Canadian Energy Research Institute

The Impacts of Canadian Oil Sands Development on the United States' Economy

FINAL REPORT

October 2009

CANADIAN ENERGY RESEARCH INSTITUTE

Relevant • Independent • Objective

THE IMPACTS OF CANADIAN OIL SANDS DEVELOPMENT ON THE UNITED STATES' ECONOMY

The Impacts of Canadian Oil Sands Development on the United States' Economy

This study was undertaken for the American Petroleum Institute.

Authors:

Asghar Shahmoradi
Afshin Honarvar
Peter Howard
Paul Kralovic

Special Thanks to:

Marwan Masri
David McColl
Thorn Walden
Rami Shabaneh
Martin Slagorsky

Acknowledgements: The authors of this report would like to extend our thanks and gratitude to everyone involved in the production and editing of the material, including, but not limited to, Capri Gardener, Megan Murphy, and Marwan Masri.

CANADIAN ENERGY RESEARCH INSTITUTE
#150, 3512 – 33 STREET NW
CALGARY, ALBERTA
CANADA T2L A6

TELEPHONE: (403) 282-1231

October 2009
Printed on Recycled Paper Canada

The Canadian Energy Research Institute (CERI) is a cooperative research organization established by government and industry parties in 1975. Our mission is to produce relevant, independent, objective economic research and education on energy and environmental issues to benefit business, government, and the public.

CERI's public sector sponsors include departments and agencies of the federal and several provincial governments, plus one university; private sector sponsors consist of more than one hundred corporate and trade association members from the energy production, transportation, marketing, distribution, and consuming sectors in Canada and abroad, and from the financial community.

CERI's research program is guided by a board of directors named by the sponsoring organizations. Project advisory committees consisting of experts from government and industry are established to assist CERI staff and to review preliminary drafts of CERI reports. Responsibility for the content of studies rests with the author(s) and CERI's officers.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background: CERI, a non-profit Canadian energy and environmental research institute, examines the impacts of developing Canadian oil sands on the United States' economy. The study covers the period from 2009 to 2025 and is based on the 2009 CERI "Economic Slowdown Projection". This production forecast envisions raw bitumen production slowly climbing from current levels of approximately 1.2 million barrels per day to around 4 million barrels per day in 2025. CERI estimates the annual capital investment and operating costs needed to achieve this output at $379 billion. This study estimates the impact to the US economy of these investments and related oil sands production occurring in Alberta, Canada.

Results: Canada and the US are major trading partners, and the results clearly show significant economic benefits to the US from increased economic activity in Canada. As investment and production in oil sands ramps up in Canada, the pace of economic activity quickens and demand for US goods and services increase rapidly, resulting in an estimated 343 thousand new US jobs between 2011 and 2015. Demand for US goods and services continues to climb throughout the period, adding an estimated $34 billion to US GDP in 2015, $40.4 billion in 2020, and $42.2 billion in 2025.

National Impacts ($US Billion)	2010	2015	2020	2025
U.S. Output	23.0	69.2	78.5	80.9
U.S. Gross Domestic Product	11.5	34.0	40.4	42.2

National Impacts (Thousand Person Year)	2009-2010	2011-2015	2016-2020	2021-2025
U.S. Employment	172	343	88	22

"Thousand Person Year" equates to the number of jobs created, times 1,000, for a given year and for as long as the project operates. With regards to the table above, the number of jobs listed indicates the number of incremental jobs that are created. For example, between 2011 and 2015 an incremental 343 thousand jobs are created.

The benefits of oil sands development do not fall to any one industry or any one region in the US but are broadly shared across many industrial sectors and regions. This is because oil sands development requires a large quantity of inputs from broad segments of the manufacturing and service sectors of the Canadian and US economies. It is this increase in demand for goods and

services in both countries, and the increased trade resulting there from, that broadly increases the level of economic activity to the United States.

Conclusions: Developing the Canadian Oil Sands is a very capital intensive endeavor, requiring billions of dollars of investment over the next several decades. This investment would give rise to a long-lived, robust period of increased economic activity in Canada. Due to the deep and rich trading relationship between Canada and the United States, the US derives significant benefit from this increased economic activity across many sectors throughout the United States.

CHAPTER 1
INTRODUCTION

1.1 Background

Amidst a global financial crisis, uncertain commodity prices and an unclear geopolitical landscape, the public in both the United States and Canada are expecting policy-makers to formulate a balanced set of energy and environmental policies. More specifically with respect to the issue of Canadian oil sands, a clear understanding of the contribution of oil sands development to the US economy in terms of jobs, economic growth and energy security will hopefully inform the public debate. This understanding is crucial as the petroleum industry is characterized by capital-intensive projects with long lead times. Policy decisions made today can have large impacts on investment levels and energy supply for decades into the future,

Canada's petroleum industry is a significant contributor to both Canadian and US Gross Domestic Product (GDP). The petroleum industry has widespread economic impacts that extend far beyond the province of Alberta—-Canada's largest producer of oil and gas. Investments in new developments and expenditures in ongoing operations provide jobs that generate multiplier effects across economic sectors and borders, benefiting all regions of Canada and the US..

1.2 Objective of the Study

Canada is one of the most important energy producers in the world and the largest supplier of petroleum to the US—a fact that is often not realized. While other regions of Canada are attracting a lot of attention and offer tremendous potential for export, the heart of the Canadian industry is located in the western province of Alberta. It is well known that Canada's most important energy resource is the oil sands, located predominantly in Alberta, but stretches into neighbouring Saskatchewan. With an estimated initial volume in-place of approximately 1.7 trillion barrels of crude bitumen, Canada's oil sands are one of the largest hydrocarbon deposits in the world and provide the most secure supply to the US. By year-end 2008, about 10 percent (i.e., 170.4 billion barrels) of this volume is recoverable using today's technology. Of this recoverable bitumen reserves, 18 percent is accessible through surface mining technologies, while the remaining 82 percent requires in situ recovery technologies.

The oil sands are receiving increasing attention, especially as conventional oil production declines and demand for oil increases. As a result, oil sands reserves play an increasingly important role in the economic development of Alberta, Canada and the United States. What is often not clearly understood is that the large investment in the oil sands industry contributes to increased economic activity in the rest of North America by stimulating demand for goods and services across a wide range of industries.[1] The same is true for other investments in the oil and natural gas industries in any province, state or territory, be it British Columbia, Texas or Newfoundland.

[1]Inventory of Major Alberta Projects, September 2008.

What are the impacts of a certain investment on output of goods and services, GDP, and employment? More specifically, what are the economic impacts of hydrocarbon developments on key macroeconomic variables such as output, GDP, and employment in a particular state? Is there any way to quantify those impacts? How can we study the impacts of such investments on macroeconomic variables in other states? As a result of investment in the oil sands, how many new jobs would be created in Ohio? Providing answers to such questions requires economic tools sufficiently rich in detail to track economic transactions across industries, regions and international borders.

The Canadian Energy Research Institute (CERI) has conducted a number of Input–Output (I/O) analyses, the latest of which was a comprehensive assessment of the contributions of Canada's petroleum industry to the Canadian economy in terms of output, employment and government revenue, both at the provincial and national levels. Released in July 2009, this study focused entirely on Canada.

The primary objective of this study is to measure the incremental impacts of the development in the oil sands industry and the resulting impacts on all US states and the US as a whole. The current study builds on CERI's previous I/O work, focusing only on the Canadian oil sands industry and its importance to the US economy. In particular, CERI examines the impact that the oil sands have on other industries in the US by assessing industry output, GDP, and employment impacts. It identifies the direct, indirect, and induced impacts (discussed in Chapter 3) of current and future investments in Canada's oil sands industry.

This study, like its predecessor, utilizes the I/O modeling approach, which is well established in the literature to determine the impacts of investments in an industry on the operations of other industries. I/O analysis considers relations between industries in an economy and tracks the output of one industry as input into other industries.

Using the I/O accounts published by Canada's System of National Economic Accounts (CSNEA) and Bureau of Economic Analysis's (BEA) *Make*, *Use* and *Final Demand* of the US economy, CERI has constructed a United States-Canada Multi-Regional I/O model (UCMRIO) for the US and Canada. Appendix A discusses further the details of the methodology.

CERI's UCMRIO model reveals the details of the economic linkages between the US and Canadian economies. For instance, it identifies the GDP impact of investment in the oil sands on the economy of Alberta, other Canadian provinces and US regions as well as the national, impacts of the total investments and production of each sector of the economy.

This study sheds light on the Canadian oil sands industry and its importance to the US economy, assisting policy-makers to make informed decisions regarding this industry. Furthermore, it informs the public about an important industry that is not well understood.

