil and gas sector as a whole experiencing labour productivity growth of -5.7 per cent, in line with the trend over the 2000-2007 period (-4.4 per cent).

[8] Official estimates of capital input and total factor productivity growth in Canada and the United States are not entirely comparable, because Statistics Canada changed its methodology for measuring capital stocks in 2006. Yet, internationally comparable sources such as the Groningen Growth and Development Centre (GGDC) and the OECD only provide estimates up to 2003 and do not provide industry detail beyond the mining and oil and gas extraction sector. As such, data from Statistics Canada and the Bureau of Economic Analysis (BEA) are used for comparisons between the two countries.

[9] This section draws on CSLS (2003), CSLS (2004), and Sharpe (2007).

[10] Total Factor Productivity (TFP) is also referred to as Multi Factor Productivity (MFP). The difference is purely semantic as both measures attempt to capture the growth in value added that is not accounted for by growth in measured inputs, in particular labour and capital inputs (CSLS, 2005).

strong assumption of short-run profit maximization is made, the elasticity of output with respect to the labour input is identical to the share of total output paid to labour. The labour share in 1997 is calculated by multiplying average weekly earnings by employment and dividing by current-dollar value added, all for 1997. There are a number of limitations with this approach. Therefore the interpretation of TFP growth must be very broad and it is not possible to simply ascribe changes in TFP to technological change.

Productivity can be expressed either in growth rates or in levels. Economists most often focus on productivity growth rates, which should be based on constant price output and productivity measures to reflect increases in the real volume of output produced per hour worked or per unit of capital stock. In contrast, business analysts most often focus on productivity levels expressed in current dollars as this estimate will capture increases in relative prices. Often, current-dollar productivity levels and real productivity growth rates can move in opposite directions. This is especially true of the oil and gas extraction sub-sector which has experienced volatile prices, and in recent years rapidly rising energy prices.

D. Measurement Issues

The reliability of estimated productivity trends is highly dependent on the quality of the underlying data on current-dollar output, industry price deflators, capital input, and labour input (CSLS, 2003). Since the oil and gas extraction sub-sector produces a marketed output, there is no ambiguity concerning the appropriate measure of output as there often is in non-market sectors such as health care and national defence. In addition, the output of the oil and gas extraction sub-sector can be measured in physical terms, for example, barrels of oil or cubic meters of natural gas. Price data are also relatively reliable due to the physical nature of the output.

In 2007, Statistics Canada rated the quality of input and GDP data from the input-output tables for each NAICS industry for the 2002-2003 period (Statistics Canada, 2007). GDP data for the oil and gas extraction sub-sector were rated as “reliable” while input data was rated “acceptable”. This report assumes that output, price, capital, and labour data are generally reliable and that the productivity estimates therefore capture the true productivity trends. However, there are some issues that may affect productivity estimates that should be noted.

First, it is often difficult to accurately capture quality changes of outputs over time. The quality of oil and gas extraction output refers to factors such as ease of extraction, grade, purity, and size of a reserve. Therefore, quality deterioration of a natural resource base is often correlated with higher costs of extraction. For example, according to Statistics Canada estimates of expenditures in the oil and gas extraction sub-sector, expenditures for exploration, development, and operations for conventional oil increased by 30.1 per cent in 2005 while the volume of marketable conventional oil decreased by 3.49 per cent in 2005 (Appendix Table 20). This indicates that the quality of oil resources is declining in Canada.

Second, the treatment of exploration and on-site construction could have significant effects on productivity estimates. Over time, as larger and more easily recoverable deposits of a resource are found and exploited, resources allocated to exploration by oil and gas firms may increase. If there is no measure of exploration in the output of oil and gas extraction sub-sector, this will show up as a slump in productivity. According to Statistics Canada's implementation of the International System of National Accounts in 1993, expenditures on oil and gas exploration, whether successful or not, are treated as gross fixed capital formation (Statistics Canada, 1995).

III. Productivity Trends in Oil and Gas Extraction in Canada

This part provides an overview of productivity trends in oil and gas extraction in Canada. It examines trends in output (both nominal and real), labour, and capital as well as productivity trends for labour, capital, and total factor productivity. The final section addresses trends in oil and gas extraction productivity by province.

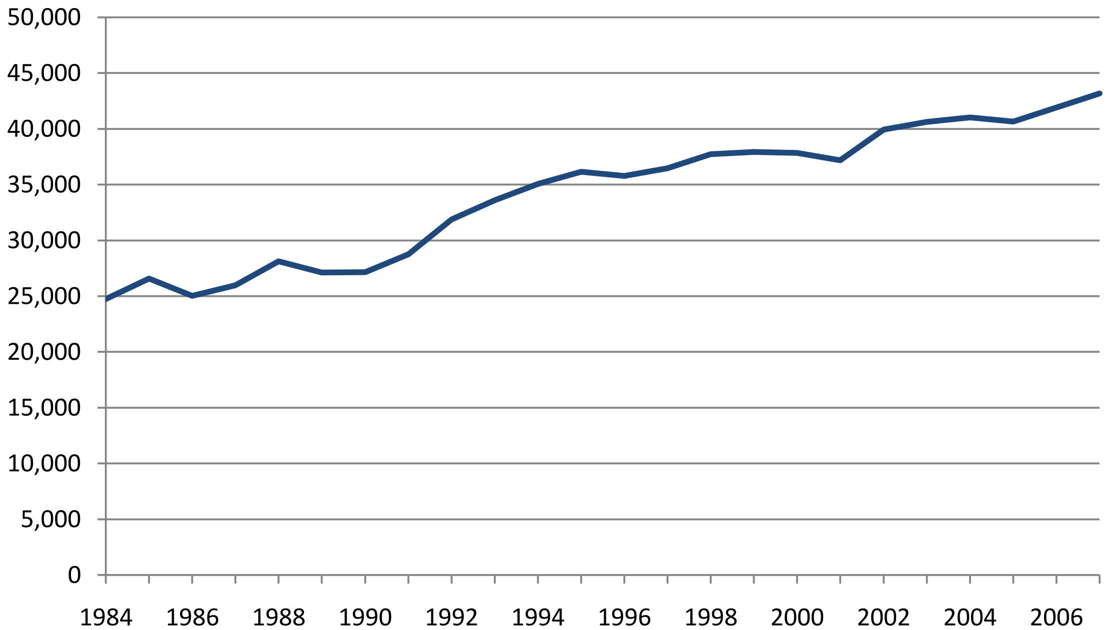
A. Oil and Gas Extraction Productivity Trends at the National Level

This section explores productivity trends in the oil and gas extraction. Each of the elements of productivity estimates, real GDP, labour input, and capital input, are examined. Then, trends in labour productivity, capital productivity, and total factor productivity are explored.

i. Real GDP

Real GDP in oil and gas extraction grew at an average annual rate of 2.61 per cent per year over the 1989-2007 period, at about the same rate as the economy as a whole (2.64 per cent per year) (Chart 1 and Summary Table 1). But this overall performance masked significant changes within this period. Between 1989 and 2000, oil and gas extraction real GDP experienced faster growth (3.07 per cent per year) than the all industries average (2.70 per cent per year). This pattern was reversed in 2000-2007. Real GDP in oil and gas extraction expanded by 1.90 per cent per year, behind the 2.55 per cent per year achieved in the economy as a whole.

Chart 1: Real GDP, Oil and Gas Extraction, Canada, Millions of Chained 2002 Dollars, 1984-2007



Source: Appendix Table 1

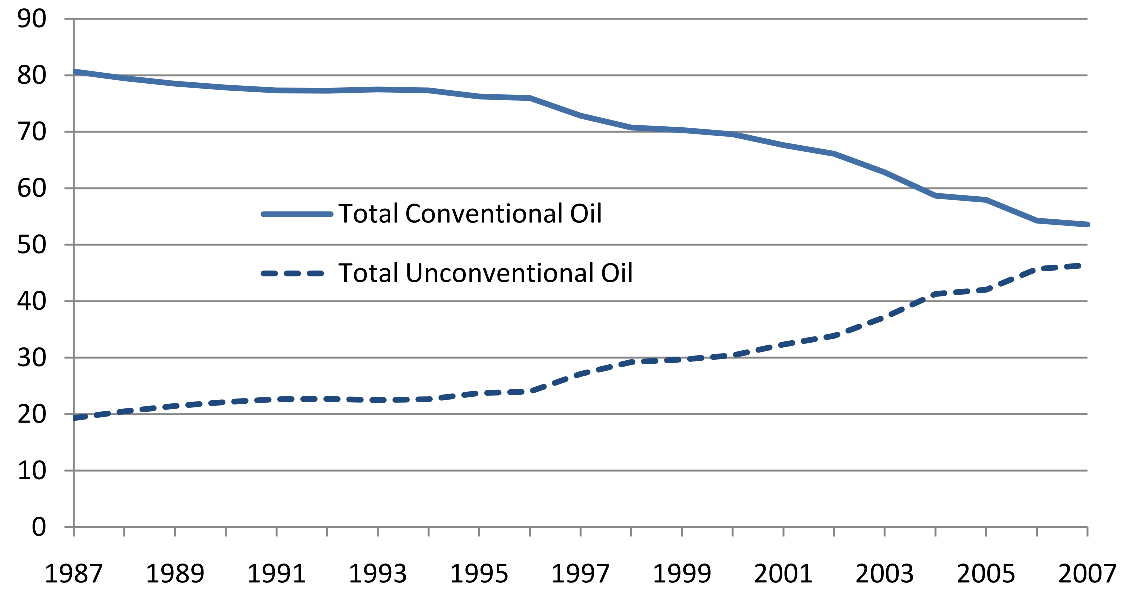
Summary Table 1: Real GDP, Oil and Gas Extraction, Canada, Chained Dollars, Compound Annual Growth Rates, per cent, 1989-2007

	1989-2007	1989-2000	2000-2007
All Industries	2.64	2.70	2.55
Oil and Gas Extraction	2.61	3.07	1.90

Source: Appendix Tables 1 and 1a

The oil and gas extraction sub-sector, is further divided into conventional oil and gas extraction and non-conventional oil extraction industry groups. Unfortunately, this sub-division is made at the six-digit NAICS level and there is no output data for these industries based on the NAICS definitions.[11] However, data based on volume of production clearly shows that the importance of non-conventional oil (synthetic crude and crude bitumen) has increased significantly in the 1985-2007 period (Appendix Table 21 and Chart 2).[12] Unconventional oil as a share of total oil production has increased from 15 per cent in 1985 to 46 per cent in 2007.[13]

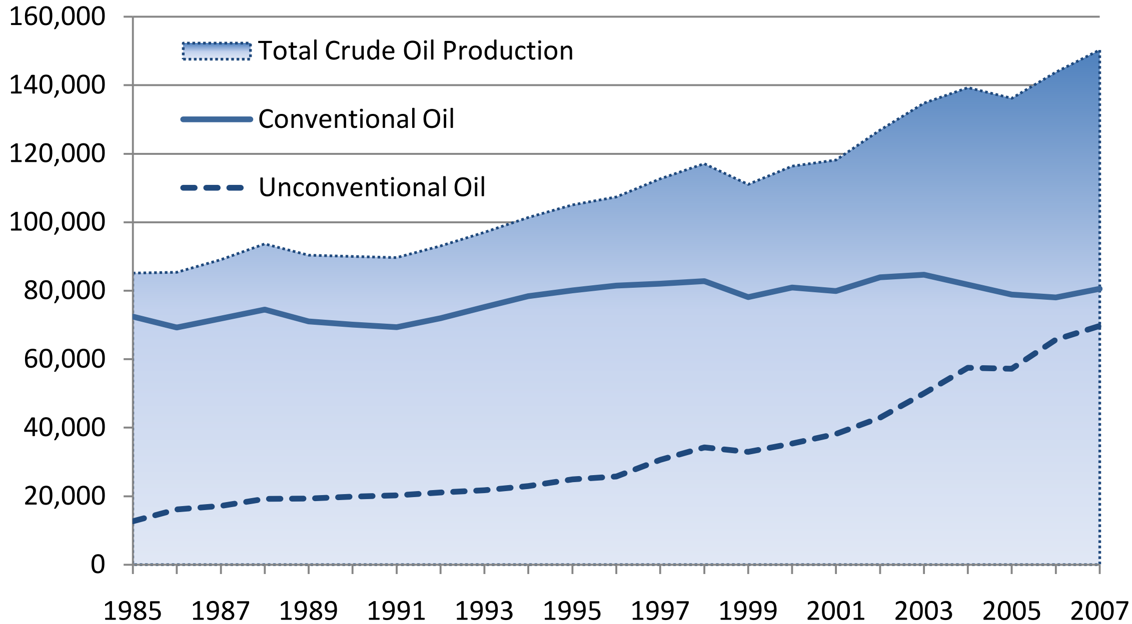
Chart 2: Conventional and Non-Conventional Oil Production, Canada, As a Share of Total Oil Production, Per Cent, 1985-2007



Source: Appendix Table 21

[11] Employment and productivity data are also not available at the six-digit NAICS level.
[12] These data are not officially published according to NAICS, but provide a clear picture of trends within oil and gas extraction.
[13] Synthetic crude oil as a share of total crude oil production increased from 11.4 per cent in 1985 to 19.3 per cent in 2007. Crude bitumen oil production as a share of total crude oil production increased from 3.5 per cent in 1985 to 27.8 per cent in 2007. Over this same period, the production of conventional light and medium crude oil as a percentage of total oil production has fallen from 72.8 percent to 33.8 per cent. Heavy crude oil, also conventional oil, has seen an increase in its relative importance, from 12.2 per cent of total production in 1985 to 19.3 per cent in 2007.

Chart 3: Volume of Oil Production, Canada, Millions of Cubic Meters, 1985-2007



Source: Appendix Table 20

In terms of absolute levels of production of crude oil, total crude oil production has been increasing steadily over the 1985-2007 period, increasing by 2.62 per cent per year (Appendix Table 20, Chart 3). Conventional crude oil production, however, has remained relatively stagnant, increasing by only 0.49 per cent per year over the 1985-2007 period. In fact, between 2000 and 2007 the production of conventional crude oil has decreased by 0.07 per cent per year. In contrast, the production of unconventional oil in Canada has increased by 8.04 per cent per year between 1985 and 2007. The majority of this increase occurred in the 2000-2007 period, when the production of unconventional oil increased by 10.18 per cent per year.

ii. Labour Input

Labour input, measured as the number of hours worked, has increased at an average annual rate of 4.95 per cent over the 1989-2007 period in oil and gas extraction (Appendix Table 8). Growth in hours worked accelerated from 1.25 per cent per year from 1989 to 2000, to a staggering 11.03 per cent per year from 2000 to 2007. In contrast, hours worked in the economy as a whole expanded by a mere 0.92 per cent per year from 1989 to 2000, and by 1.58 per cent per year from 2000 to 2007.