1.3 Structure of the Report

This report has been structured as follows. Chapter 2 discusses briefly the oil sands industry in Canada and addresses several key facts about the industry. This chapter sets an important foundation to understanding this massive and unique resource. Chapter 3 discusses and presents the economic impacts of oil sands development on the US economy. The report also contains two appendices. The first discusses in-depth the methodology of this study. It is divided into four parts: overall modeling framework, the USMRIO model, data sources and assumptions and limitations of the I/O approach. The second provides additional information regarding the Canadian oil sands.

CHAPTER 2
OIL SANDS INDUSTRY IN CANADA

This chapter discusses the oil sands industry in Canada. It is divided into two sections: background and oil sands production and investment projection. A discussion of crude bitumen reserves and mineable crude bitumen reserves (under active development) are in Appendix A.

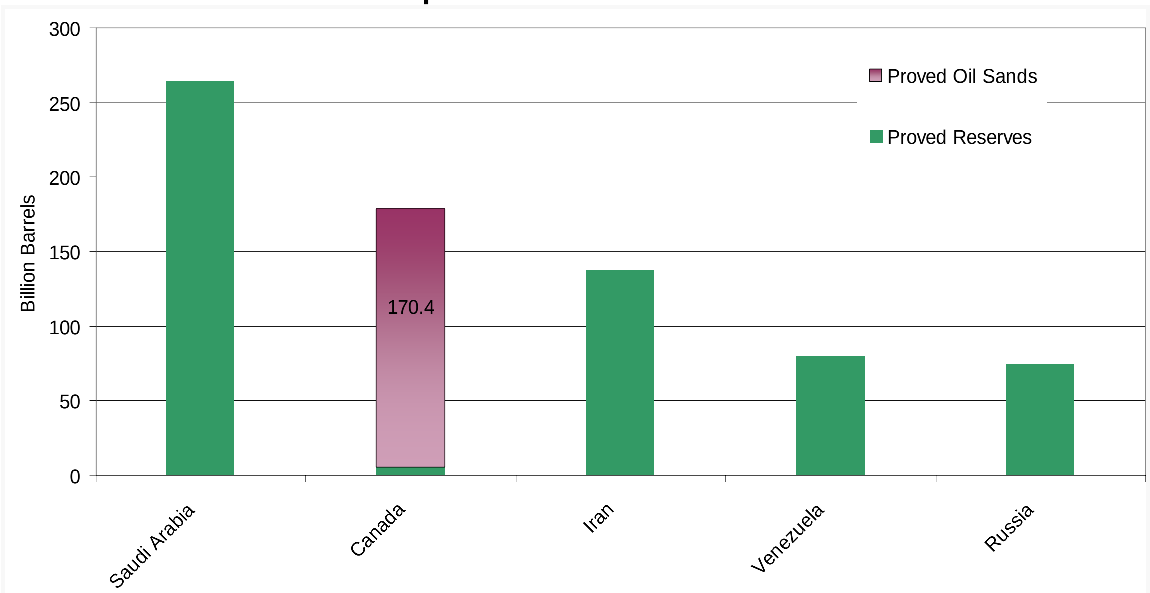
2.1 Background

As reserves and production of conventional crude oil decline, unconventional resources have moved to center stage in Canada, and are becoming increasingly important to the global oil industry. As previously mentioned, with an estimated initial volume in-place of approximately 1.7 trillion barrels (269 billion m^3) of crude bitumen, Canada's oil sands are one of the largest hydrocarbon deposits in the world.[2] While not quite matching Saudi Arabia's conventional oil reserves, the enormous remaining established reserves of Canada's crude bitumen places Canada in the top tier of the world's oil reserves (see Figure 2.1).[3] The resource places Canada second to only Saudi Arabia in total reserves, cutting the Organization of Petroleum Exporting Countries' (OPEC's) share of world oil reserves by more than 10 percent.

[2]Alberta Energy and Utilities Board, *Alberta's Reserves 2005 and Supply/Demand Outlook 2006 – 2015,* June 2006. Latest numbers from Alberta Energy indicate that, due to production, proved oil sands reserves are 170.3 billion barrels. The disparity does not affect the results.

[3]The BP Group, *BP Statistical Review of World Energy 2003*, www.bp.com. Saudi Arabia's proved oil reserves at the end of 2002 stood at 261.8 billion barrels. Proved reserves are generally taken to be those quantities that geological and engineering information indicates can be recovered in the future from known reservoirs under existing economic and operating conditions with reasonable certainty.

Figure 2.1
The Top Five World Proven Reserves



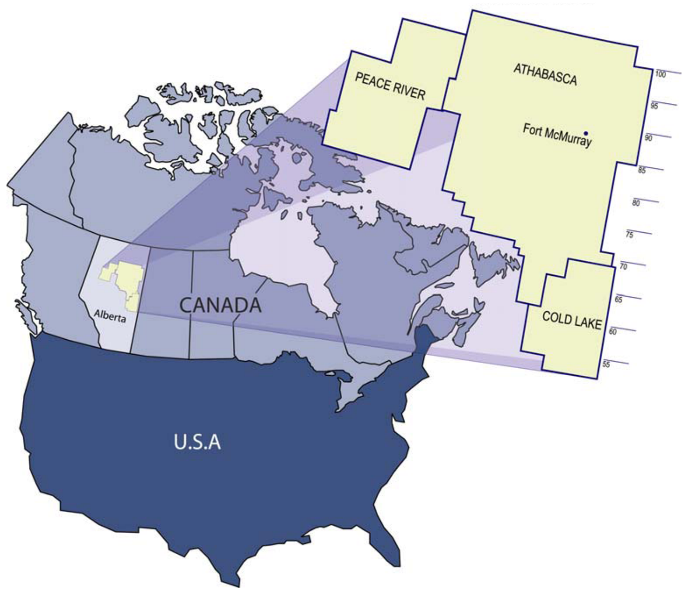
SOURCES: (1) Statistical Series 2003-98, Alberta's Reserves 2005 and Supply/Demand Outlook 2006-2015, (AEUB); and (2) BP Statistical Review of World Energy 2006.

Predominantly located in northern Alberta in the Western Canada Sedimentary Basin (WCSB), Canada's oil sands resources are spread across more than 140,000 square kilometers (see Figure 2.2).[4] They are primarily contained in sand and carbonate formations that are located in the following areas:

- Athabasca in the northeast;
- Cold Lake in the east-central; and
- Peace River in the northwest parts of the province.

[4] Oil sands deposits also exist in Saskatchewan.

Figure 2.2
Oil Sands Areas in Alberta



SOURCE: Alberta Department of Energy.

The oil sands areas in fact stretch east into the neighbouring province of Saskatchewan. As their timescale is not within the scope of this study and are still being delineated, they are not included in this study. However, while far less known than its Albertan counterpart, oil sands in Saskatchewan are attracting a great deal of attention as well and it is important to discuss them briefly. The oil sands in Saskatchewan are found in the lower cretaceous Dina Formation, which extends from Alberta's McMurray Formation.

The first interest in Saskatchewan's oil sands took place from 1974 to 1976 in Clearwater River Valley, located in the northwestern part of the province. During that period, drilling activity started by Shell Canada and Gulf Canada in which they identified the bitumen deposits. Exploitation of the resource, however, was ruled uneconomic due to technological limitations. Nearly thirty years later, in June 2004, the interest for the oil sand deposits in the region was renewed, when Powermax Energy Inc. of Calgary acquired approximately 570,000 hectares, north of the Clearwater River.[5] The area of interest, located along the Alberta-Saskatchewan border, is just north of the Cold Lake Weapons Range. Oilsands Quest Inc. later acquired these land permits, in which they relinquished 228,000 hectares and soon after started drilling exploration wells in the remaining 342,000 hectares of the region. By November 2007, 221 wells have been drilled and an initial report of about 1.5 billion barrels of bitumen was noted and in June 2008, Oilsands Quest nudged that number up to 6.6 billion barrels. The area of the original discovery by Oilsands Quest is now called the Axe Lake Discovery in which three reservoir test sites began construction in March of 2008 and plans for placing horizontal wells should commence in 2009.

[5] "Oil Sands in Saskatchewan", Saskatchewan Industry and Resources, 2005.

The remainder of the report focuses on the oil sands in Alberta.

Canada's oil sands are composed of approximately 80 to 85 percent sand, clay and other mineral matter, 5 to 10 weight percent water, and anywhere from 1 to 18 weight percent crude bitumen. Bitumen content greater than 12 percent is considered rich, while anything less than 6 percent is poor and not usually considered economically feasible to develop.

In the Athabasca region, the oil sands are hydrophilic or "water wet". A thin film of water, which is surrounded by crude bitumen, envelops each grain of sand. The sands are unconsolidated with grain-to-grain contact. Being silica quartz, the sands are extremely abrasive, thus posing significant challenges in the mining and extraction processes. Early developers of the oil sands experienced the challenges associated with this abrasive product, damaging pipelines and equipment. This resulted in alternative methods to transport the bitumen in pipelines, such as creating bitumen emulsions and adding large quantities of water into pipelines for hydro transport. These and other innovative initiatives helped turn the resource into a viable source of oil.

Crude bitumen is a thick, viscous crude oil that, at room temperature, is in a near solid state. The definition used in the industry is that crude bitumen is "a naturally occurring viscous mixture, mainly of hydrocarbons heavier than pentane, that may contain sulphur compounds and that, in its naturally occurring viscous state, will not flow to a well".[6]

The term crude bitumen generally refers to petroleum with a density greater than 960 kilograms per cubic meter.[7] In fact, much of the bitumen in Canada's oil sands deposits has densities that exceed 1,000 kg/m^3 (API Gravity of less than 10 degrees). Because of its high gravity and high viscosity characteristics, crude bitumen may be blended with a light hydrocarbon liquid (condensate) before it is shipped to markets by pipeline.

Table 2.1 compares the densities of a number of crude oil types, including blended bitumen from Athabasca and Cold Lake.

---

[6]Alberta, Canada, *Oil Sands Conservation Act, Section 1(1)(c)*, Alberta Statutes and Regulations. Note that more than 100 thousand b/d (16,000 m^3/d) of crude bitumen from the Cold Lake and Athabasca Oil Sands Areas was produced using primary production techniques during 2002, in apparent contravention of this definition.

[7] Alberta Department of Energy, http://www.energy.gov.ab.ca/OilSands/793.asp, February 2008.

Table 2.1
Crude Oil Densities (kg/m3)

Crude Oil Type	Density
Athabasca Crude Bitumen	1,015
Cold Lake Crude Bitumen	1,009
Maya	921
Athabasca Bitumen Blend	919[a]
Cold Lake Bitumen Blend	919[a]
Bow River Blend	894
Arab Light	858
Bonny Light	841
West Texas Intermediate	827
Federated Light	826
Commercial Condensate	720

[a] Athabasca and Cold Lake Bitumen Blends are derived by adding diluent to crude bitumen to reduce viscosity prior to being transported by pipeline. The most commonly used diluent is very light natural gas liquid (C5+ or pentanes plus), which is a by-product of natural gas processing. A condensate diluent typically constitutes 24-32 percent of the bitumen blend.
Sources: (1) *Markets for Canadian Bitumen-Based Feedstock*, CERI Study No. 101; and (2) Alberta Research Council Open File Report 1993-25.

Because of the nature of oil sands, two different methods are used to produce oil from the oil sands – surface mining and in-situ – or producing in place. Currently a majority of the oil derived from oil sands being produced are by surface mining, although only about 20 percent of oil sands are recoverable through this method. This method is used when bitumen is close to the surface.

The remaining 80 percent of resources are recoverable through in-situ technology. This method is employed when the bitumen deposits are further underground. Most in-situ operations use steam-assisted gravity drainage (SAGD). This involves pumping steam underground through a horizontal well to liquefy the bitumen and pump it to the surface. Current investments in advanced technology will make this method of extraction more widely used in the years to come.

2.4 Oil Sands Production and Investment Projections

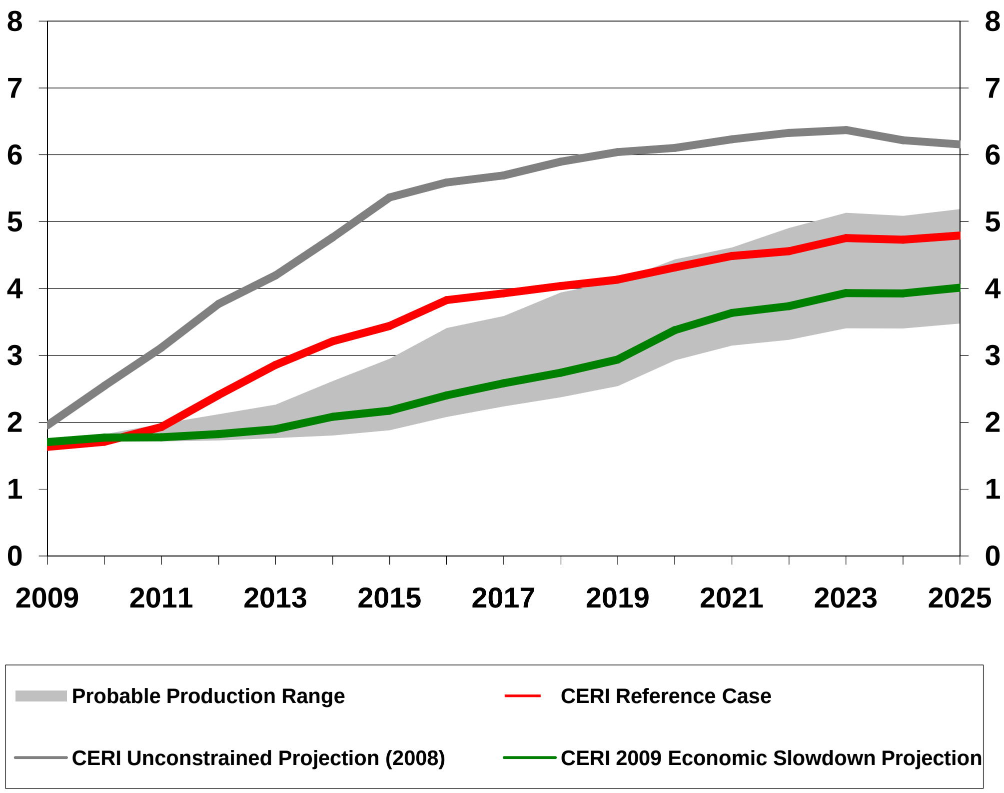
The oil sands production and investment forecast used in this study are based heavily on an oil sands briefing entitled "The Eye of the Beholder: Oil Sands Calamity or Golden Opportunity?" released by CERI in February of this year. In late 2008, CERI released[8] updated oil sands

[8] D. McColl, M. Slagorsky, "Canadian Oil Sands Supply Costs and Development Projects (2008 – 2030)", Study No. 118, November 2008: http://www.ceri.ca/#OilSandsIndustryUpdate, January 29, 2009.

projections.[9] The landscape has, however, dramatically changed since then; these sentiments are shared and reflected in the useful briefing released in February 2009.

Various proponents of oil sands projects have withdrawn their applications, announced delays and/or placed their proposed projects on hold until the economy rebounds and the investment can generate a reasonable rate of return. Figure 2.3 represents CERI's outlook for oil sands production.

Figure 2.3
Bitumen Production Capacity, Million Barrels per Day (MMbpd)



In 2008, CERI was projecting a potential for oil sands production of over 5 million barrels per day (MMbpd) by 2015, and over 6 MMbpd by 2030. It was our opinion that the likely development path of the oil sands would be far lower than the CERI Unconstrained Projection (2008). The CERI Reference Case Projection (2008) indicated 3.4 MMbpd of bitumen production by 2015, increasing to just under 5 MMbpd by 2025. In the 2008 report, CERI provided a global slowdown case: based upon information available in late October, relating to both the global slowdown and the initial signs of an eventual slowdown in the oil sands. While these data are not presented in

[9] The values that are presented in this briefing reflect the "name plate capacity" for the oil sands and will be higher than actual production. While a facility is built for a certain capacity, it typically doesn't achieve that level of production on a constant basis. There is a litany of reasons why this is the case, and discussing it goes beyond the scope and purpose of the briefing. Actual production values are only slightly under the name plate capacity.

this report, CERI has updated the scenario and it is now presented as the "CERI 2009 Economic Slowdown Projection".

The slowdown projection reflects a scenario in which the price of oil stays below US$60 WTI/bbl for most of 2009 and the credit markets still lack liquidity. Under this projection, economic recovery begins in early 2010, as indicated by the previously provided oil price forecast, and liquidity slowly starts to return to the economy. In conjunction with the economic recovery, oil sands development stalls until 2013, with no major growth until 2015. Previously announced and approved (by government) projects remain delayed, and some remain in peril. This scenario is similar to what is currently taking place in the oil sands industry.