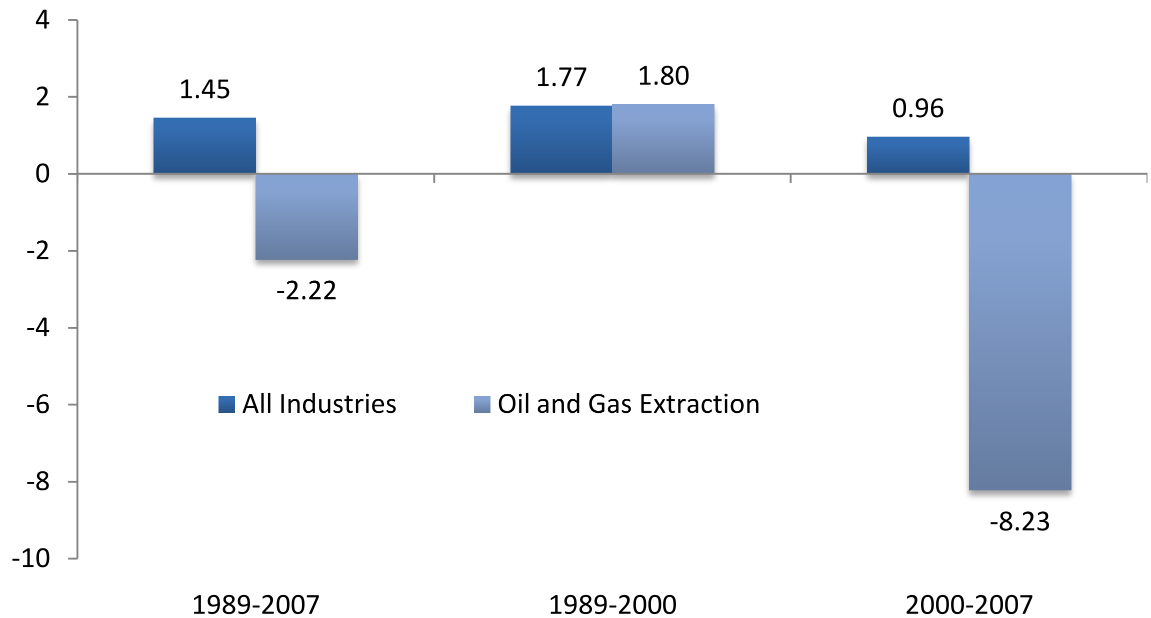
iii. Capital Input

The real capital stock (chained 2002 dollars) in oil and gas extraction has consistently exhibited average annual growth rates above the all industries average over the 1989-2007 period, 5.79 per cent compared to 1.77 per cent (Appendix Table 10). Between 1989 and 2000 the capital stock in oil and gas extraction grew by 4.18 per cent per year, above the all industries average of 1.32 per cent. Growth in the real capital stock accelerated in 2000-2007, to a modest 2.48 per cent per year in the economy as a whole, but to a brisk 8.36 per cent per year in oil and gas extraction. Oil and gas extraction is a highly capital-intensive business. In 2007, capital intensity was $1,179 (chained 2002 dollars) per hour worked, more than 28 times the capital intensity of the economy as a whole (Appendix Table 42).

iv. Labour Productivity

Labour productivity, measured as real GDP per hour worked, in oil and gas extraction fell by 2.22 per cent per year between 1989 and 2007 (Chart 4). Oil and gas extraction experienced labour productivity growth of 1.80 per cent per year in 1989-2000. However, from 2000 to 2007, labour productivity fell by 8.23 per cent per year. The level of real GDP per hour in oil and gas extraction was very high throughout the 1989-2007 period (Appendix Table 16).

Chart 4: Labour Productivity, Real GDP Per Hour Worked, Oil and Gas Extraction, Canada, Chained 2002 Dollars, Compound Annual Growth Rate, Per Cent, 1989-2007

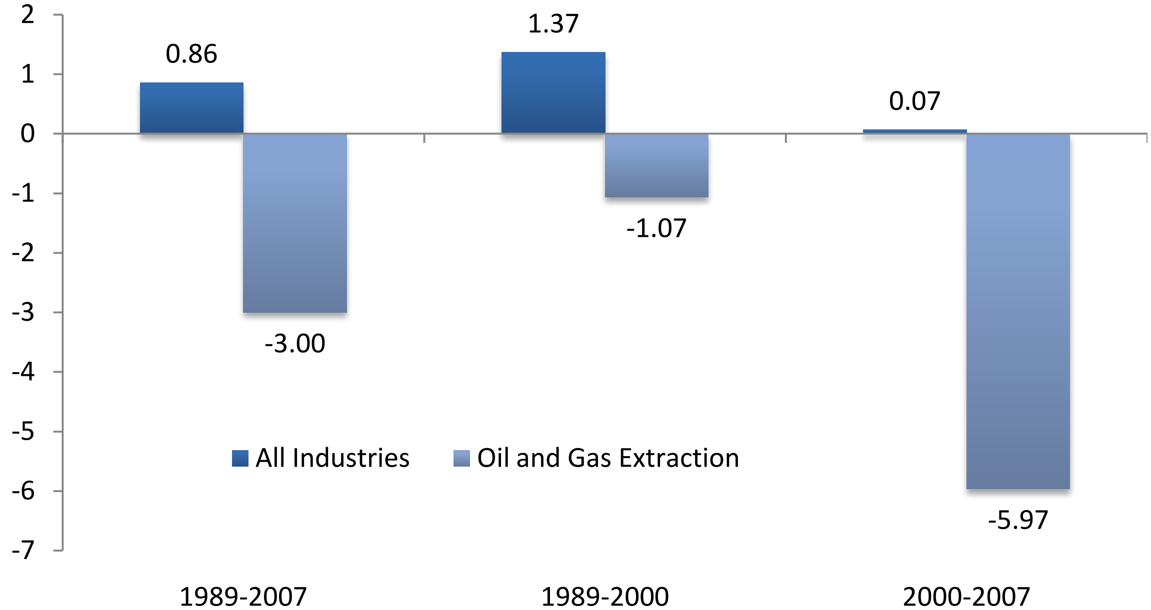


Source: Appendix Table 15

v. Capital Productivity

Oil and gas extraction also experienced negative capital productivity growth in the 1989-2007 period (Appendix Table 11). Real GDP per thousand dollars of capital stock (chained 2002 dollars) fell by 3.00 per cent per year between 1989 and 2007 (Chart 5). Capital productivity in oil and gas extraction experienced a slow decline in the 1990s, falling by 1.07 per cent per year. After 2000, the decline of capital productivity accelerated to 5.97 per cent per year from 2000 to 2007. All industries average capital productivity also slowed from the 1989-2000 period, when it grew by 1.37 per cent per year, to the 2000-2007, when it barely grew at all, by 0.07 per cent per year.

Chart 5: Capital Productivity, Real GDP Per $1,000 of Real Capital Stock, Oil and Gas Extraction, Canada, Chained 2002 Dollars, Compound Annual Growth Rate, Per Cent, 1989-2007

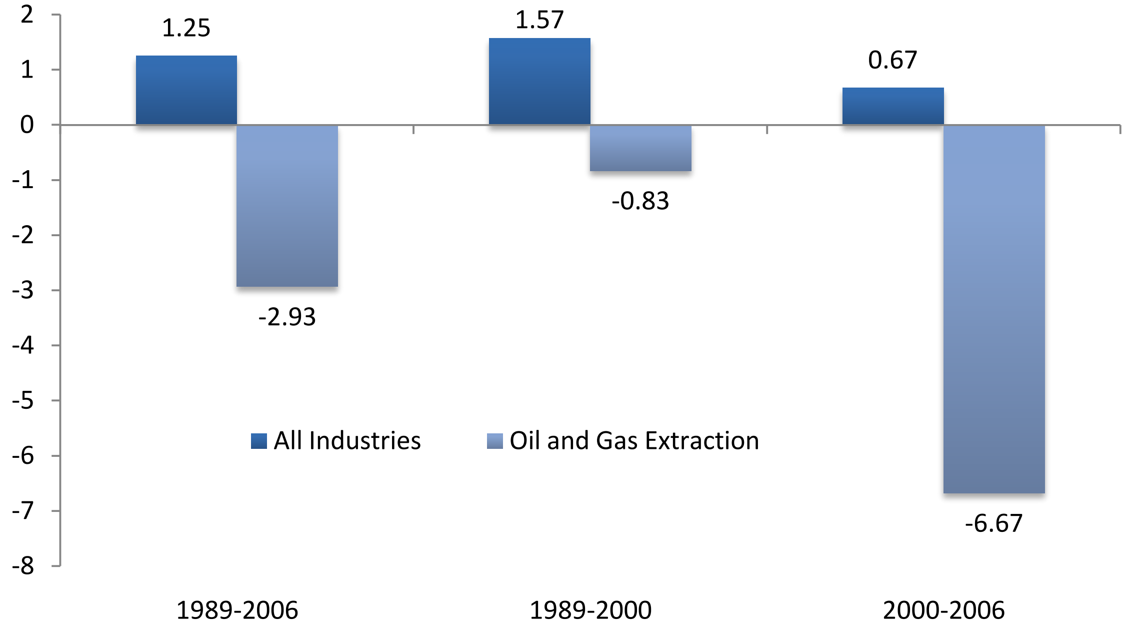


Source: Appendix Table 11

vi. Total Factor Productivity

Oil and gas extraction saw TFP decline by 2.93 per cent per year in the 1989-2006 period (Appendix Table 17, Chart 6). This performance was considerably worse than that of the all industries average, where TFP grew by 1.25 per cent per year. As was the case with capital productivity, oil and gas extraction saw declines in TFP accelerate from the 1990s to the 2000s. TFP fell at an average annual rate of 0.83 per cent from 1989 to 2000 and at an average annual rate of 6.67 per cent between 2000 and 2007.

Chart 6: Total Factor Productivity, Oil and Gas Extraction, Canada, Compound Annual Growth Rate, 1989-2007



Source: Appendix Table 17

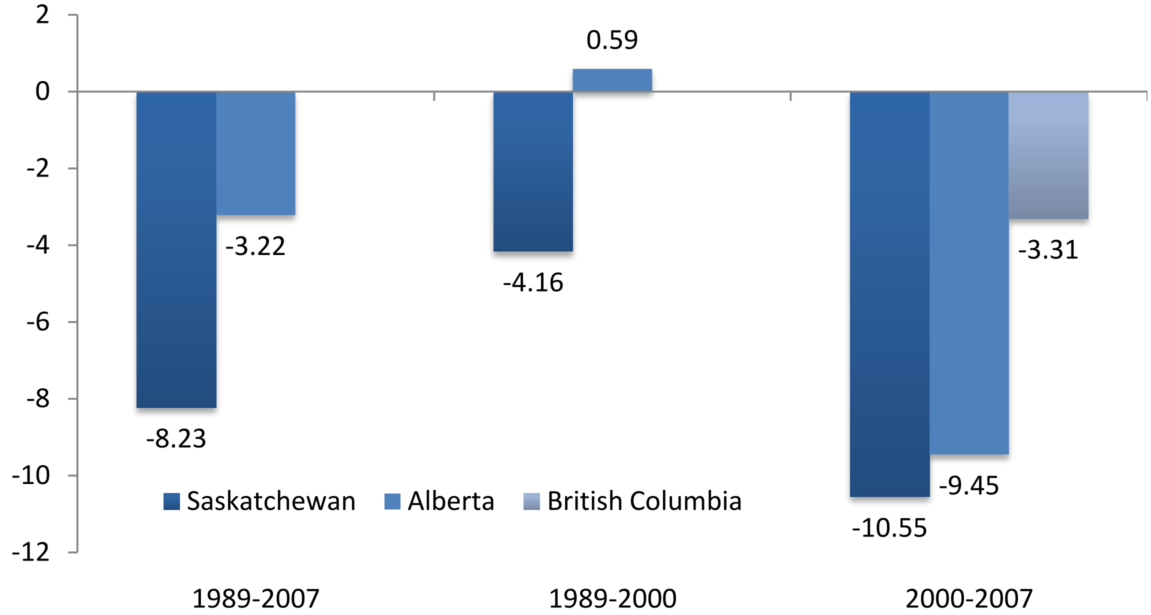
B. Oil and Gas Extraction Productivity Trends by Province

This section analyses productivity trends in the oil and gas extraction sector in Alberta, Saskatchewan, and British Columbia. These provinces dominate oil and gas extraction in Canada; together they accounted for over 87 per cent of real GDP in the oil and gas extraction sub-sector in 2007. No data were available for Newfoundland and Labrador or the Maritime Provinces. Ontario, Quebec, and Manitoba together accounted for less than one per cent of output in 2007 (Appendix Table P12).

As was noted in the previous section, oil and gas extraction experienced a significant decline in labour productivity over the 2000-2007 period relative to the 1989-2000 period. In Saskatchewan, oil and gas extraction experienced negative labour productivity growth over the 1989-2000 period of 4.16 per cent per year (Appendix Table P22, Chart 7). Alberta experienced a slight increase in labour productivity over the same period of 0.59 per cent per year (Appendix Table P23). Over the 2000-2007 period, both Saskatchewan and Alberta experienced a substantial labour productivity contraction, with labour productivity in the sub-sector declining by more than nine per cent per year. In contrast, British Columbia [14] experienced a smaller decline in labour productivity growth, falling 3.3 per cent per year from 2000 to 2007.

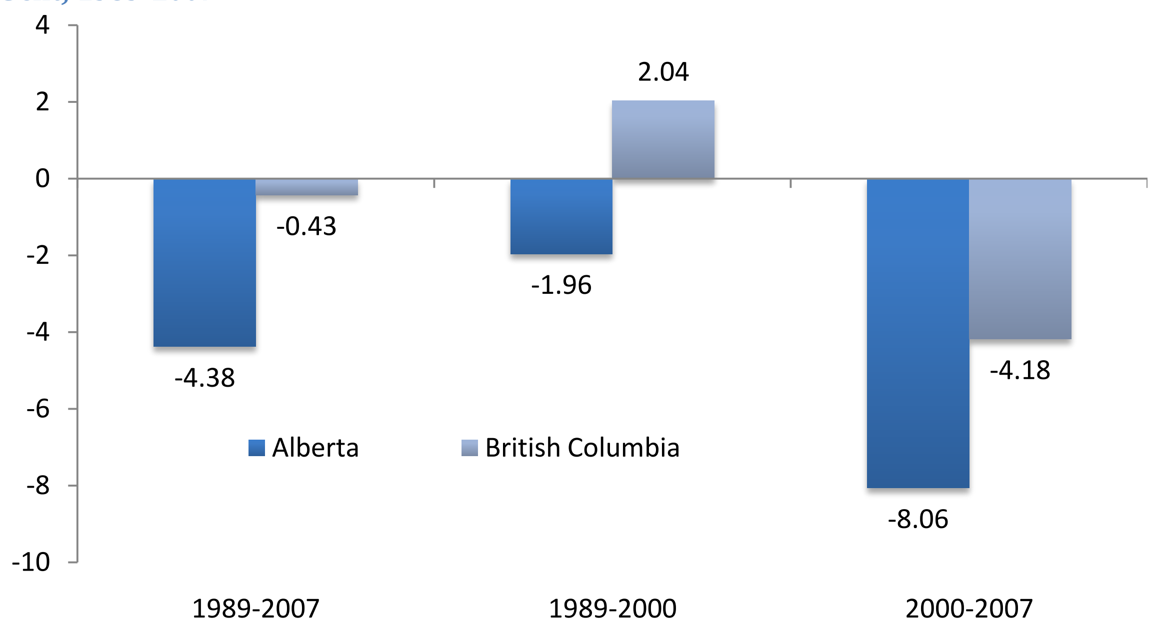
[14] Data were not available for British Columbia prior to 1993.