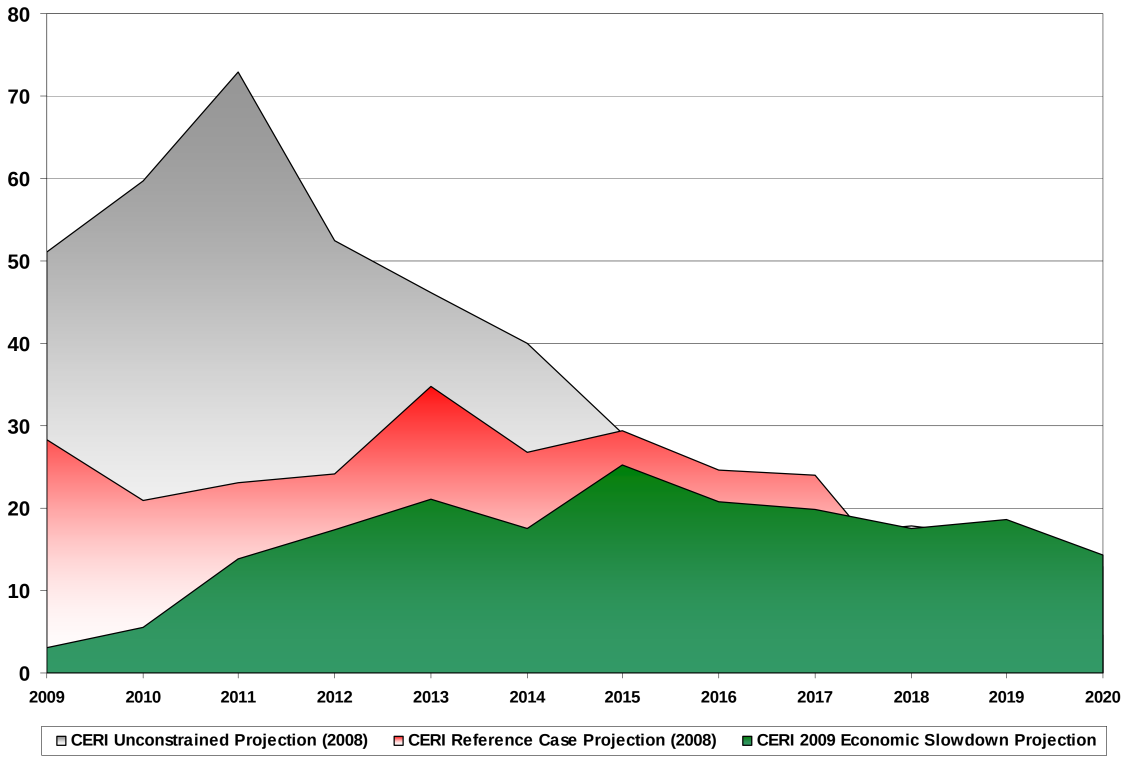
While the price of oil and the global economy are expected to rebound in 2010, it will take another two years before oil sands production growth resumes. CERI assumes this resumption to be limited to established oil sands projects and others with adequate financing in place prior to the credit collapse of 2008; it takes at least two years for most mining and in situ projects to start production after construction begins. However, many projects will not start construction in 2010, but will begin a reassessment and refinancing period that could take several years. Some projects are likely to be deferred until 2015, which will create a further backlog in projects, pushing those with 2015 plans (as announced in 2006 to early 2008) beyond 2020.

While CERI does not anticipate a rapid recovery and explosion in growth, as many had previously projected, we have included a margin of error in our projections, as indicated by the grey area on Figure 2.3. This reflects the Probable Production Range for oil sands development, which is highly dependent upon the recovery in the price of oil and increased liquidity in the capital markets. In 2015 the total production band is 1.9 to 2.9 MMbpd, which broadens by 2025 to 3.5 to 5.1 MMbpd.

Figure 2.4 depicts the total capital expenditure on new oil sands projects (i.e., excluding ongoing or sustaining capital) for the period 2009 to 2020.[10]

[10] Upon request, annual capital spending beyond 2020 is available to organizations that purchase(d) our 2008 report.

Figure 2.4
Oil Sands Capital Investment (2008 $Billions)



As is apparent, capital spending peaks that were previously projected are not likely to occur over the next 11 years.[11] Oil sands spending will be modest, and at a level that CERI believes the Canadian economy can easily absorb (based upon historic oil sands spending).

The harsh reality is the total "loss" of investment that CERI is estimating. While part of this is a direct result of the economic slowdown, it cannot be solely attributed to the slowdown; there are other factors involved, such as labour and equipment availability. Another way to look at the "loss" is as a gain that is created by the existence and development of the oil sands. The CERI 2009 economic slowdown projection indicates that $218 billion will be invested in the oil sands for new production. This is $97 billion less (the "loss") than previously projected under the CERI reference case projection (2008) and a shocking $241 billion less than the CERI unconstrained projection (2008).

[11] The previous peaks were over $70 billion in 2011 for the CERI Unconstrained Projection (2008), and over $40 billion in 2013 for the CERI Reference Case Projection (2008).

CHAPTER 3
IMPACTS ON THE UNITED STATES' ECONOMY

This chapter describes the modeling process (for a more detailed discussion, refer to Appendix B) and impact of Canadian oil sands development on the United States at both the national and state levels. In particular, US economic impacts (industry output, GDP and employment) associated with Canadian oil sands investment and operations are presented.

3.1 Overall Modeling Framework

Input/Output (I/O) Analysis was chosen as the most appropriate way to analyze the impact on the US economy of oil sands development. An I/O analysis looks at the relationships between various industries in an economy and how the output of one industry feeds into another industry as an input. This shows us how one industry is dependent upon another for its inputs. For each industry, it displays from which industries its inputs come from and to which industries its output goes.

An I/O analysis lets you examine the impacts that happen to an industry because of the activity in another industry. For example, in this analysis CERI examined the impact that the oil sands development and production has on industries in the US economy by looking at: output (goods and services), GDP, and employment at the national and state levels. Investments in oil sands leads to increased demand, for example, for manufactured goods from Ontario and several US states, including heavy machinery and large trucks. This increase in demand leads to increased demand from other industrial sectors in other Canadian provinces and US states.

Changes in economic variables (e.g., GDP) are the sum of three distinct impacts: direct, indirect, and induced. Of course, there are the ***direct*** costs and employment associated with development of oil sands consisting for example of geophysical expenditures, drilling, and facilities construction for *In Situ* development. Next, there is a long term effort associated with extraction of the resource. At the end of the field's useful life, there are another set of activities associated with site restoration.

Each of these direct activities generate demands for the goods and services produced in other sectors, such as steel pipe, electricity, transportation, financial services and numerous other sectors. These inter-industry transactions, or ***indirect*** effects, are captured in the input-output tables published for the United States periodically by the Bureau of Economic Analysis (BEA) of the US Department of Commerce.

Both the direct and indirect activities raise income levels, giving rise to a third set of ***induced*** effects in response to this increased income. The sectoral breakdown of this activity generally reflects broad patterns of consumer spending based on the Consumer Expenditure Survey data maintained by the Bureau of Labor Statistics (BLS).

A multistage process was used to build the US-Canada Multi-Regional I/O Model (UCMRIO). First, CERI developed a Multi-Regional I/O model for Canada. This model identifies domestic trade flows for Canada covering Canada's 10 provinces and 3 territories based on Statistics Canada data. Next, the US I/O tables, constructed using the I/O tables issued by the Bureau of Economic Analysis (BEA), were connected to the Canadian I/O model, thus creating the UCMRIO. The UCMRIO simulates the trading patterns between each Canadian province and territory with the US economy.

The last step was to take the aggregate impacts on the US economy (national level) reported by the UCMRIO and disaggregate those impacts to the state level. This was done by constructing a series of disaggregating coefficients to allow CERI to depict the economic impacts of Alberta's oil sands developments on each US state.

I/O models, while extremely useful for gaining insight into the linkage between sectors and regions in an economy, have limitations. This is due to three reasons. First, I/O coefficients are based on value relationships between one sector's outputs to other sectors. This could change overtime, thus changing the results. Second, the I/O approach assumes that there are no supply or resources constraints. Third, an I/O model is incapable of representing the feedback mechanism between price change, investment and production. Because of these factors, they are typically used to characterize an economy over a short period of time. In this analysis, a period of 17 years was examined (2009-2025).

3.2 Data and Assumptions

As mentioned above, data for the Canada Multi-Regional I/O model came from Statistics Canada. The data for the US I/O model came from the Bureau of Economic Analysis (BEA). Oil prices are assumed to remain at current levels for the next year, eventually rising which results in an average over the analysis of US$100/barrel WTI.[12]

Oil sands production is based upon CERI's Economic Slowdown Projection, an arguably conservative assumption.[13] In this scenario, raw bitumen production exceeds 4.3 million barrels per day (MMBPD) by 2030 and remains constant thereafter (see Figure 2.3). SCO production reaches 2.5 MMBPD by 2030 and remains constant thereafter. In this scenario, oil sands development is curtailed from its potential (unconstrained) development by various factors: oil prices, resources, regulatory. However, it is assumed that there are no barriers to entry into the US.

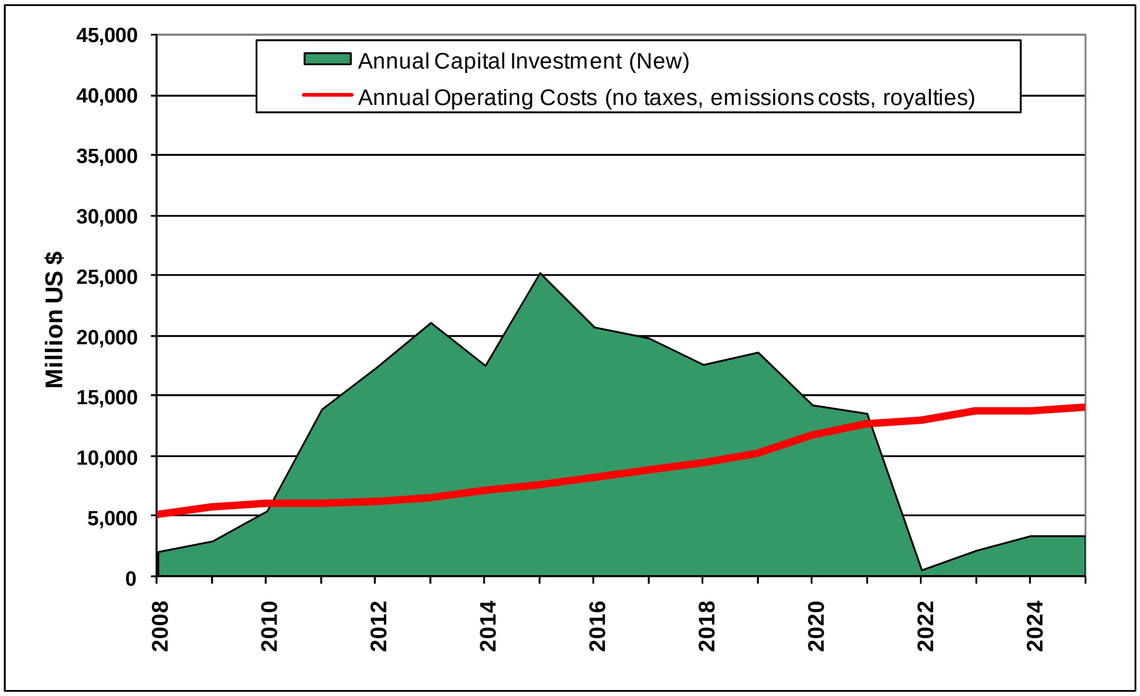
Based on the capital costs in Table 3.1, the investment required to meet the production forecast in the Economic Slowdown Projection is $218 billion (US$). In the peak year of investment (2015), approximately $25 billion in new investment is required and $7 billion in operating costs (see Figure 3.1).

[12] Expressed as an annual average price of CERI's long range oil price forecast (real dollars) over the next 25 years.
[13] http://www.ceri.ca/Publications/documents/CERIOilSandsBriefingFebruary2009.pdf

Table 3.1
Capital Costs[14] (based upon late 2008 estimates expressed in US$/barrel of capacity)

In situ	US$29,000
Mining and Extraction	US$90,000
Stand-alone upgrading	US$58,000
Integrated Mining and Extraction and Upgrading	US$127,000

Figure 3.1
Investment Required to Meet Production Scenario



Source: www.ceri.ca/Publications/documents/CERIOilSandsBriefingFebruary2009.pdf

It is important to note that investment and operation expenditures are initially determined on a project basis, totaled and allocated to the production type level (i.e. mining and extraction, In Situ, integrated mining, extraction and upgrading and stand alone upgrader). These dollars are used in the model to "shock" the Alberta economy in various sectors (coincident shocks) including the Oil Sands, the Construction, the Refinery, and the Manufacturing sectors. These shocks are considered at the field plant outlet, or to the upgrader outlet for a stand alone upgrader, and include bitumen and SCO products. The relationship between the Oil Sands industry and the Pipeline and Refining industries is captured in the base economy and thus shocks on the supply side results in impacts on these and other industries. The US sectors are

[14] Capital costs derived from publicly announced project estimates and local market participants and where necessary inflated to 2008 dollars utilizing the Nelson-Farrar Refinery Cost Index. Refer to the CERI report "Canadian Oil Sands Supply Costs and Development Projects (2008-2030)" November 2008

represented in the model as the 14th segment (10 Canadian provinces + 3 territories + US). Investment shocks in Alberta result in impacts to the US economy at the sector level. The BEA data is used to link these shocks on the US sectors to the US state and US industry levels. Thus refinery upgrades to handle oil sand crudes are not directly handled by the model but generic refiner upgrades would be associated with the indirect impact relationship between the investment shocks and the refinery sector (both in Canada and the US). In other words, investment and operating dollar shocks are only done to Alberta industries; no direct shocks are made to the US sectors. Hence, the economic impacts reported herein do not capture the direct investments in US refineries that may be undertaken to process increased crude oil from Canada.

3.3 Results

Canada and the US are major trading partners, and the results clearly show significant economic benefits to the US from increased economic activity in Canada. As investment and production ramps up in Canada, the pace of economic activity quickens and demand for US goods and services increase rapidly, resulting in an estimated 343 thousand new US jobs between 2011 and 2015. Demand for US goods and services continues to climb annually throughout the period, adding an estimated $34 billion to US GDP in 2015, $40.4 billion in 2020, and $42.2 billion in 2025. As explained earlier, these are the sum of direct, indirect and induced impacts.

Table 3.2
Impact on US Output, GDP, and Employment

National Impacts ($US Billion)	2010	2015	2020	2025
U.S. Output	23.0	69.2	78.5	80.9
U.S. Gross Domestic Product	11.5	34.0	40.4	42.2
National Impacts (Thousand Person Year)	**2009-2010**	**2011-2015**	**2016-2020**	**2021-2025**
U.S. Employment	172	343	88	22

"Thousand Person Year" equates to the number of jobs created, times 1,000, for a given year and for as long as the project operates. With regards to the table above, the number of jobs listed indicates the number of incremental jobs that are created. For example, between 2011 and 2015 an incremental 343 thousand jobs are created.

The economic benefits of oil sands development and production do not fall to one industry but are broadly shared across many industrial sectors. Table 3.3 shows the increase in output of goods and services from various US industrial sectors due to the development and production of Canadian oil sands. On average, US output of goods and services increases by $62 billion per year over the period of analysis, 2009- 2025. Although all US economic sectors gain in output, “Other manufacturing” has the greatest increase in output, followed by “Finance, Insurance, and Real Estate”. [15] An example of the increase in “Other Manufacturing”, is the increased production of heavy trucks in the US that are used to transport the oil-bearing sand. The mines in Alberta’s Wood Buffalo region are the largest surface mines in the world, with equipment sized to match. Steel products that would generally be manufactured in western Canada from scrap steel include casing, tubing and other welded pipe; I-beams, tubular beams and other simple structural components. More sophisticated and metallurgically-altered steel products would be imported from the United States (primarily the upper Midwest) and overseas, or else manufactured in Ontario from steel produced in Ontario using metallurgical coal imported from the United States (primarily Appalachia). Some of the manufactured products that are likely to be sourced in the upper Midwest include trucks, shovels, dump hoppers, conveyer equipment, pumping equipment, tanks, and some boilers and chemicals.

[15] The increase in US sectoral output due to Canadian oil sands development increases the demand for oil and natural gas. It was beyond the scope of this study to determine the share of the increased oil and natural gas demand that would be met from increased domestic production, and hence oil and natural gas sector results are not available.

Table 3.3
Change in US Output by Industry

Change in Output by Industry ($US Million)	2010	2015	2020	2025	Annual Average
Forestry, fishing, agriculture and other activities	494	1,598	1,517	1,414	1,253
Mining, except oil and gas	230	655	848	921	643
Support activities for mining	372	1,061	1,373	1,492	1,041
Utilities	429	1,259	1,514	1,601	1,171
Construction	320	940	1,147	1,212	881
Refinery	1,026	3,021	1,411	1,467	1,878
Petrochemical	721	2,191	2,452	2,495	1,929
Other Manufacturing	5,693	18,396	18,644	17,533	14,925
Wholesale Trade	1,118	3,432	3,709	3,728	2,953
Retail Trade	947	2,794	3,383	3,559	2,602
Transportation and Warehousing	867	2,581	2,967	3,090	2,328
Information and Cultural Industries	993	2,939	3,538	3,713	2,725
Finance, Insurance, Real Estate and Rental and Leasing	5,082	14,412	19,064	20,825	14,351
Professional, Scientific and Technical Services	1,521	4,444	5,507	5,853	4,211
Administrative and Support, Waste Management and Remediation Services	970	2,848	3,483	3,684	2,673
Educational Services	97	289	342	358	265
Health Care and Social Assistance	164	482	586	619	451
Arts, Entertainment and Recreation	245	722	877	924	674
Accommodation and Food Services	793	2,317	2,870	3,052	2,196
Other Services and Non-Profit organisations	761	2,293	2,625	2,699	2,052
Government Sector	170	500	606	639	466
Total	23,012	69,173	78,463	80,876	61,668

"Annual Average" equates to the total increase in output over the 17 year forecast divided by 17 years.