Chart 7: Labour Productivity, Real GDP Per Hour Worked, Oil and Gas Extraction, Saskatchewan, Alberta, and British Columbia, Compound Annual Growth Rate, Per Cent, 1989-2007



Source: Appendix Tables P22, P23, and P24. No data for British Columbia prior to 1994.

Chart 8: Capital Productivity, Real GDP Per $1,000 of Capital Stock, Oil and Gas Extraction, Alberta and British Columbia, Compound Annual Growth Rate, Per Cent, 1989-2007

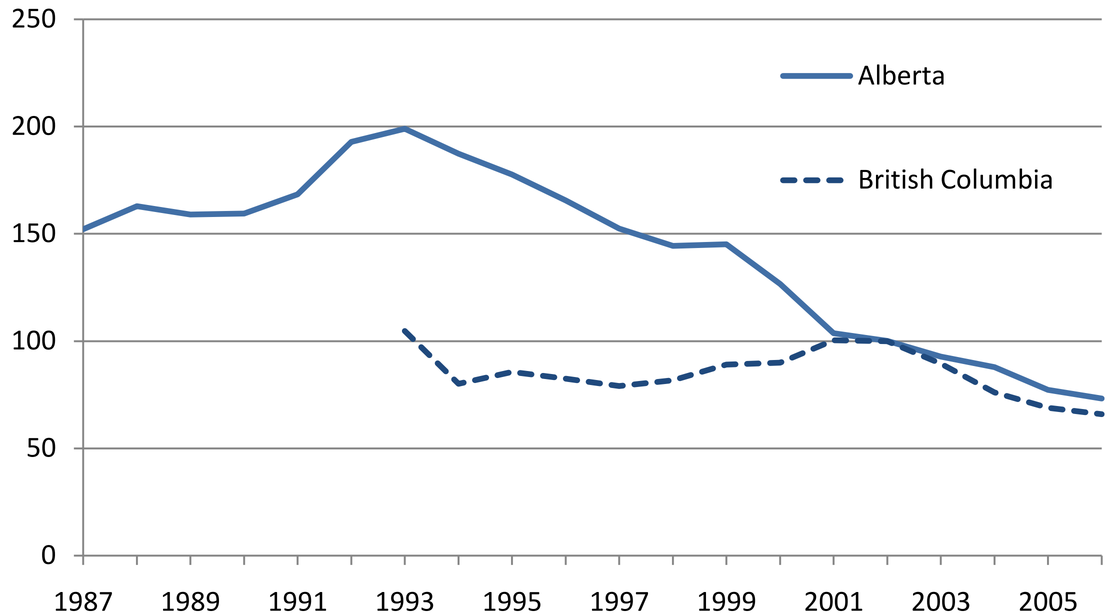


Source: Appendix Tables P33

Capital productivity in oil and gas extraction has been contracting in Alberta and British Columbia over the 1989-2007 period (Appendix Table P33, Chart 8).[15] In Alberta, capital productivity declined by 1.96 per cent per year in 1989-2000. From 2000 to 2007 oil and gas extraction capital productivity has fallen rapidly in Alberta, by 8.06 per cent per year. Oil and gas extraction in British Columbia has also experienced contracting capital productivity, although to a lesser extent than in Alberta, falling by 4.18 per cent per year over the 2000-2007 period.

Total factor productivity in oil and gas extraction declined in Alberta over the 1989-2006 period (Chart 9, Appendix Table P35). TFP fell by 2.05 per cent per year between 1989 and 2000. From 2000 to 2006, both Alberta and British Columbia experienced declining TFP. TFP in Alberta fell by an average of 8.73 per cent per year, while TFP in British Columbia fell by 5.04 per cent per year.

Chart 9: Total Factor Productivity, Oil and Gas Extraction, Alberta and British Columbia, 1987-2007; 2002 = 100



Source: Appendix Table P35

[15] Data for every year for capital productivity are only available for Alberta and British Columbia.

IV. Productivity Trends in Oil and Gas Extraction in the United States

Due to the proximity of Canada to the United States, many of the factors that influence the oil and gas industry in the United States also influence the industry in Canada. Furthermore, many oil and gas extraction firms operate in both countries, and as a result have access to similar technologies and processes in both countries. Therefore, comparisons of inputs, outputs and productivity measures provide context for Canada's productivity performance and can suggest potential explanations for the productivity slowdown in Canada.

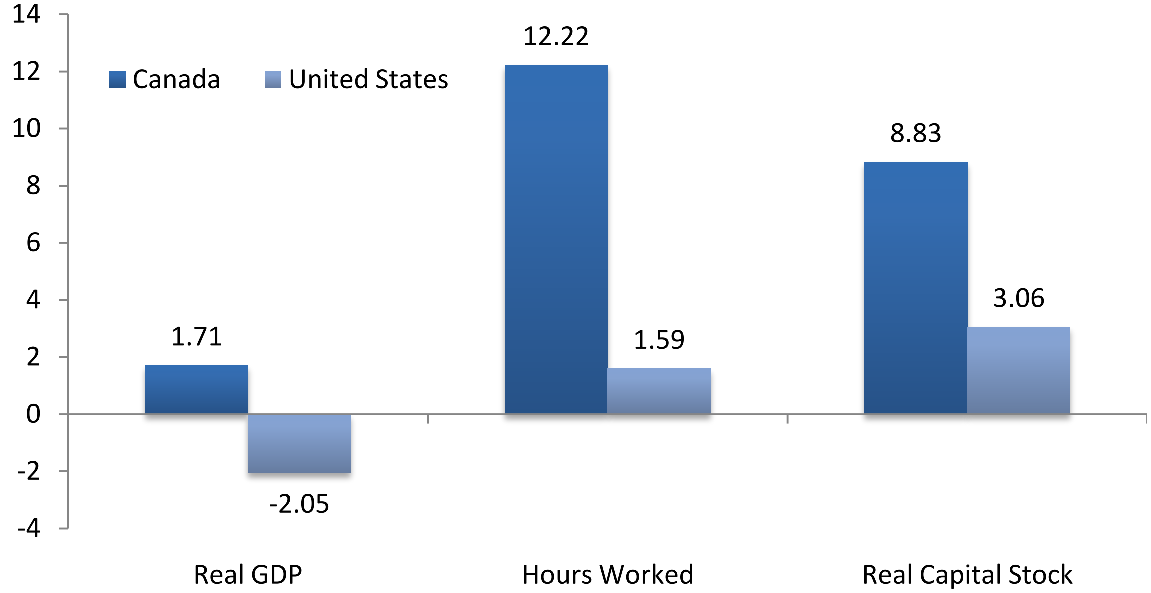
A. The Relative Importance of Oil and Gas Extraction

Oil and gas extraction is relatively less important in the United States than in Canada in terms of both output and employment. According to the Bureau of Economic Analysis, nominal GDP data, oil and gas extraction accounted for only 0.98 per cent of total economy nominal GDP in 2004, much lower than the estimate of 5.51 per cent in Canada for that same year. Employment in oil and gas extraction accounted for 0.10 per cent of all industry employment in 2007 in the United States, one-quarter the level of Canada (Appendix Table 27). Unlike Canada, real GDP in oil and gas extraction in the United States has been declining over the 1989-2006 period, falling by 2.06 per cent per year (Appendix Table 22). Over the 2000-2006 period real GDP fell 2.05 per cent per year in the United States while it rose 1.71 per cent per year in Canada (Appendix Table 1 and Chart 10).

B. Labour and Capital Inputs

In the United States, the number of hours worked in oil and gas extraction fell over the 1989-2006 period by 2.51 per cent per year while total industry hours worked increased by 0.91 per cent per year (Appendix Table 26). During the 2000-2006 period, hours worked in oil and gas extraction increased by 1.59 per cent per year, considerably faster than the all industries average, which saw an annual decline of 0.08 per cent. However, the increase in hours worked in oil and gas was much slower in the US than in Canada, where the growth rate of hours worked in oil and gas was 12.22 per cent per year over the same time period. The level of employment showed similar trends to the number of hours worked.

Chart 10: Comparison of Oil and Gas Extraction, Canada and the United States, Average Annual Growth Rates, 2000-2006



Source: CSLS calculations based on Statistics Canada, Bureau of Labor Statistics, and Bureau of Economic Analysis data.

Capital input growth in oil and gas extraction has been weak over the 1989-2006 period, growing by 0.69 per cent per year, well below the 2.56 per cent annual increase for all industries (Appendix Table 30). Over the 2000-2006 period, the real capital stock in oil and gas extraction experienced growth of 3.06 per cent per year, slightly faster than the all industries growth rate of 2.40 per cent per year. This is in contrast to the Canadian experience, where capital input increased by 8.83 per cent per year, considerably faster than the all industries growth rate in Canada and considerably faster than the growth rate in the United States (Chart 10).[16]

C. Productivity

Labour productivity in US oil and gas extraction has exhibited a similar productivity slowdown to that observed in Canada (Appendix Table 28 and Chart 11). From 1989 to 2006, real GDP per hour worked increased by 1.63 per cent per year, faster than in Canada (-2.29 per cent). Canada experienced weaker labour productivity growth over the 1989-2000 period than the United States (1.80 versus 4.18 per cent per year). Similarly, over the 2000-2006 period labour productivity in the United States fell by 2.87 per cent per year, while in Canada labour productivity fell by 9.37 per cent per year. These trends suggest that similar factors may be at play in both countries, but that there are also important differences.

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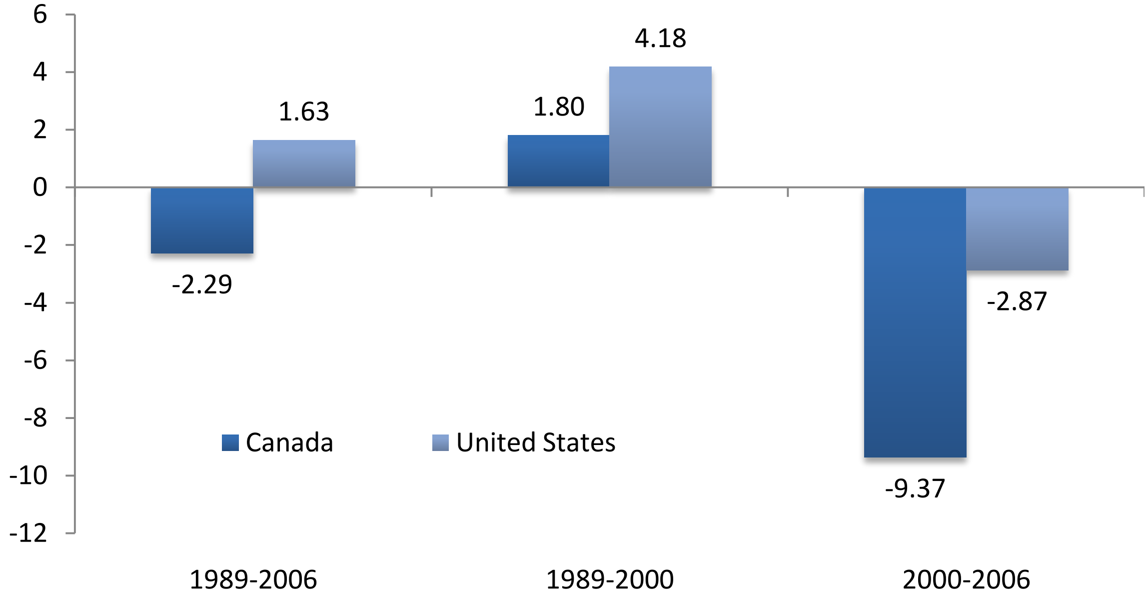
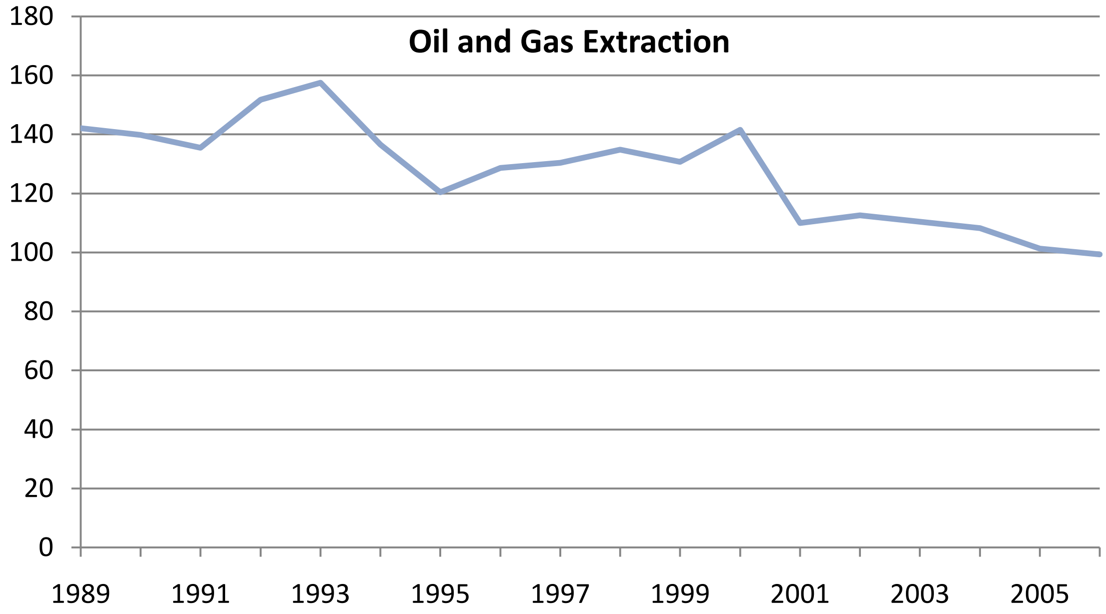
[16] We wish to remind the reader that, as previously noted in the data sources section, capital input estimates between Canada and the United States are not entirely comparable since Statistics Canada change its methodology in 2006. Yet, the Bureau of Economic Analysis and Statistics Canada remain the only sources of data available for years beyond 2003 and will thus be used to provide a rough idea of differences between the two countries.

Chart 11: Real GDP per Hour Worked in Oil and Gas Extraction, Canada and the United States, Average Annual Growth Rate, 1989-2006



Source: Appendix Tables 15 and 28.