Table 3.4 tells a similar story but with regard to various sectors' contribution to the increase in GDP. The difference between the two measures, output and GDP is due to the standard procedure followed in estimating national accounts. GDP accounts only for value added during the production processes and excludes intermediate goods, which are produced not for final consumption but for use as inputs in the production of other goods and services.

Table 3.4
Change in US GDP by Industry

Change in Value Added by Industry (GDP) $US Million	2010	2015	2020	2025	Annual Average
Forestry, fishing, agriculture and other activities	185	597	567	529	469
Mining, except oil and gas	121	345	447	486	339
Support activities for mining	174	495	641	697	486
Utilities	258	758	912	964	705
Construction	160	471	575	607	441
Refinery	150	442	206	215	275
Petrochemical	212	646	723	736	569
Other Manufacturing	1,560	5,040	5,108	4,803	4,089
Wholesale Trade	836	2,567	2,775	2,789	2,209
Retail Trade	652	1,925	2,331	2,452	1,793
Transportation and Warehousing	450	1,340	1,540	1,603	1,208
Information and Cultural Industries	462	1,369	1,648	1,729	1,269
Finance, Insurance, Real Estate and Rental and Leasing	3,398	9,636	12,745	13,923	9,595
Professional, Scientific and Technical Services	931	2,721	3,372	3,584	2,579
Administrative and Support, Waste Management and Remediation Services	658	1,931	2,361	2,497	1,812
Educational Services	58	172	204	213	158
Health Care and Social Assistance	102	299	364	385	280
Arts, Entertainment and Recreation	154	455	553	583	425
Accommodation and Food Services	408	1,192	1,476	1,570	1,129
Other Services and Non-Profit organisations	414	1,246	1,429	1,469	1,116
Government Sector	107	316	382	404	295
Total	11,451	33,963	40,359	42,237	31,240

“Annual Average” equates to the total increase in output over the 17 year forecast divided by 17 years.

Table 3.5 shows changes in sectoral employment in the US due to development and production of Canadian oil sands. The table shows the number of new jobs created. For example, between 2011 and 2015, an additional 57.7 thousand jobs are estimated to be created in “Other Manufacturing”. Building on the earlier example, a portion of the increase in demand for workers in “Other Manufacturing” represents the need for workers to build the heavy trucks and other equipment imported into Canada from the US for use in the production and processing of the oil sands. As the capital investment tapers off between 2021 and 2025, the need for new jobs diminishes and the sector loses 5 thousand of the 85 thousand jobs that had been created since 2009 for a net gain in employment in the sector of 80 thousand over the life of the project This is because CERI projections of oil sands investment are based on actual project announcements and these do not go beyond 2025.

Table 3.5
Change in US Employment by Industry

Employment by Industry (Thousand Person Year)	2009-2010	2011-2015	2016-2020	2021-2025
Forestry, fishing, agriculture and other activities	7.3	16.3	(1.2)	(1.5)
Mining, except oil and gas	1.3	2.4	1.1	0.4
Support activities for mining	1.9	3.4	1.6	0.6
Utilities	0.7	1.4	0.4	0.1
Construction	4.0	7.8	2.6	0.8
Refinery	0.6	1.1	(0.9)	0.0
Petrochemical	1.4	2.9	0.5	0.1
Other Manufacturing	25.8	57.7	1.1	(5.0)
Wholesale Trade	9.8	20.2	2.4	0.2
Retail Trade	19.2	37.4	11.9	3.6
Transportation and Warehousing	6.7	13.2	3.0	0.9
Information and Cultural Industries	4.1	8.0	2.5	0.7
Finance, Insurance, Real Estate and Rental and Leasing	23.8	43.7	21.8	8.2
Professional, Scientific and Technical Services	11.3	21.7	7.9	2.6
Administrative and Support, Waste Management and Remediation Services	11.3	21.9	7.4	2.3
Educational Services	2.2	4.3	1.2	0.3
Health Care and Social Assistance	2.9	5.5	1.8	0.6
Arts, Entertainment and Recreation	6.0	11.7	3.8	1.2
Accommodation and Food Services	15.1	29.0	10.5	3.5
Other Services and Non-Profit organisations	14.7	29.3	7.2	1.7
Government Sector	2.0	3.8	1.2	0.4
Total	171.9	342.7	87.8	21.7

Note: "Thousand Person Year" equates to the number of jobs created, times 1,000, for a given year and for as long as the project operates. With regards to the table above, the number of jobs listed indicates the number of **incrementa**l jobs that have been created. For example, between 2011 and 2015 an incremental 343 thousand jobs have been created, 57.7 thousand of which are estimated to be created in "Other Manufacturing". These jobs are the sum of direct, indirect and induced employment impacts.

Just as the benefits of Canadian oil sands development and production do not fall solely to one US economic sector, nor do they fall to just one region of the country. Table 3.6 shows that industrial output increases around the country. For example, the increase in industry output in Michigan ($2 billion in 2015) captures the increased production of heavy trucks for oil sands development along with other goods and services. Similarly, Table 3.7 shows the change in GDP by state.

Table 3.6: Change in Industry Output by State

Change in Industry Output by State ($US Million)	2010	2015	2020	2025	Annual Average
Alabama	275	837	936	950	736
Alaska	58	169	200	211	156
Arizona	404	1,210	1,421	1,470	1,100
Arkansas	159	486	544	550	427
California	3,228	9,691	10,755	11,092	8,545
Colorado	374	1,114	1,306	1,359	1,015
Connecticut	340	1,014	1,200	1,246	928
Delaware	102	299	356	376	277
District of Columbia	98	286	353	374	270
Florida	1,062	3,151	3,763	3,938	2,906
Georgia	605	1,821	2,110	2,174	1,641
Hawaii	77	227	273	289	211
Idaho	95	289	325	329	255
Illinois	1,027	3,083	3,544	3,658	2,769
Indiana	487	1,494	1,638	1,649	1,295
Iowa	234	719	800	806	629
Kansas	198	601	661	673	525
Kentucky	274	835	925	937	730
Louisiana	535	1,583	1,375	1,433	1,246
Maine	69	208	241	247	187
Maryland	353	1,049	1,251	1,308	966
Massachusetts	593	1,784	2,084	2,149	1,615
Michigan	679	2,069	2,319	2,355	1,821
Minnesota	442	1,337	1,497	1,533	1,181
Mississippi	153	464	493	503	399
Missouri	362	1,096	1,255	1,286	979
Montana	52	155	178	186	140
Nebraska	128	389	439	447	344
Nevada	199	585	713	753	548
New Hampshire	94	283	328	337	255
New Jersey	708	2,103	2,480	2,591	1,925
New Mexico	130	393	441	451	347
New York	1,703	5,015	6,101	6,433	4,687
North Carolina	698	2,130	2,410	2,444	1,883
North Dakota	47	144	159	162	126
Ohio	807	2,454	2,733	2,779	2,154
Oklahoma	228	683	755	782	602
Oregon	394	1,228	1,336	1,321	1,053
Pennsylvania	848	2,552	2,921	3,009	2,285
Rhode Island	67	201	238	248	184
South Carolina	238	724	823	837	642
South Dakota	57	173	197	201	154
Tennessee	415	1,263	1,428	1,452	1,118
Texas	2,087	6,275	6,834	7,033	5,475
Utah	177	530	605	626	475
Vermont	42	127	145	147	113
Virginia	555	1,659	1,955	2,028	1,513
Washington	486	1,462	1,651	1,700	1,300
West Virginia	93	276	324	339	252
Wisconsin	418	1,282	1,438	1,451	1,126
Wyoming	58	169	206	219	159
Total US	23,012	69,173	78,463	80,876	61,668

Table 3.7: Change in State GDP ("Value-Added")

Value Added by State (GSP) $US Million	2010	2015	2020	2025	Annual Average
Alabama	128	384	448	464	348
Alaska	30	87	106	113	82
Arizona	213	629	759	797	584
Arkansas	74	224	259	267	201
California	1,576	4,672	5,523	5,783	4,287
Colorado	198	583	704	740	542
Connecticut	181	533	648	683	498
Delaware	57	165	205	219	157
District of Columbia	59	171	212	225	162
Florida	604	1,776	2,164	2,285	1,663
Georgia	316	938	1,117	1,167	863
Hawaii	45	131	161	171	124
Idaho	45	135	157	162	122
Illinois	529	1,567	1,871	1,960	1,445
Indiana	210	635	729	749	569
Iowa	107	322	371	382	289
Kansas	92	275	319	331	249
Kentucky	124	373	432	446	336
Louisiana	183	540	576	606	471
Maine	36	106	127	133	98
Maryland	197	580	706	746	543
Massachusetts	307	910	1,096	1,149	844
Michigan	320	960	1,124	1,164	872
Minnesota	216	644	758	789	588
Mississippi	68	202	232	241	182
Missouri	182	542	640	666	496
Montana	27	81	97	102	75
Nebraska	63	189	220	228	171
Nevada	113	330	407	432	312
New Hampshire	48	144	172	180	133
New Jersey	387	1,140	1,381	1,456	1,063
New Mexico	60	179	211	220	164
New York	978	2,856	3,540	3,766	2,708
North Carolina	324	971	1,139	1,179	883
North Dakota	23	68	78	81	61
Ohio	379	1,135	1,327	1,375	1,031
Oklahoma	107	317	373	391	290
Oregon	162	493	558	566	436
Pennsylvania	428	1,271	1,512	1,582	1,170
Rhode Island	36	107	131	138	101
South Carolina	115	345	406	421	314
South Dakota	29	86	102	106	79
Tennessee	200	598	701	726	544
Texas	954	2,835	3,304	3,447	2,577
Utah	89	262	314	329	242
Vermont	20	60	71	74	55
Virginia	296	876	1,058	1,112	815
Washington	245	728	862	901	668
West Virginia	47	139	168	177	129
Wisconsin	192	579	674	695	523
Wyoming	30	87	108	116	83
Total US	11,451	33,963	40,359	42,237	31,240

Employment increases across the county with some of the largest impacts occurring in California (43 thousand jobs created between 2011 and 2015), Florida (20 thousand jobs created between 2011 and 2015), and Texas (27 thousand jobs created between 2011 and 2015). These US jobs are created by the indirect and induced impacts of Canadian oil sands development and production.

Table 3.8 Change in State Employment.

Incremental Employment by State Thousand Person Year	2009-2010	2011-2015	2016-2020	2021-2025
Alabama	2.6	5.2	1.1	0.2
Alaska	0.5	0.9	0.2	0.1
Arizona	3.3	6.5	1.9	0.5
Arkansas	1.6	3.2	0.7	0.1
California	21.6	43.2	10.6	2.5
Colorado	3.0	6.0	1.7	0.5
Connecticut	2.0	4.0	1.1	0.3
Delaware	0.5	1.0	0.3	0.1
District of Columbia	0.6	1.2	0.3	0.1
Florida	10.3	20.3	5.6	1.5
Georgia	5.3	10.5	2.7	0.7
Hawaii	0.7	1.4	0.4	0.1
Idaho	0.9	1.9	0.4	0.1
Illinois	7.3	14.6	3.7	0.9
Indiana	3.7	7.6	1.6	0.3
Iowa	1.9	3.9	0.9	0.2
Kansas	1.6	3.2	0.8	0.2
Kentucky	2.4	4.8	1.1	0.2
Louisiana	2.4	4.8	1.2	0.4
Maine	0.8	1.7	0.3	0.1
Maryland	2.9	5.7	1.7	0.5
Massachusetts	3.9	7.7	2.1	0.5
Michigan	5.3	10.6	2.5	0.5
Minnesota	3.4	6.8	1.6	0.4
Missouri	1.5	2.9	0.6	0.1
Montana	0.6	1.2	0.3	0.1
Nebraska	1.1	2.3	0.6	0.1
Nevada	1.7	3.2	1.1	0.3
New Hampshire	0.8	1.6	0.4	0.1
New Jersey	4.7	9.3	2.6	0.7
New Mexico	1.0	2.0	0.6	0.2
New York	9.8	19.4	5.6	1.5
North Carolina	5.1	10.3	2.5	0.5
North Dakota	0.4	0.8	0.2	0.1
Ohio	6.5	13.2	3.1	0.7
Oklahoma	2.0	4.0	1.0	0.3
Oregon	2.3	4.7	1.0	0.2
Pennsylvania	6.9	13.8	3.4	0.8
Rhode Island	0.5	1.1	0.3	0.1
South Carolina	2.3	4.7	1.2	0.3
South Dakota	0.5	1.0	0.2	0.1
Tennessee	3.5	7.0	1.8	0.4
Texas	13.8	27.3	7.2	1.9
Utah	1.6	3.1	0.9	0.2
Vermont	0.4	0.8	0.2	0.0
Virginia	4.3	8.4	2.4	0.6
Washington	3.7	7.3	1.8	0.4
West Virginia	0.9	1.7	0.5	0.1
Wisconsin	3.5	7.2	1.6	0.3
Wyoming	0.4	0.8	0.3	0.1
Total US	171.9	342.7	87.8	21.7

3.4 Conclusion

Developing the Canadian oil sands is a very capital intensive endeavor, requiring billions of dollars of investment over the next several decades. This investment would give rise to a long-lived, robust period of increased economic activity in Canada. Due to the deep and rich trading relationship between Canada and the United States, the US derives significant economic benefits from this increased economic activity across many sectors throughout the United States. The benefits manifest themselves in terms of increased economic output, GDP and job creation. In addition, the US benefits from a stable supply of oil, something not considered by the report but critically important to US energy security.

APPENDIX A
CRUDE BITUMEN RESERVES

This appendix discusses crude bitumen reserves and is divided into two parts: crude bitumen reserves and mineable crude bitumen reserves.

A.1 Crude Bitumen Reserves

The Alberta Energy and Utilities Board (EUB) estimates the initial volume of crude bitumen in-place to be 270.3 billion m^3 (1,701 billion barrels) as of December 31, 2006. The Athabasca region alone accounts for almost 80 percent or 217.7 billion m^3 (1,369 billion barrels) of the total.

Table A.1 summarizes the volumetric resources by oil sands area (OSAs) and oil sands deposit (OSDs). OSAs define the geographical boundaries of crude bitumen occurrence, while OSDs contain the specific geological zones declared as oil sands deposits. Both, OSAs and OSDs are designated by the ERCB.

Table A.1
Initial In-Place Volumes of Crude Bitumen

			Average Bitumen Saturation (%)		
Oil Sands Area Oil Sands Deposit	Initial Volume In-Place (10^6m^3)	Average Pay Thickness (m)	Mass	Pore Volume	Average Porosity
Athabasca					
Grand Rapids	8,678	7.2	6.3	56	30
Wabiskaw-McMurray (mineable)	16,087	30.5	9.7	69	30
Wabiskaw-McMurray (in situ)	132,128	13.2	10.2	73	29
Nisku	10,330	8.0	5.7	63	21
Grosmont	50,500	10.4	4.7	68	16
Sub-Total	217,723				
Cold Lake					
Grand Rapids	17,304	5.9	9.5	66	31
Clearwater	9,422	11.8	8.9	59	31
Wabiskaw-McMurray	4,287	5.4	7.3	59	27
Sub-Total	31,013				
Peace River					
Bluesky-Gething	10,968	6.1	8.1	68	26
Belloy	282	8.0	7.8	64	27
Debolt	7,800	23.7	5.1	65	18
Shunda	2,510	14.0	5.3	52	23
Sub-Total	21,560				
Total	270,296				

SOURCE: Alberta Energy and Utilities Board, Alberta's Energy Reserves 2006 and Supply/Demand Outlook 2007 – 2016, June 2007, http://www.eub.gov.ab.ca/bbs/products/STs/st98_current.pdf.

As of December 31, 2008, remaining established reserves were estimated by the EUB to be 27.07 billion m^3 (170.4 billion barrels). Remaining established reserves are calculated separately for those that are likely to be recovered by mining methods and those by in situ methods using established technology and under anticipated economic conditions.

Bitumen from the shallower oil sands deposits is extracted through open-pit mining operations. These mines expose the oil sands by stripping the overburden. The oil sand is then removed by using truck and shovel mining methods. Bitumen is separated from the sand through a process of adding warm water and agitation. Roughly two tons of sand are mined, moved and processed to produce one barrel of bitumen.

In situ, on the other hand, means "in-place", and indicates that the bitumen is extracted from the sand in the reservoir. These techniques are employed for deeper oil sands deposits (generally greater than about 75m to the top of the oil sands formation). The two main in situ processes currently being used are cyclic steam stimulation (CSS) and steam-assisted gravity drainage (SAGD). These methods inject steam into the formation to heat the bitumen, allowing it to flow and be pumped to the surface.