Chart 12: Real GDP per Worker in Oil and Gas Extraction in Canada as a Percentage of that of the United States, 1989-2006



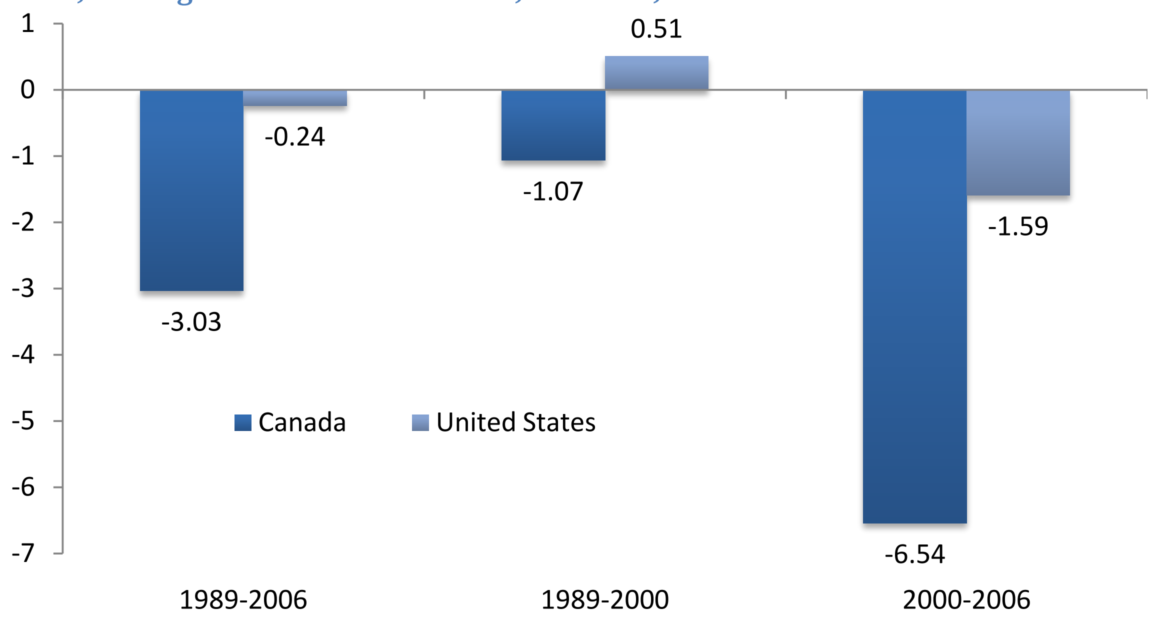
Source: Appendix Table 43

Hours worked are only provided in index form by the Bureau of Labor Statistics. Therefore, it is not possible to compare real GDP per hour worked in levels between Canada and the United States for the oil and gas extraction sub-sector. We can, however, compare the levels of real GDP *per worker* across the two countries once the levels have been adjusted for purchasing power parity (Chart 12, Appendix Table 43). Over the 1989-2006 period, real GDP per worker in oil and gas extraction in Canada has consistently been above the US level, although the Canadian advantage has been shrinking since at least the early 1990s. Real GDP per worker in oil and gas extraction in Canada was roughly on par with the United States in 2006 at 99.4 per cent.

In terms of growth rates of capital productivity, the United States has performed better than Canada over the 1989-2006 period (Chart 13, Appendix Table 44). The average annual rate of change capital productivity over the 1989-2006 period in the United States was -0.24 per cent per year compared to -3.03 per cent per year in Canada. Over the 2000-2006 period, the United States experienced a significant contraction of capital productivity, 1.59 per cent per year, although this was considerably less than the 6.54 per cent per year contraction experienced in Canada.

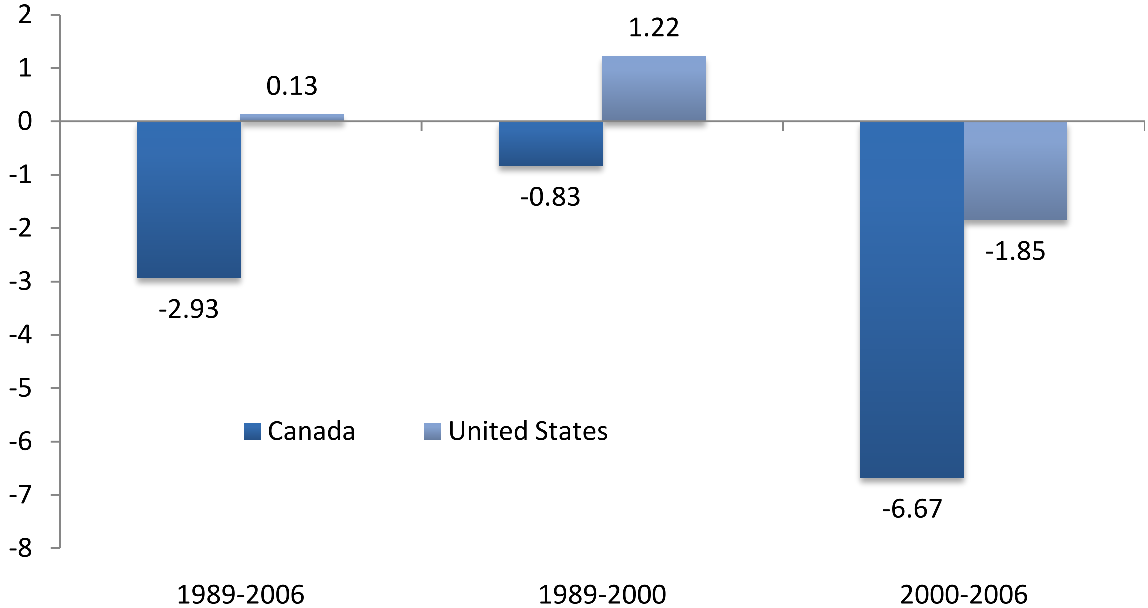
Over the 1989-2006 period, TFP in US oil and gas extraction declined 0.24 per cent per year (Chart 14, Appendix Table 45). Compared to Canada, the United States experienced faster growth during the 1989-2000 period when TFP in oil and gas extraction in Canada declined 0.83 per cent per year, while the TFP in US oil and gas extraction grew by 1.22 per cent per year. Since 2000, TFP continued to decline faster in Canada than in the United States. In particular, TFP in Canada fell 6.67 per cent per year, while TFP in the United States contracted by only 1.85 per cent per year.

Chart 13: Capital Productivity in Oil and Gas Extraction, Canada and the United States, Average Annual Growth Rates, Per Cent, 1989-2006



Source: Appendix Tables 11 and 44

Chart 14: Total Factor Productivity in Oil and Gas Extraction, Canada and the United States, Average Annual Growth Rates, Per Cent, 1989-2006



Source: Appendix Tables 17 and 44

V. The Contribution of Oil and Gas Extraction to Aggregate Productivity Growth in Canada

This part of the report provides estimates of the contribution of oil and gas extraction to aggregate labour productivity growth in Canada.[17] In this analysis, we use the methodology developed by Tang and Wang (2004).[18] Tang and Wang's methodology can be applied to chained-Fisher index real GDP even though such measures are not additive across industries. Our analysis covers the 1987-2006 period and selected sub-periods.[19] This part of the report also estimates the contribution of oil and gas extraction to the aggregate productivity slowdown between the 1996-2000 and 2000-2006 periods.

A. The Contribution to Aggregate Labour Productivity Growth

The methodology developed by Tang and Wang (2004) provides a way to decompose aggregate labour productivity growth into industrial components.[20] Their method is based on the assumption that aggregate labour productivity growth attributed to a single industry can arise from three sources: improvements in labour productivity, increases in an industry's labour share, and increases in the real output price of the industry. The contributions of these three sources are quantified in three components: the pure productivity growth effect, the relative size change effect, and the interaction of the first two. The pure productivity growth effect is an industry's labour productivity growth rate weighted by its nominal output share at the beginning of the period. The relative size of an industry is defined as the labour share of the industry multiplied by the relative implicit deflator of the industry. The relative size change effect is weighted by the relative labour productivity of the industry at the beginning of the period. The interaction effect captures the interaction between industry labour productivity growth and the relative industry size, weighted by relative labour productivity.

It is important to note that according to Tang and Wang's methodology, even an industry experiencing negative productivity growth might contribute positively to aggregate productivity growth due to the relative size change effect. This effect captures the impact of the reallocation of labour from low productivity industries to high productivity industries as well as changes in relative prices across industries with

[17] Throughout this part, labour productivity is measured as real GDP per hour worked.
[18] Appendix tables also include more common labour productivity growth decompositions using labour input and real output shares as weights (Appendix Tables 55 and 57).
[19] Since nominal GDP data was only available up to 2004 at the time this report was prepared, the nominal GDP series is extended by applying the growth rate of oil and natural gas prices (weighted using the weights of the Bank of Canada commodity price index) to the implicit price deflator series for the 2004-2006 period. It is then possible to calculate nominal GDP with the extended implicit price deflator series and real GDP data available to 2006.
[20] The methodology developed by Tang and Wang is similar to the one developed in Nordhaus *et al.* (1972) where aggregate labour productivity growth is decomposed to calculate industry contributions. The Nordhaus *et al.* method takes into account that an increase in the relative size of a highly productive industry, measured by both nominal output share and employment share, can result in an industry with negative productivity growth contributing positively to aggregate productivity growth. Nordhaus *et al.*, however, do not account for the non-additivity of the chained-Fisher index. Sharpe (2009) developed and applied a methodology similar to that of Nordhaus *et al.*, and found that the mining and oil and gas extraction sector did not contribute to productivity growth over the 2000-2007 period (-0.06 percentage points per year).

different productivity level. To calculate the relative size change effect, the change in the relative size of an industry, which encompasses both the change in its employment share and the change in relative output prices, is weighted by the relative labour productivity level of that industry. Since the level of labour productivity in oil and gas extraction has been around ten times the average level of all industries, and since prices and hours worked in oil and gas extraction have been growing faster than in other industries in recent years, the relative size change effect is large and positive even though the sub-sector has experienced falling productivity. In general, unless the economy exhibits a sustained structural shift across industries, the effect of changing relative sizes cannot be the main driver of productivity growth over long periods of time. Over shorter periods, however, shifts across industries can be strong drivers of productivity growth.

Summary Table 2: The Contribution of Oil and Gas Extraction to Aggregate Labour Productivity Growth, Canada, 1987-2006

	Average Annual Labour Productivity Growth (per cent)		**Average Annual Absolute Contribution Over the Period to Aggregate Labour Productivity Growth** (percentage points)				**Relative Contribution** (per cent)
	Total Economy	Oil and Gas Extraction	Pure Productivity Growth Effect	Relative Size Change Effect	Interaction Effect	Total Effect	Total Effect
	A	B	C	D	E	F=C+D+E	G=F/A*100
87-06	1.26	-1.66	-0.04	0.16	-0.05	0.08	6.06
87-96	0.94	0.72	0.02	-0.10	-0.01	-0.09	-9.25
96-00	2.35	5.34	0.16	0.34	0.08	0.58	24.56
00-06	1.02	-9.37	-0.35	1.45	-0.68	0.41	40.52
Difference, 00-06 – 96-00	-1.33	-14.71	-0.52	1.11	-0.76	-0.16	16.00

Source: Calculated by the Centre for the Study of Living Standards from Appendix Table 46a.
Note: Methodology based on Tang and Wang (2004).

According to Tang and Wang's methodology, oil and gas extraction made a contribution of 0.08 percentage points to average annual aggregate Canadian labour productivity growth over the 1987-2006 period (Summary Table 2). The contribution of the sub-sector fluctuated significantly across time. Over the 1996-2000 period, oil and gas extraction contributed 0.58 percentage points to average annual aggregate labour productivity growth, much higher than in either the 1987-1996 period (-0.09 percentage points) or the 2000-2006 period (0.41 percentage points).

Over the 2000-2006 period, labour productivity in oil and gas extraction declined by 9.37 per cent per year, while labour productivity in the entire Canadian economy increased by 1.02 per cent per year. Nonetheless, oil and gas extraction made a strong positive contribution of 0.41 percentage points to total economy labour productivity growth, 41 per cent of aggregate labour productivity growth. This counter-intuitive positive contribution is due to the relative size change effect. That is, the size of the oil and gas extraction sub-sector increased due to rising real relative output prices and a rising share of hours worked, high relative labour productivity level (which is used to weight the relative size of the industry). In terms of a pure productivity growth effect, ignoring changes in relative size, oil and gas extraction made a negative contribution of 0.35 percentage points over the 2000-2006 period.

B. The Contribution to the Post-2000 Productivity Slowdown

The contribution of oil and gas extraction to the post-2000 productivity slowdown can be calculated using Tang and Wang's estimates. The total economy in Canada experienced a labour productivity slowdown of 1.33 percentage points between the 1996-2000 period and the 2000-2006 period.[21] Oil and gas extraction experienced a considerably larger labour productivity slowdown of 14.71 percentage points. The final row of Summary Table 2 provides the estimates of the contribution of oil and gas extraction to Canada's aggregate post-2000 labour productivity slowdown.

From 1996 to 2000 oil and gas extraction made a contribution of 0.58 percentage points to the 2.35 annual aggregate labour productivity growth rate. Over the 2000-2006 period, the contribution was 0.41 percentage points of the 1.02 annual aggregate labour productivity growth rate. Oil and gas extraction made a negative contribution of 0.16 percentage points to the -1.33 percentage-point productivity slowdown in aggregate labour productivity growth, accounting for 16 per cent of the slowdown. Ignoring relative size effects, oil and gas extraction would have made an even larger negative pure productivity growth contribution of 0.52 percentage points.

[21] The measure of the aggregate productivity slowdown is sensitive to the base period. Aggregate labour productivity in Canada experienced uncharacteristically large growth over the 1996-2000 period. If the 1989-2000 period had been used as a base year, the productivity slowdown would have been only 0.75 percentage points for the aggregate economy.

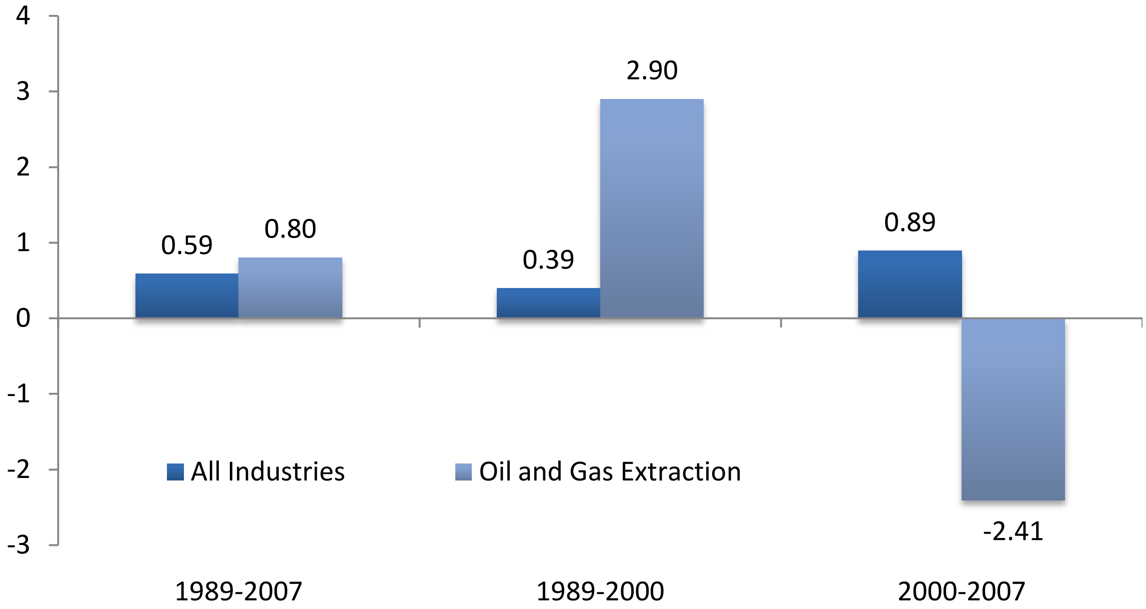
VI. Causes of Falling Oil and Gas Extraction Productivity

As discussed earlier, all three measures of productivity (labour, capital, and total factor) in oil and gas extraction in Canada have fallen since 2000. This part will examine in detail possible reasons for this falling productivity: a declining capital intensity; higher oil and gas prices; lagging innovation and technological progress; deterioration of the average quality of the workforce; greater environmental regulation; deterioration of the average quality of resources exploited independent of price effects; labour relations; and taxation.

A. Capital Intensity

A key driver of labour productivity is the capital intensity of production, measured as the capital-labour ratio, as an increase in capital intensity means that each worker has more capital to work with to produce output. According to the neoclassical growth accounting framework, the growth rate of labour productivity is equal to the sum of the growth rate of TFP and the growth of capital intensity weighted by the capital share in GDP.

Chart 15: Capital Intensity, Oil and Gas Extraction, Canada, Compound Annual Growth Rate, Per Cent, 1989-2007



Source: Appendix Table 42

The compound annual rate of growth of the capital-labour ratio was much weaker over the 2000-2007 period (-2.41 per cent) than over the 1989-2000 period (2.90 per cent) in oil and gas extraction (Chart 15, Appendix Table 42). This slowdown in capital intensity growth is particularly striking given that capital intensity grew much more quickly in oil and gas extraction from 1989 to 2000 than it did in the economy as a whole, which saw capital intensity grow by only 0.39 per cent per year. Moreover, for the all industries average, capital intensity growth actually accelerated from 1989-2000 to 2000-2007, from 0.39 per cent per year to 0.91 per cent.

Summary Table 3: Contribution of Capital Intensity Growth to Labour Productivity Growth, Canada, 1989-2007

	Compound Annual Growth Rate (per cent)				Contribution of Capital Intensity Growth to Labour Productivity Growth	
	Capital Stock	Hours Worked	Capital Intensity	Labour Productivity	Absolute (percentage points)	Relative (per cent)
	A	B	C≈A-B	D	E=Capital Share*C	F=E/D*100
All Industries						
1989-2000	1.32	0.92	0.39	1.77	0.21	12.0
2000-2007	2.48	1.58	0.89	0.96	0.48	49.9
Difference	1.17	0.66	0.50	-0.81	0.27	-33.0
Oil and Gas Extraction						
1989-2000	4.18	1.25	2.90	1.80	2.59	143.8
2000-2007	8.36	11.03	-2.41	-8.23	-2.15	26.1
Difference	4.18	9.78	-5.30	-10.03	-4.74	47.3

Source: Tables 8, 10, 15 and 42.

Note: The value used for the capital share of real GDP is from the CSLS productivity database and reflects 1997 values. The capital share was 89.41 per cent in oil and gas extraction and averaged 53.78 per cent for the all industries.

Summary Table 3 provides estimates of the contribution of the declining capital intensity to the decline in labour productivity in oil and gas extraction. From 1989 to 2000, increasing capital intensity explained all of the labour productivity improvement in oil and gas extraction. In the 2000-2007 period, capital intensity explained about 26 per cent of the negative productivity growth in oil and gas extraction, with the residual 74 per cent explained by negative TFP growth.

If we focus on the source of the labour productivity slowdown since 2000, declining capital intensity becomes a key factor. Indeed, the fall in capital intensity accounted for 47 per cent of the labour productivity slowdown between the 1989-2000 and 2000-2007 periods in the oil and gas extraction sub-sector. The fall in capital intensity is driven by labour input increasing at a faster rate than capital input over the two periods. Declining capital intensity appears to provide a partial explanation for the post-2000 slowdown in labour productivity growth, with falling TFP growth explaining the rest. The reasons why labour input might have increased more rapidly than capital input and why TFP growth has declined are explored below.

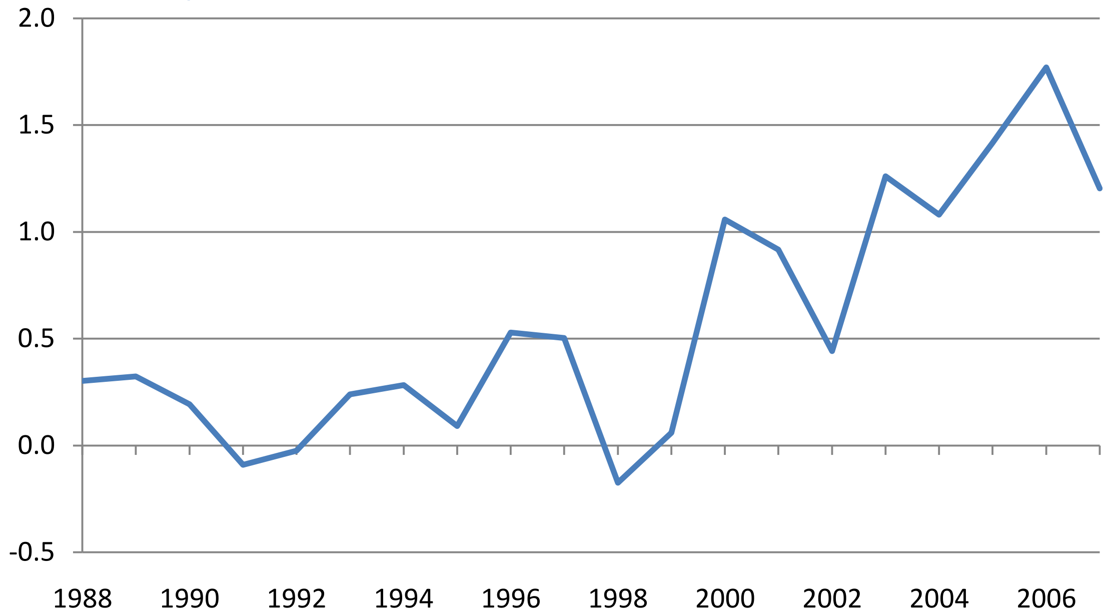
B. Higher Oil and Gas Prices

Prices can have significant impacts on productivity, since changing prices can alter the profitability and composition of an industry or sector. The price of oil and gas extraction outputs is likely driving the productivity performance of the oil and gas extraction sub-sector. When the price of a natural resource increases sharply there are two mechanisms that can act to reduce productivity: a Ricardian effect and a behavioural effect.

As prices rise, it becomes profitable to increase extraction rates from existing deposits and to extract from marginal deposits that were previously unprofitable due to high costs of extraction; this is the Ricardian effect of higher prices. In the short term, because labour is less rigid than capital, we expect this adjustment process to translate into a falling capital intensity. Given different grades and pricing conventions for oil and gas, there is not one best single price series to examine, and this report will use implicit price deflators, supplemented by commodity price indices when necessary.

The second effect of higher prices is behavioural. While economists place great weight on productivity, in general, profitability trumps productivity as an objective for firms (Chart 16, Appendix Table 71). By this indicator, the oil and gas extraction sub-sector has performed well since 2000. Indeed, annual net profits in oil and gas extraction and the support activities sub-sectors (NAICS codes 211 and 213, the only series available) were 1.14 per cent of Canada`s nominal GDP, on average, over the period 2000-2007 – significantly higher than the annual average of 0.19 per cent over the period 1988-1999.

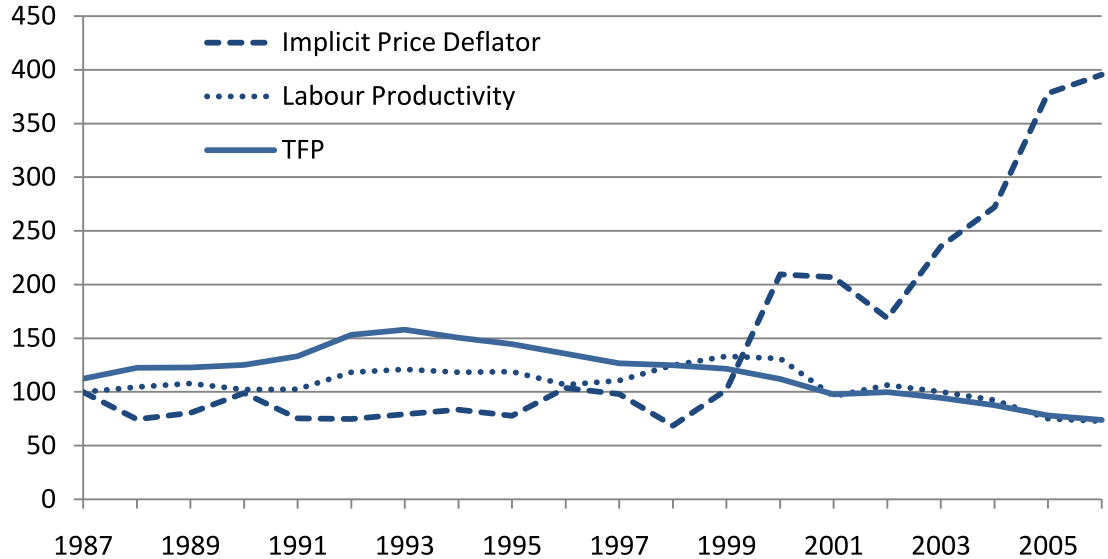
Chart 16: Net Profits, Oil and Gas Extraction and Support Industries, As a Share of Total Economy GDP, Per Cent, 1988-2007



Source: Appendix Table 71

Normally the objectives of improving productivity and profitability coincide, but when they diverge, as for example when commodity prices are extremely high, the productivity growth of a firm, measured in constant prices, may suffer. High prices translate into less attention paid to waste of labour and resources during the production process. Despite greater X-inefficiency in operations, the firm will continue to profit due to high prices.[22] As the data has shown, individual commodity prices in oil and gas extraction have experienced strong growth since 2000, and especially since 2002. This feeds into poorer productivity growth for the firm, the industry as a whole and, in turn, at the aggregate level (CSLS, 2004). In general, this fall in efficiency would largely be reflected in a fall in TFP growth.

Chart 17: Prices and Productivity, Oil and Gas Extraction, Canada, Index 1987 = 100, 1987-2006



Source: Appendix Tables 5, 15, and 17. BP Global Report, Statistical Review of World Energy, 2007, Oil Prices, Historical Data.
Note: Nominal GDP data are available from CANSIM up to 2004, therefore the implicit price deflator series ends in 2004. For the 2004-06 period, the weights used by the Bank of Canada for Crude Oil and Natural Gas from the Energy Commodity Price Index were used to weight the growth rate of crude oil prices (West Texas Intermediate, Cushing Oklahoma, USD per barrel) and natural gas prices (Canada, USD per BTU). These growth weights were then applied to the implicit price deflator for the 2004-06 period. Commodity prices are those reported in the BP Statistical Review of World Energy, 2007; available at http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622.

Oil and gas extraction has experienced dramatic declines in TFP since the early 1990s; TFP fell over 50 per cent between the 1993 peak and 2006 and over 30 per cent between 2000 and 2006 (Chart 17, Appendix Table 17). Labour productivity in oil and gas extraction fell from $514.71 in 2000 to $292.96 in 2007, a decline of over seven per

[22] The term 'X-inefficiency' refers to inefficiency in production that cannot be explained with reference to standard economic theory. In the case of resource industries, for example, it is possible that high profitability as a result of high output prices may make firm managers less motivated to encourage productivity growth than they would be if productivity were more integral to their firms' profitability.

cent per year on average (Appendix Table 15). The implicit price deflator for this industry increased more than four-fold between 1993 and 2006, and nearly doubled between 2000 and 2006.

Coinciding with the rising oil and gas prices, there has been a significant shift away from conventional crude oil towards unconventional crude oil. The reason for this shift was the sudden profitability of these marginal resources once crude oil prices showed significant growth. Over the 1985-2007 period, the volume of production of conventional crude oil increased by only 11 per cent while production of unconventional crude oil increased 448 per cent (Appendix Table 20). In 2007, unconventional oil accounted for 46 per cent of total crude oil production, up from just 15 per cent in 1985. Between 2000 and 2007, the production of unconventional oil increased 97 per cent, while production of conventional oil and natural gas was essentially unchanged.

This shift to unconventional oil is likely a key driver of falling productivity in oil and gas extraction. As stated in Statistic Canada's *Overview of Energy* in regards to unconventional oil in Alberta, "it takes roughly two tonnes of oil sands to extract enough oil to fill one barrel" (Macdonald, 2007a). Additionally, even after the oil has been extracted using either mining techniques or by injecting steam, the oil must be separated from water and other mineral matter before being refined. The operating cost of extracting a barrel of unconventional oil ranges from \$6 per barrel to \$22 per barrel (in 2005 Canadian dollars) depending on the mining technique needed to extract the bitumen (NEB, 2006). The operating cost of extracting a barrel of conventional oil is \$6 per barrel (NEB, 2006). Since Statistics Canada does not currently measure output and employment data separately for conventional and unconventional oil and gas production, it is not possible to determine the actual productivity of the conventional oil, unconventional oil, and natural gas industries.

In general, the expansion of oil sands production should have translated into negative TFP growth. As was shown in the previous part of this report, this has indeed occurred. Yet, a large part of the more recent decline in labour productivity is also explained by falling capital intensity growth. How can this be reconciled with an expansion of oil sands production? Historically, the exploitation of oil sands has relied on open pit mining methods. Even though higher prices have led to an increase in the use of in situ alternatives to open pit mining which are more efficient, these extraction techniques do not yet constitute an important part of oil sands production (Mining Technology, 2007). With prices rising, increasing current production became increasingly important. Bottlenecks in the production of certain equipment used in open pit mining limited the availability of new capital, so output could only be increased by increasing hours worked while making use of the same electric and hydraulic shovels, excavators, haul trucks, and dozers. In addition, firms increasingly hired support companies that themselves increased the amount of hours worked. In the short term, it is thus not surprising that higher prices have lead not only to a declining TFP, but also to a significant fall in capital intensity.

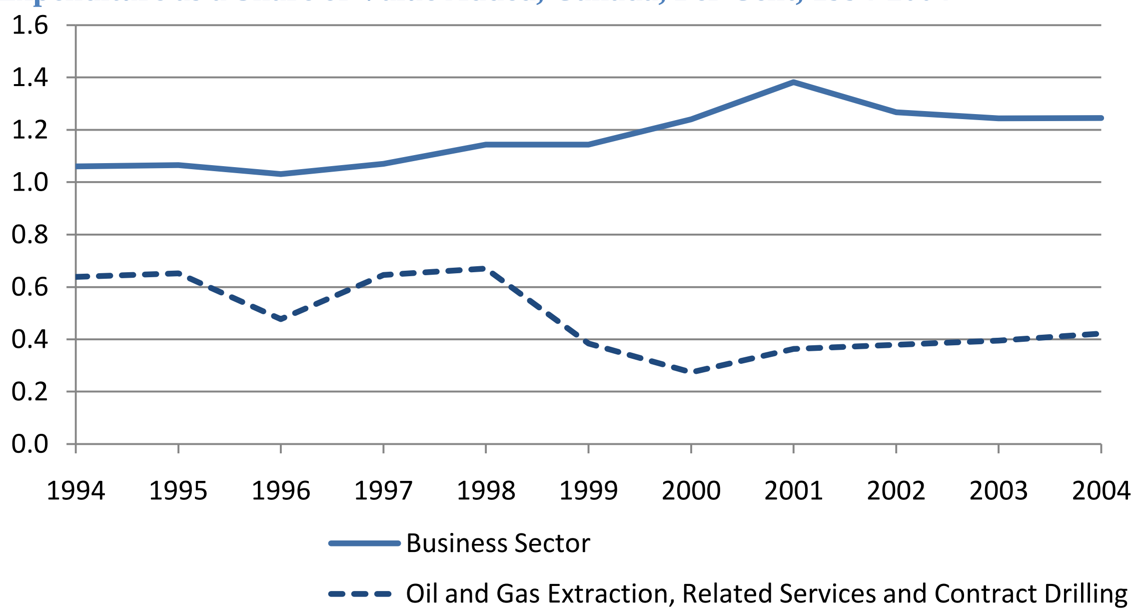
C. Lagging Innovation and Technological Progress

Innovation and technological progress have been identified as key drivers of productivity growth. In practice, however, it is difficult to assess the pace of innovation and technological progress. Innovation measures, such as the growth of research and development (R&D) can be used as indicators of the rate of change of technological progress. However, R&D trends within oil and gas extraction may not be relevant as the sub-sector can draw on international technological advances. For example, research undertaken by the higher education sector, government or other sectors which supply inputs (*e.g.* machinery manufacturing or construction) to oil and gas extraction will be excluded from R&D measures for the oil and gas extraction sub-sector despite being relevant. Further, R&D is neither a necessary nor sufficient condition for innovation or technological progress (CSLS, 2005). This section will first provide estimates of R&D expenditures provided by Statistics Canada. It will then provide estimates from a 2006 study by the Council of Canadian Academies.

i. R&D Expenditures and R&D Intensity

According to Statistics Canada's Business Enterprise Research and Development (BERD) expenditure estimates, nominal intramural R&D expenditures increased 27 per cent for all industries from 2000 to 2007 (Appendix Table 61).[23] In oil and gas extraction and related services (including NAICS industries 213111 (oil and gas contract drilling) and 213118 (services to oil and gas extraction)), intramural R&D expenditures increased by nearly 150 per cent between 2000 and 2007.

Chart 18: Research and Development Intensity, Oil and Gas Extraction, R&D Expenditure as a Share of Value Added, Canada, Per Cent, 1994-2004



Source: Appendix Table 61

[23] Intramural expenditures are expenditures for research and development work performed within the reporting company, including work financed by others. 2007 estimates are preliminary.

R&D intensity, measured as nominal R&D expenditures over nominal value added, stayed above one per cent for the business sector in Canada between 1994 and 2004 (Chart 18).[24] Oil and gas extraction experienced falling R&D intensity over the 1994 to 2004 period, dropping from 0.64 to 0.42 per cent. Over the 2000-2004 period, however, R&D intensity increased in oil and gas extraction and related services from a trough of 0.27 per cent in 2000.

ii. Council of Canadian Academies Study

The Council of Canadian Academies published a study in 2006, *The State of Science & Technology in Canada* for Industry Canada. The report addressed the connection between science and technology (S&T) and innovation. Although there is no "linear progression" between S&T and innovation, they state that S&T is essential for an economy's capacity to innovate. The study undertook various approaches to identify the strengths and weaknesses of Canada's S&T system. The first approach was an opinion survey of Canadian S&T experts who were asked to rank the strength of S&T and its application in 50 areas. According to the survey the application of S&T in the oil sands (*e.g.* unconventional oil) area was rated the strongest. Conventional oil and gas exploration/extraction ranked second, and offshore oil and gas ranked fourteenth. Survey respondents were also asked to rank federal government research institutions; Natural Resources Canada institutions as well as federal environmental regulation institutions were given high ranks in terms of S&T capacity and infrastructure.

A second approach was a bibliometric perspective which measured the intensity of Canadian publications in various fields relative to the rest of the world. The analysis found that publication intensity was above the world average in geology. The study also included a review of the foreign perspective on Canada's S&T strengths in which natural resources, specifically mining and energy, were given high rankings consistent with the domestic survey results. The perception of Canada as a world leader in oil and gas technology suggests that lagging technical progress does not explain the post-2000 oil and gas extraction productivity slowdown. However, there are no time series data to determine whether the pace of technological progress has fallen off since 2000 despite Canada's high rank in this area on the global stage.

D. Deterioration of the Average Quality of the Workforce

The quality of the labour force can significantly affect labour productivity levels and growth. The level of skill and the ability to acquire new skills, proxied by educational attainment, can fuel labour productivity growth (CSLS, 2003). The level of advanced technology prominent in oil and gas extraction requires a workforce that is highly educated and experienced. Since the oil and gas extraction sub-sector has experienced rapid growth in hours worked and employment some have suggested that the low rate of

[24] Available only to 2004 as nominal value added is only available up to 2004 while R&D intramural expenditures are available to 2007.

unemployment and subsequent hiring of low quality workers has caused the average quality of the workforce to deteriorate.

i. Rapid Employment Growth

As noted earlier, hours worked in oil and gas extraction rose at the staggering rate of 10.44 per cent per year from 2000 to 2007 (Appendix Table 8). In contrast, in the economy as a whole, hours worked increased by a mere 1.56 per cent per year over the same period. Moreover, this break-neck pace of growth in labour input came after a period of much slower increase in hours worked. Hours worked only grew by 1.25 per cent per year from 1989 to 2000 in oil and gas extraction.

This significant increase in hours worked has largely come from new workers entering the oil and gas extraction labour force, since the average work week only increased slightly, from 39.7 hours in 2000 to 40.3 hours in 2007. This level of hours per week per worker was very similar to the level of 1989, 40.0 hours. Between 1989 and 2000 the number of jobs in oil and gas extraction grew from 30,800 to 35,600, a modest average annual increase of 1.31 per cent. However, from 2000 to 2007, the number of jobs grew to 70,300, a near doubling in seven years. It seems likely that such a large influx of workers would have contributed to the decline in productivity in oil and gas extraction.

ii. Educational Attainment

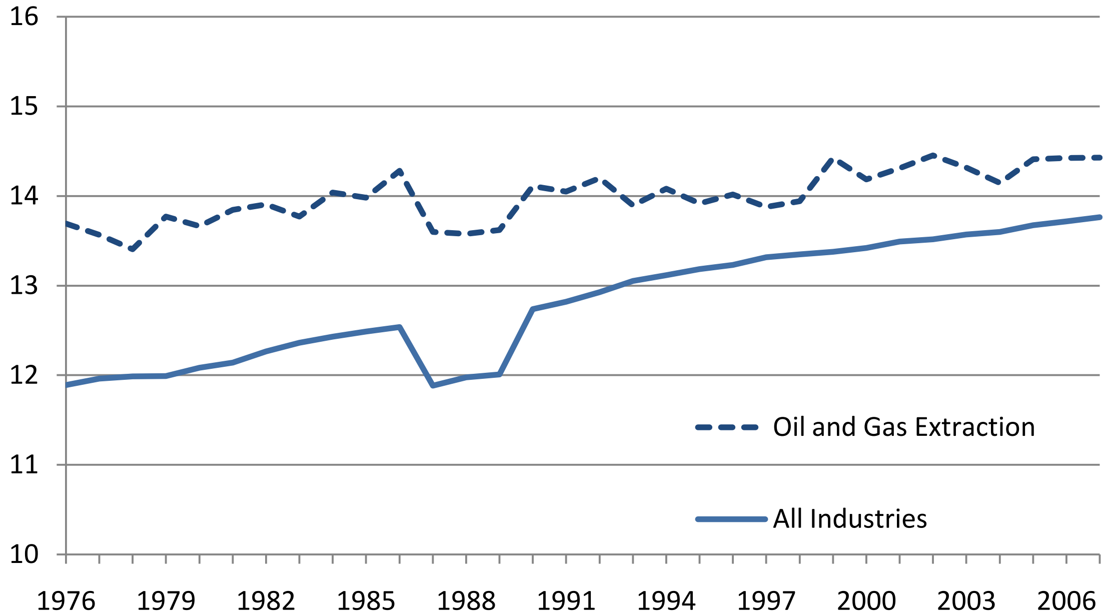
The average years of schooling in oil and gas extraction was above the all industries average in 2007 (Appendix Table 62 and Summary Table 4). In oil and gas extraction, 29.26 per cent of workers had a university degree in 2007. The percentage of workers with a post-secondary certificate or diploma as their highest level of educational attainment was above 40 per cent in oil and gas extraction in 2007, slightly above the percentage for Canadian workforce as a whole.

Summary Table 4: Employment by Highest Level of Educational Attainment in Oil and Gas Extraction, Canada, 2007

	All Industries	Oil and Gas Extraction
Average Years of Schooling	13.76	14.43
Employment by Highest Level of Educational Attainment as a Per Cent of Industry Employment		
0-8 Years	2.56	na
Some High School	10.36	4.2
High School Graduate	20.35	17.16
Some Post-Secondary	8.22	8.52
Post-Secondary Certificate or Diploma	35.02	40.49
University Degree or Above	23.48	29.26

Source: Appendix Table 62

Chart 19: Average Years of Schooling, Oil and Gas Extraction, Canada, 1976-2007



Source: Appendix Table 62. There are two breaks in the data: (1) in 1987 the industrial classification changed from SIC to NAICS and (2) in 1990 the definition changed from number of years completed to highest level completed.

Over the 1976-2007 period, oil and gas extraction experienced rising average years of schooling (Appendix Table 62 and Chart 19).Yet, there appears to be a slight downward trend in the growth rate of the average quality of the workforce relative to the Canadian workforce as a whole, a trend which may have been reinforced by the rapid increase in employment in the sub-sector since 2000.

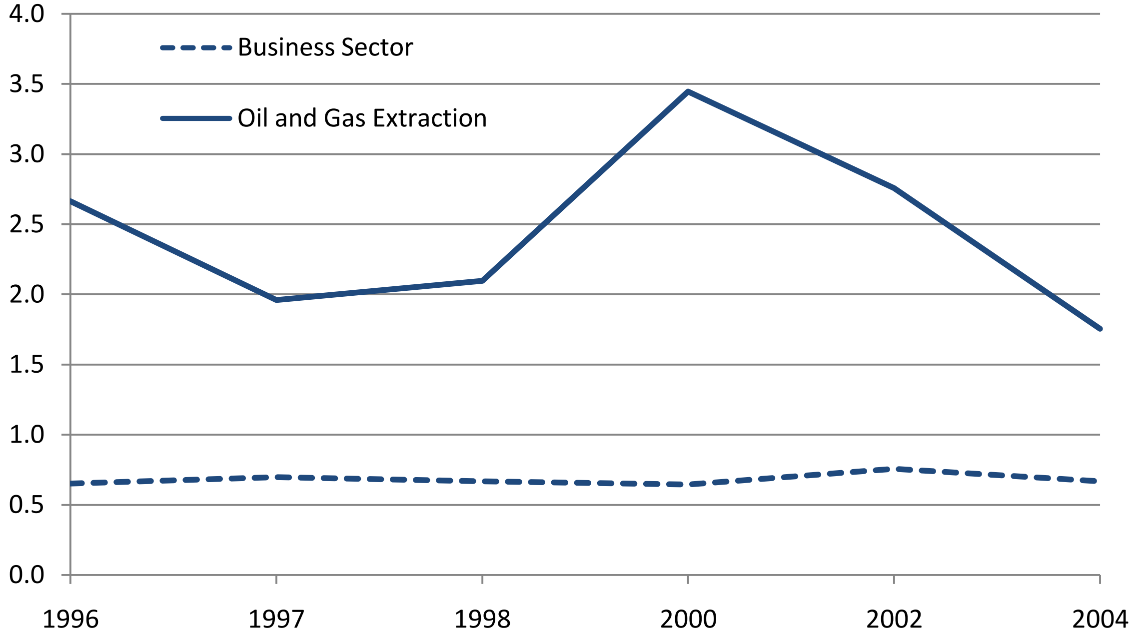
E. Greater Environmental Regulation

It is unclear whether more burdensome environmental regulation has an overall detrimental effect on productivity. Increased resources allocated towards processes needed to meet environmental standards that do not improve the efficiency of the production process will certainly decrease productivity. These resources, however, may indirectly lead to improved productivity-enhancing processes (CSLS, 2004). Despite rising costs associated with environmental regulations, a 2002 study identified strong federal and provincial government support for the mining and oil and gas extraction sector compared to government support for environmental protection (Winfield *et al.*, 2002). This government support may have dampened the effect of environmental regulation on the sector's productivity. Another issue to consider is the value of improvements in the state of the environment arising from environmental expenditures are not captured in conventional measures of productivity despite improving living standards. Alternatively, if the state of the environment is worse due to oil and gas extraction activities, a productivity measure which accounts for environmental degradation would indicate that this sector is doing far worse than the conventional measures indicate (Gollop and Swinand, 2001).

Statistics Canada (2004) provides estimates of total expenditures on environmental protection (EP) by industry for the 1996-2004 period (Appendix Table 69).[25] Oil and gas extraction spent 1.8 per cent of current-dollar value added on EP in 2004, equivalent to $1,161 million dollars. In 2004, the entire business sector spent an estimated $6,754 million dollars on EP, or 0.7 per cent of total current-dollar business sector value added. Oil and gas extraction accounted for over 17 per cent of EP expenditures in the business sector.

In 2004, across all industries, over 36 per cent of expenditure on pollution abatement and control (PAC) and pollution prevention occurred in the western provinces and territories.[26] Operating expenditures on PAC and pollution prevention were highest in Ontario, which accounted for more than a third of total operating expenditures, Alberta accounted for nearly a quarter. Capital expenditures on PAC and pollution prevention were highest in Alberta, which accounted for over 40 per cent of total expenditures, Ontario accounted for 23 per cent (Statistics Canada, 2004).

Chart 20: Environmental Expenditures, Oil and Gas Extraction, As a Share of Nominal GDP, Canada, 1996-2004



Source: Appendix Table 69

The estimates of EP expenditures suggest that oil and gas extraction faces a greater environmental regulation burden than many other industries. Expenditures on EP have increased by 161 per cent between 1996 and 2004 in the oil and gas extraction industry and 62 per cent in the business sector. The share of total business sector EP

[25] Environmental Protection includes the following activities: environmental monitoring, environmental assessments and audits, reclamation and decommissioning, wildlife and habitat protection, pollution abatement and control processes (end-of-pipe), pollution prevention processes, and fees, fines and licenses.
[26] Western province and territories includes Manitoba, Saskatchewan, Alberta, Yukon Territory, Northwest Territories, and Nunavut.

expenditures undertaken in oil and gas extraction increased significantly between 1996 and 2004, from 11 to 17 per cent. Despite this large increase in the share of business sector expenditures, EP expenditures in oil and gas extraction as a share of current-dollar GDP fell between 1996 and 2004 from 2.0 per cent to 1.8 per cent (Appendix Table 69 and Chart 20).

Despite the fact that oil and gas extraction faces a greater environmental regulatory burden, it does not appear that this burden has changed significantly since 2000. While the level of EP expenditures increased dramatically between 2000 and 2004 in oil and gas extraction, as a percentage of nominal GDP the EP expenditures have declined. Therefore, it does not appear as though environmental regulation is a cause for the post-2000 productivity slowdown in oil and gas extraction.

F. Deterioration of Average Quality of Resources Independent of Price Effects

Independent of price effects, the geological characteristics of oil and gas resources extracted may have contributed to the productivity slowdown. In the natural resources literature, a decline in the quality of a resource is associated with a rise in the cost of extraction. The quality of an extractive resource is determined by various characteristics: geographical location, size of reserve, ease of extraction, and grade and purity of reserve. Over time, independent of price movements, the quality of extractive resources tends to decline since large, easily accessible resources are often the first to be located and extracted. However, the deterioration of the quality of a resource independent of price effects is not easily identifiable as extraction activity is often determined by resource prices. There are often many forces affecting the quality of a resource, notably: price, transportation costs, and geological characteristics.

In oil and gas extraction, there has been a shift towards unconventional oil, which is a lower quality resource, because more inputs are required to obtain the same amount of oil extracted conventionally. It is estimated that the world price of oil had to exceeed $25 US per barrel before the oil sands would be profitable to exploit (Macdonald, 2007a). In other words, this quality deterioration is attributable primarily to price effects. No evidence of significant quality deterioration independent of price changes has been identified.

G. Labour Relations

According to Statistics Canada, the unionization rate is declining in some natural resource industries. The unionization rate in the forestry, fishing and mining and oil and gas extraction industry fell from 30.9 per cent in 1997 to 22.6 per cent in 2007 (Appendix Table 72). These are much lower rates than in the 1970s and 1980s. In 1976, 43.2 per cent of natural resource industry employees (including the utilities industry) were unionized, (Galarneau, 1996). This figure fell to 33.5 per cent in 1986. The total number of strikes in Canada fell from 1028 in 1980, to 379 in 2000 and to 293 in 2005 (Table

72). Overall it seems unlikely that unionization has had major impact on oil and gas extraction productivity since 2000.

H. Taxation

The taxation policies facing the industry could have productivity effects since such policies affect the incentives to invest.[27] Oil and gas extraction companies face both corporate taxes and resource royalties, the latter designed to capture the economic rent of oil and gas extraction, or in other words the return over and above the cost of extracting the resource. There are, however, special provisions in the corporate tax code for oil and gas extraction industries, including deductibility of exploration expenses and accelerated depreciation on some capital investments. It does not appear that taxes are a major impediment of productivity in the oil and gas extraction industries.

As was noted earlier, industry profit data from Statistics Canada show that net profits have risen in oil and gas extraction and the support activities sub-sectors (NAICS codes 211 and 213) from $11,397 million in 2000 to $18,476 million in 2007 (Appendix Table 71 and Chart 16). As a share of nominal GDP, this represents an increase from 1.06 per cent in 2000 to 1.20 per cent in 2007. In addition to rising profits, investment has increased since 2000 in oil and gas extraction. Investment in oil and gas extraction and the support activities increased from $21,663 million in 2000 to $66,690 million in 2007. Rising profits and investment since 2000 indicate that the Canadian taxation system does not seem to be a cause of the post-2000 productivity slowdown.

The Alberta Royalty Review could have consequences for the future productivity of oil and gas extraction in Alberta, and consequently at the aggregate level. In September 2007, the Alberta Royalty Review Panel released a document calling for a restructuring of the royalty rates and formulas in Alberta. They concluded that royalty rates have not kept pace with the changes in Alberta's crude oil and natural gas resource base. They recommended increasing the royalty rate for conventional oil, unconventional oil and natural gas by five to seven per cent. In October 2007 the Government of Alberta released the *New Royalty Framework* which, when implemented in January 2009, could increase the provinces revenue by 20 per cent. A consequence of the Royalty Review is that some planned projects have been made uneconomic. The Royalty Review could have a positive effect on productivity in the sub-sector as the projects that are now deemed uneconomic were likely the projects at the margin with low productivity.

I. Key Findings

This section examined eight possible explanations of falling oil and gas extraction productivity in Canada: declining capital intensity; higher oil and gas prices; lagging innovation and technological progress; deterioration of the average quality of the workforce; greater environmental regulation; deterioration of the average quality of resources exploited independent of price effects; labour relations; and taxation. Summary

[27] This discussion is drawn from Smith (2004b).

Table 5 provides a summary of the evidence and conclusions regarding these nine potential drivers.

Summary Table 5: Summary of Causes of Falling Oil and Gas Extraction Productivity in Canada

Hypothesis	Evidence	Conclusion
1. Capital Intensity	The capital-labour ratio fell over the 2000-2007 period (-1.88 per cent per year), while it rose over the 1989-2000 period (2.90 per cent per year).	The falling growth rate of the capital-labour ratio accounted for about 47 per cent of the post-2000 slowdown in oil and gas extraction labour productivity growth. The declining capital-labour ratio accounted for 26 per cent of the negative growtin in oil and gas labour productivity since 2000.
2. High Prices for Energy and Minerals	The implicit price deflator for the oil and gas extraction industry doubled between 2000 and 2006. This resulted in increased economic rents and profitability in the industry.	Profitability appears to have trumped productivity.
a. Ricardian Effect / Price Related Compositional Shift	More intensive exploitation of current deposits and exploitation of marginal oil and gas deposits were driven by higher oil and gas prices. Unconventional oil production accounted for 46 per cent of total crude oil production in Canada in 2007, up from 30 per cent in 2000. The cost of extracting a barrel of unconventional oil can range from $6-$22 per barrel, compared to an average of $6 per barrel for conventional oil (in 2005 Canadian dollars) (NEB, 2006).	Oil and gas extraction firms are running into diminishing returns to labour. High oil and gas prices are driving output expansion at a high rate, and technological progress is not fast enough to keep diminishing returns from setting in.
b. Behavioural Effect	Profits in the oil and gas extraction and the support activities increased from 1.06 per cent of total Canadian nominal GDP in 2000 to 1.2 per cent in 2006.	Significant increases in economic rents have likely resulted in an increase in X-inefficiency.
3. Lagging Innovation and Technological Progress	R&D Intensity in oil and gas extraction is below the Canadian business sector average, but has been increasing since 2000. Evidence shows that most establishments in the industry do not develop their own new technologies, but rather introduce new "off the shelf" technologies.	The Canadian oil and gas extraction sub-sector is at the forefront of the technological frontier and therefore does not appear to be lagging behind in innovation.
4. Deterioration of the Average Quality of the Workforce	The educational attainment of the average worker in oil and gas extraction is higher than the average in the economy as a whole. However, a large influx of new workers may have created a less experienced workforce.	Because of rapid increase in labour input, there appears to be a slight downward trend in the growth rate of the average quality of the workforce relative to the Canadian business sector.
5. Greater Environmental Regulation	Environmental protection expenditures, as a share of nominal value added, are much higher in oil and gas extraction than in the business sector.	Oil and gas extraction faces a higher environmental burden than the average industry in the business sector. However, this burden does not appear to have increased since 2000.
6. Deterioration of Average Quality of Resources Independent of Price Effects	There has been a shift from conventional to unconventional oil and gas extraction.	There is no evidence of decreasing quality of resources independent of price effects.
7. Labour Relations	The level of unionization has fallen in the forestry, fishing, and mining and oil and gas extraction industries between 1997 and 2007.	There is no evidence that strikes or unionization have affected productivity growth.
8. Taxation	Investment and profits in oil and gas extraction have increased substantially between 2000 and 2007.	There is no evidence that the Canadian taxation system is a cause of the industry's productivity slowdown.

Upon examining various hypotheses put forward to explain falling productivity in oil and gas extraction, both in terms of growth and levels, the most robust seems to be the effect of higher prices on both capital intensity and TFP. When the price of a natural resource increases sharply there are two mechanisms which can act to reduce productivity: a Ricardian effect and a behavioural effect. As prices rise it becomes profitable to increase extraction rates at existing deposits and to extract from marginal resource deposits that were previously unprofitable due to high costs of extraction. This is the Ricardian effect of higher prices. In the short term, because labour is less rigid than capital, we can expect this adjustment process to translate into a falling capital-labour ratio. The shift from conventional to unconventional resources should also put downward pressure on TFP growth. The second effect of higher prices is behavioural. While economists place great weight on productivity, profitability trumps productivity as an objective for firms. The objectives of productivity and profitability normally coincide, but when they diverge – as, for example, when commodity prices are extremely high – the productivity growth of an industry, measured in constant prices, may suffer due to greater X-inefficiency in operations. This would be reflected in a fall in TFP growth.

Data on TFP and capital intensity suggest that falling capital intensity growth rates can explain a large part of the productivity slowdown in oil and gas extraction between the 1996-2000 and 2000-2006 periods. Yet, it also suggests that the decline in labour productivity (negative growth) in oil and gas extraction is largely due to sustained negative TFP growth. These findings imply that while more intense extraction at the margin has driven the recent slowdown, it is the shift towards unconventional oil and an increase in X-inefficiency which are the main explanation behind negative labour productivity growth. These findings reinforce the idea that higher prices were the main driver of both the post-2000 labour productivity slowdown and the negative productivity growth in oil and gas extraction.

VII. Implications of Falling Oil and Gas Extraction Productivity for the Canadian Economy

Since productivity growth is the key driver of increases in living standards, the deceleration of labour productivity growth in Canada after 2000 would have been expected to lead to a slower rate of increase in living standards. But improving terms of trade are also a source of increases in real income. The higher commodity prices that Canada has enjoyed in recent years, in addition to the negative effect on oil and gas extraction productivity, have boosted the real income of Canadians (Kohli, 2006 and Macdonald, 2007b). This development has offset some of the shortfall in real income growth from lagging productivity growth in oil and gas extraction. This part of the report will first describe the implications of falling productivity in oil and gas extraction on living standards. It will then explore the offsetting effects of improved terms of trade. The final section will outline a suggested policy response to the falling productivity in oil and gas extraction.

A. Implications of Falling Oil and Gas Extraction Productivity and the Post-2000 Aggregate Productivity Slowdown

Economic well-being is best defined as a country's standard of living which can be proxied by the level and growth of a country's per capita income (Sharpe, 1998). In the short run, per capita incomes can be increased by increases in the employment-population ratio, average hours worked, and the terms of trade (price of exports relative to price of imports). The growth of these factors, however, is limited. In the long run, the only way to sustain increases in per capita income is through productivity growth. Productivity growth provides resources to invest in areas that can improve the quality of life for individuals such as education, the environment, infrastructure, and health (Rao *et al.*, 2005).

Rao *et al*. (2005) attribute much of the post-2000 productivity slowdown to the sector producing information and communications technologies, which experienced a productivity collapse in 2000. They suggest that the productivity slowdown in Canada is a return to trend productivity growth of the 1973-1996 period after experiencing abnormally rapid growth in the 1996-2000 period. Over that 23-year period, labour productivity in the total Canadian economy grew 1.06 per cent per year. During the 1996-2000 period, aggregate labour productivity grew more than twice as fast at 2.35 per cent per year. Over the 2000-2007 period, aggregate labour productivity grew 0.98 per cent per year, which supports the hypothesis that the post-2000 slowdown is a return to the 1973-1996 trend. While it is important to be aware of how oil and gas extraction has affected aggregate productivity growth, particularly in Alberta, it is also important to recognize that the boost in real incomes of Canadians due to high commodity prices has dampened the effect of lagging productivity on real income growth.

Box 1: Environmental and Socio-Economic Impacts of Oil and Gas Extraction

While the level of per capita income is a commonly used proxy for a country's standard of living, many other factors contribute to living standards such as health, security, equality, and environmental quality. The negative effects of oil and gas extraction on the environment are not insignificant. With the rapid expansion of the oil sands in Alberta, environmental degradation and socio-economic impacts have become increasingly important issues.

Between 2.0 to 4.5 barrels of water are drawn from the Athabasca River in Alberta to produce one barrel of synthetic crude oil. It is estimated that the Athabasca River will not be able to support all planned oil sands operations. The production of unconventional oil has been identified as the biggest contributor to the growth of green house gas emissions in Canada. Additionally, the construction of roads and exploration sites will have irreversible affects on Alberta's landscape, destroying wetlands and lakes.

There are also various negative socio-economic impacts of the rapid expansions of the unconventional oil industry in Alberta. There is a shortage of affordable housing, increased demand for government health and education services, impacts on traditional aboriginal lands and aboriginal way of life, insufficient infrastructure, and alcohol and drug abuse.

Given these environmental and socio-economic impacts, the conventional measure of productivity is likely not capturing the whole story of the impact of oil and gas extraction on living standards. The literature does provide suggestions to address this shortcoming of conventional productivity measures. For example, Gollop and Swinland (2001) suggest a measure, total resource productivity (TRP). TRP would account for changes in environmental quality by including a measure of the level of pollution in the measure of output.

Source: National Energy Board (2006)

B. Can Improved Terms of Trade Offset the Negative Impact of Falling Oil and Gas Extraction Productivity on Real Incomes?

High commodity prices have coincided with and indeed produced falling productivity growth in oil and gas extraction, and therefore a decline in the rate of growth of the real income of Canadians. However, there is a positive impact of high commodity prices on the incomes of Canadians: improved terms of trade. As a country's terms of trade improve, the volume of imports a country can purchase for a given volume of exports increases. An improvement in terms of trade has a similar effect on real incomes as that of productivity growth: consumers are able to consume more goods and services from their available resource base (Macdonald, 2007b).

Summary Table 6: Real GDP and Real GDI Growth in Canada and Selected Provinces, 2002-2005

	Total Real GDP Growth (per cent)	Total Real GDI Growth (per cent)	Trading Gains (percentage points)
	A	B	C=B-A
Canada	8.3	13.4	5.1
Newfoundland and Labrador	5.7	23.2	17.5
Nova Scotia	3.6	9.3	5.7
Quebec	6.3	7.8	1.5
Manitoba	6.7	8.4	1.7
Saskatchewan	10.8	18.9	8.1
Alberta	13.5	38	24.5

Source: Macdonald (2007b)

Macdonald (2007b) quantified the gains due to improvements in terms of trade in Canada and the provinces over the 1981-2005 period (Summary Table 6). According to his calculations, real gross domestic income (GDI), which is a measure of the real purchasing power of income, grew at the same rate as real GDP over the 1981-2002 period. However, real GDI increased by 13.4 per cent in Canada between 2002 and 2005, while real GDP increased by only 8.3 per cent over the same period.[28] The difference between real GDP and real GDI growth is due to trading gains which arise from fluctuations in the terms of trade and in the real exchange rate. According to Macdonald, the terms of trade was the dominant factor affecting trading gains in Canada over the 2002-2005 period.

In Alberta, terms of trade gains are even larger due to the importance of the energy sector and the fluctuating energy prices. Over the 1987-1998 period, real GDP and real GDI growth in Alberta are similar. In 1998, real GDI began to grow faster than real GDP due to terms of trade improvements driven by higher energy prices. This pattern continued to 2005; between 2002 and 2005, real GDP in Alberta increased 13.5 per cent while real GDI increased 38.0 per cent. Driven largely by terms of trade improvements, real GDI in Alberta was 31.6 per cent higher than real GDP in 2005. This represented the largest trading gains to a province over the 2002-2005 period.

[28] Kohli (2006) also estimated the average annual growth rate of real GDP and real GDI over the 2002-2005 period. His estimates are consistent with those of Macdonald (2007b), with real GDP growth of 8.2 per cent over the period and real GDI growth of 13.4 per cent. More recently, Ross (2009) defined, estimated and discussed trends for eight measures of income and product for Canada and the United States for the 1980-2008 period. He found that in Canada, income measures have grown faster than product measures between 1980 and 2008, while this was not the case in the United States. This trend was even more apparent over the 2000-2008 period.

C. Should There be a Policy Response to Falling Oil and Gas Extraction Productivity?

This report does not recommend any industry-specific policies to improve productivity growth in mining above and beyond general public policies to improve productivity, such as investments in human capital and innovation (e.g. Sharpe, 2007). Despite the rapid decline in the growth rate of productivity in oil and gas extraction it is not necessarily true that Canadians are worse off. The sub-sector's falling productivity is the result of business decisions driven by profits and the exploitation of marginal deposits. Therefore, falling productivity in the oil and gas extraction is not a public policy issue. Furtherm

ore, the landscape of oil and gas extraction is determined largely by oil and gas prices, over which policy-makers have very limited control.

With the rapid increase in commodity prices, employment in oil and gas extraction has risen quickly. This higher labour demand by the sub-sector has had significant benefits for Canada. According to a CSLS research report, interprovincial migration in Canada resulted in real GDP gains of $883 million in 2006 (Arsenault *et al.*, 2007). The high level of productivity in oil and gas extraction in Alberta was a dominant contributor to this output and productivity gain, since Alberta had the highest level of positive net interprovincial migrants in 2006.[29] As employment rose in oil and gas extraction so did the incomes of Canadians.

Another reason why a policy response to address the falling productivity in oil and gas extraction is not necessary is that there does not appear to be technological stagnation. The decline in productivity in oil and gas extraction is largely a composition effect. Additional resources have been allocated to less productive operations which are now profitable due to high prices. Further, Canada is considered to be on the frontier of technological developments related to oil and gas extraction. In contrast, other industries, such as manufacturing, face intense cost competition and productivity growth is necessary in order to maintain competitiveness. In oil and gas extraction, the high economic rent makes productivity less important compared to other areas of the economy, though certainly still desirable.

[29] In 2006, 62,291 persons moved to Alberta. British Columbia, the only other province to have net positive interprovincial migration in 2006, had 7,449 migrants.

VIII. Conclusion

Oil and gas extraction has had weak output growth and rapid input growth resulting in negative labour productivity growth over the 2000-2007 period. The following are the key highlights:

- Real GDP increased 1.90 per cent per year between 2000 and 2007, much more slowly than the 2.55 per cent per year for the economy as a whole.
- Hours worked increased 11.03 per cent per year between 2000 and 2007, 14.75 percentage points faster than the growth rate over the 1996-2000 period, and 9.45 percentage points faster than the total economy. Capital input increased 8.36 per cent per year between 2000 and 2006, 1.00 percentage point faster than the growth rate over the 1996-2000 period, and 5.88 percentage points faster than the total economy.
- Between 2000 and 2007, labour productivity fell 8.23 per cent per year, capital productivity fell 5.97 per cent per year and TFP fell 6.67 per cent per year (2000-2006).

Oil and gas extraction experienced a labour productivity slowdown of 14.71 percentage points between the 1996-2000 and 2000-2006 periods. According to the methodology developed by Tang and Wang (2004), oil and gas extraction contributed 0.16 percentage points to the aggregate labour productivity slowdown of 1.33 percentage points, about 12.3 per cent of the slowdown.

Upon examining various hypotheses put forward to explain falling productivity in oil and gas extraction, the most robust seems to be the effect of higher prices. When the price of a natural resource increases sharply there are two mechanisms which can act to reduce productivity: a Ricardian effect and a behavioural effect. As prices rise it becomes profitable to extract from marginal deposits that were previously unprofitable due to high costs of extraction, this is the Ricardian effect of higher prices. The second effect of higher prices is behavioural. While economists place great weight on productivity, in general, profitability trumps productivity as an objective for firms. Normally the objectives of productivity and profitability coincide, but when they diverge, as for example when commodity prices are extremely high, the productivity growth of a firm, measured in constant prices, may suffer due to greater X-inefficiency in operations.

The analysis in this report was limited by the data availability for oil and gas extraction. At the time this report was prepared Statistics Canada's National Accounts did not provide nominal GDP data by industry more recent than 2004. This limited availability of industry deflators and the analysis of movements in nominal shares over the 2004-2007 period, which have likely been significant due to developments in commodity prices. A breakdown of labour and capital inputs, as well as output for the conventional and unconventional oil, would be valuable. Additionally, more detailed time series data for employment and output at the five-digit NAICS level would be valuable. Finally, a clarification of the role of exploration activity and how it is measured in output, investment and capital formation is needed.

Despite the rapid decline in productivity in oil and gas extraction, it is not necessarily true that Canadians are worse off. In fact, increases in prices and employment shares, as well as the high productivity level of oil and gas extraction have resulted in positive contributions to aggregate labour productivity growth, even though the sub-sector contributed to the post-2000 aggregate labour productivity slowdown. Moreover, the higher commodity prices in recent years have boosted the real incomes of Canadians through a terms-of-trade effect.

This report does not recommend any industry-specific policies to improve productivity growth in oil and gas extraction above and beyond general public policies to improve productivity, such as investments in human capital and innovation. Ironically, the poor productivity performance of oil and gas extraction does not appear to be an indication of crisis, but rather an indication of the strength and vitality of a sub-sector on the technological frontier.

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Appendix: Definition and Description of the Oil and Gas Extraction Sub-Sector

This appendix defines the oil and gas extraction sub-sector, as the term is used in this report. This definition is based on the North American Industry Classification (NAICS) 2002. For statistical purposes, NAICS classifies all establishments into two-digit sector, such as mining and oil and gas extraction (NAICS code 21) or manufacturing (NAICS codes 31 through 33). Two-digit sectors are further subdivided into three-digit sub-sectors, such as oil and gas extraction (211). These three-digit sub-sectors are then divided into four digit industry groups and five-digit industries.

The remainder of this appendix is a detailed description of the three-, four-, five-, and six-digit industries that make up the forest products sector. This description is drawn from Statistics Canada (2007) and can be accessed at http://www.statcan.ca/english/Subjects/Standard/naics/2002/naics02-menu.htm.

This appendix also describes an important sub-sector that is excluded due to lack of data. The sub-sector support activities for mining and oil and gas extraction (NAICS 213) is not included because the constituent industries involved in the oil and gas business cannot be separated from the industries involved in mining, which is not the subject of this report. Excluded industries are oil and gas contract drilling (213111) and services to oil and gas extraction (213118). From the standpoint of analyzing the productivity of the oil and gas business, these exclusions are not insignificant and should be kept in mind by the reader.

The superscript at the end of NAICS titles indicates comparability:

^{CAN} Canadian industry only,

[blank] Canadian, Mexican and United States industries are comparable.

211 Oil and Gas Extraction

This subsector comprises establishments primarily engaged in operating oil and gas field properties. Such activities may include exploration for crude petroleum and natural gas; drilling, completing and equipping wells; operating separators, emulsion breakers, desilting equipment and field gathering lines for crude petroleum; and all other activities in the preparation of oil and gas up to the point of shipment from the producing property. This subsector includes the production of oil, the mining and extraction of oil from oil shale and oil sands, and the production of gas and hydrocarbon liquids, through gasification, liquefaction and pyrolysis of coal at the mine site.

2111 Oil and Gas Extraction

This industry group comprises establishments primarily engaged in operating oil and gas field properties. Such activities may include exploration for crude petroleum and natural gas; drilling, completing and equipping wells; operating separators, emulsion breakers, desilting equipment and field gathering lines for crude petroleum; and all other activities in the preparation of oil and gas up to the point of shipment from the producing property. This industry includes the production of oil, the mining and extraction of oil from oil shale and oil sands, and the production of gas and hydrocarbon liquids, through gasification, liquefaction and pyrolysis of coal at the mine site.

21111 Oil and Gas Extraction

This industry comprises establishments primarily engaged in operating oil and gas field properties. Such activities may include exploration for crude petroleum and natural gas; drilling, completing and equipping wells; operating separators, emulsion breakers, desilting equipment and field gathering lines for crude petroleum; and all other activities in the preparation of oil and gas up to the point of shipment from the producing property. This industry includes the production of oil, the mining and extraction of oil from oil shale and oil sands, and the production of gas and hydrocarbon liquids, through gasification, liquefaction and pyrolysis of coal at the mine site.

Exclusion(s): Establishments primarily engaged in:

- performing oil field services for operators, on a contract or fee basis (21311, Support Activities for Mining and Oil and Gas Extraction)
- recovering liquefied petroleum gases incidental to petroleum refining (32411, Petroleum Refineries)
- recovering helium from natural gas (32512, Industrial Gas Manufacturing)

211113 Conventional Oil and Gas Extraction [CAN]

This Canadian industry comprises establishments primarily engaged in the exploration for, and/or production of, petroleum or natural gas from wells in which the hydrocarbons will initially flow or can be produced using normal pumping techniques.

Exclusion(s): Establishments primarily engaged in:

- producing crude oil from surface shales or tar sands or from reservoirs in which the hydrocarbons are semisolids and conventional production methods are not possible (211114, Non-Conventional Oil Extraction)
- performing oil field services for operators, on a contract or fee basis (213118, Services to Oil and Gas Extraction)
- recovering liquefied petroleum gases incidental to petroleum refining (324110, Petroleum Refineries)

Example activities include coal gasification at the mine site; coal pyrolysis at the mine site; condensate, cycle, natural gas production; crude oil, conventional production, mining; crude oil, conventional, secondary recovering; crude oil, conventional, waterflood recovering; fractionating natural gas liquids; gas well, natural; liquefied petroleum gases (LPG) natural; natural gas cleaning plant; natural gas from oil shale or sand; natural gas liquids production; natural gas liquids recovering, mining; natural gas pumping, mining; natural gas washing and scrubbing, mining; natural sour gas processing, mining; oil well, crude, conventional; petroleum production, crude, conventional; propane (natural) production; well, natural gas.

211114 Non-Conventional Oil Extraction CAN

This Canadian industry comprises establishments primarily engaged in producing crude oil from surface shales or tar sands or from reservoirs in which the hydrocarbons are semisolids and conventional production methods are not possible.

Exclusion(s): Establishments primarily engaged in:

- the exploration for, and/or production of, petroleum or natural gas from wells in which the hydrocarbons will initially flow or can be produced using normal pumping techniques (211113, Conventional Oil and Gas Extraction)
- performing oil field services for operators, on a contract or fee basis (213118, Services to Oil and Gas Extraction)
- recovering liquefied petroleum gases incidental to petroleum refining (324110, Petroleum Refineries)

Example activities include bitumen production, extraction by mining; bitumen production, in-situ extraction; bituminous sand and oil shale digging; heavy crude oil extracting; heavy oil in place, solution gas drive recovering; heavy oil, thermal in situ recovering; oil sand mining; petroleum, from shale or sand, production; sand, oil, mining; shale, oil, mining; tar sand mining for oil extraction.

Exclusions from the Oil and Gas Extraction Sub-Sector

213 Support Activities for Mining and Oil and Gas Extraction

This subsector comprises establishments primarily engaged in providing support services, on a contract or fee basis, required for the mining and quarrying of minerals and for the extraction of oil and gas. Establishments engaged in the exploration for minerals, other than oil or gas, are included. Exploration includes traditional prospecting methods, such as taking ore samples and making geological observations at prospective sites.

2131 Support Activities for Mining and Oil and Gas Extraction

This industry group comprises establishments primarily engaged in providing support services, on a contract or fee basis, required for the mining and quarrying of minerals and for the extraction of oil and gas. Establishments engaged in the exploration for minerals, other than oil or gas, are included. Exploration includes traditional prospecting methods, such as taking ore samples and making geological observations at prospective sites.

21311 Support Activities for Mining and Oil and Gas Extraction

This industry comprises establishments primarily engaged in providing support services, on a contract or fee basis, required for the mining and quarrying of minerals and for the extraction of oil and gas. Establishments engaged in the exploration for minerals, other than oil or gas, are included. Exploration includes traditional prospecting methods, such as taking ore samples and making geological observations at prospective sites.

Exclusion(s): Establishments primarily engaged in:

- performing geophysical surveying services for minerals, on a contract or fee basis (54136, Geophysical Surveying and Mapping Services)

213111 Oil and Gas Contract Drilling

This Canadian industry comprises establishments primarily engaged in drilling wells for oil or gas field operations, for others, on a contract or fee basis.

Example activities include directional drilling of oil and gas wells, on a contract basis; gas well drilling, on a contract basis; oil well drilling, on contract basis; redrilling oil and gas wells, on a contract basis; troubleshooting, natural gas and oil well

213118 Services to Oil and Gas Extraction [CAN]

This Canadian industry comprises establishments primarily engaged in performing oil and gas field services, except contract drilling, for others, on a contract or fee basis.

Exclusion(s): Establishments primarily engaged in:

- performing exploration for oil or gas, other than geophysical (21111, Oil and Gas Extraction)
- contract drilling for oil and gas (213111, Oil and Gas Contract Drilling)

Example activities include acidizing wells, on a contract basis; bailing wells, on a contract basis; building oil and gas well foundations on site, on a contract basis; cementing oil and gas well casings, on a contract basis; chemically treating wells, on a contract basis; cleaning out (e.g., bailing out, steam and swabbing) oil and gas wells, on a contract basis; contract battery operators; cutting casings, tubes and rods, oil field; drilling water intake wells, on a contract basis; erecting lease tank, oil and gas field, on a contract basis; excavating slush pits and cellars, on a contract basis; fire-fighting service, other than forestry or public; gas compressing (natural gas) at the fields, on a contract basis; gas well surveying, contract services (except seismographic); oil well logging, on a contract basis; perforating well casings, on a contract basis; pumping of oil and gas wells, on a contract basis; servicing oil and gas wells, on a contract basis; shot-hole drilling service, oil and gas field, on a contract basis; slush pits and cellars, excavation of, on a contract basis; swabbing wells, on a contract basis; thawing and cleaning well head oil fields; water intake well drilling, on a contract basis; well foundation building, at oil and gas wells, on a contract basis; well pumping, oil and gas, on a contract basis; wells, cleaning out, bailing, swabbing, oil field.