The EUB determined mineable established reserves by identifying potential mineable areas using economic strip ratio (ESR) criteria, a minimum saturation cutoff of 7 weight percent, and a minimum saturated zone thickness cutoff of 3.0 metres. The ESR criteria are fully explained in *ERCB Report 79-H, Appendix 3.*[16]

The EUB determined in situ established reserves for those areas considered amenable to in situ recovery methods. Reserves attributable to thermal development were determined using a minimum saturation cutoff of three weight percent crude bitumen and a minimum zone thickness of ten metres. For primary development, the same saturation cutoff of three weight percent was used, with a minimum zone thickness of three metres. Recovery factors of twenty percent for thermal development and five percent for primary development were applied to the areas within the cutoffs. The recovery factor for future thermal development is assumed to be lower than recoveries being achieved by some of the active in situ projects. This is to account for the uncertainty in the future recovery processes and the uncertainties inherent with developing poorer quality resource areas (areas under active development are of higher quality than future areas). While the resource base is very large, it is worth noting that many in situ recovery technologies are still in the early development stage and there is still considerable uncertainty about how much crude bitumen will ultimately be recovered.

[16]Alberta Canada, Alberta Energy Resources Conservation Board, *Alsands Fort McMurray Project, ERCB Report 79-H,* 1979.

Table B.2 summarizes the EUB's estimates of in-place volumes and established mineable and in situ crude bitumen reserves.[17]

Table A.2
In-Place Volumes and Established Reserves of Crude Bitumen
($10^9 m^3$ as of December 31, 2006)

Recovery Method	Initial Volume In-Place	Initial Established Reserves	Cumulative Production	Remaining Established Reserves	Remaining Established Reserves Under Active Development
Mineable	16.1	5.59	0.58	5.01	2.95
In situ	254.2	22.80	0.28	22.53	0.39
Total	270.3	28.39	0.86	27.53	3.34
	(1,701)[a]	(178.7)[a]	(5.4)[a]	(173.2)[a]	(21.0)[a]

[a] Imperial equivalent in billions of stock-tank barrels.
Source: Alberta Energy and Utilities Board, *Statistical Series 2007-98, Alberta's Energy Reserves 2006 and Supply/Demand Outlook 2007-2016*.

Of the remaining established reserves of 27.53 billion m^3, 3.34 billion m^3 (21.0 billion barrels), or 12.13 percent, were under active development at year-end 2006. Significantly, more than 80 percent of remaining established reserves are estimated to be recoverable from in situ techniques.[18]

A.2 Mineable Crude Bitumen Reserves (under active development)

Oil sands mines currently comprise operations by Suncor Energy Inc., Syncrude Canada Ltd. and Albian Sands Energy Inc. The first commercial development of Alberta's oil sands began when Great Canadian Oil Sands (now Suncor) opened its mine, extraction plant and upgrader north of Fort McMurray in 1967. This was followed by development of the Syncrude mine, extraction plant and upgrader, in the same area, in the 1970s. Construction began on the Syncrude site in 1973 and, after five years of construction, Syncrude commenced production in 1978. Albian Sands operates the Muskeg River Mine located 75 kilometers north of Fort McMurray. The project reached a major milestone with start-up and first bitumen production on December 29, 2002. Albian Sands is part of the Athabasca Oil Sands Project (AOSP), a joint venture between Shell Canada Limited (60 percent), Chevron Canada Limited (20 percent) and Marathon Oil Canada Corporation (20 percent).

The EUB publishes estimates of mineable crude bitumen reserves for each of the three operators as shown in Table B.3.

[17] Alberta, Canada, Alberta Energy and Utilities Board, *EUB Statistical Series 2007-98: Alberta's Reserves 2006 and Supply Demand Outlook 2007-2016* (Calgary, Alberta, 2007), http://www.eub.gov.ab.ca/bbs/products/STs/st98_current.pdf.
[18] Ibid.

Table A.3
Mineable Crude Bitumen Reserves
($10^6 m^3$ as of December 31, 2006)

Development	Initial Volume In-Place	Initial Established Reserves	Cumulative Production	Remaining Established Reserves
Albian Sands	672	419	32	387
Fort Hills	699	364	0	364
Horizon	834	537	0	537
Jackpine	361	222	0	222
Suncor	990	687	220	467
Syncrude	2,071	1,306	330	976
Total	5,627	3,535	582	2,953

Source: Alberta Energy and Utilities Board, Statistical Series 2007-98, Alberta's Energy Reserves 2006 and Supply/Demand Outlook 2007-2016.

APPENDIX B
METHODOLOGY

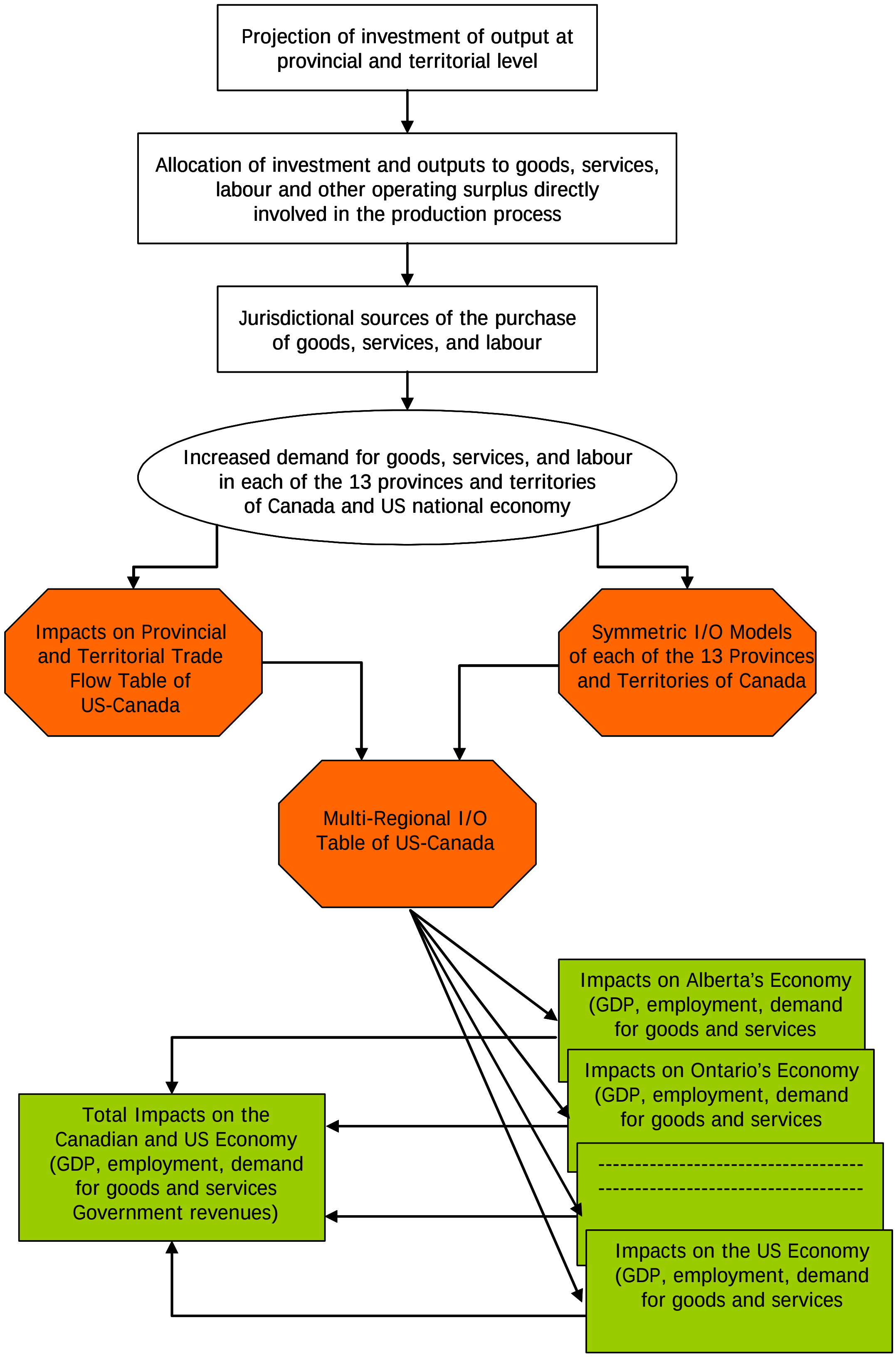
This appendix discusses briefly the methodology of this study. It is divided into four parts: overall modeling framework, the Multi-Regional I/O Model, data sources and assumptions.

The following sets out the various steps and processes in the compilation of the US-Canadian Multi-Regional I/O tables, and shows how one can trace direct and indirect, and induced effects of the Canadian oil sands sector on the Canadian and US economies. This will facilitate analysis of production and demand in Canada and the US, and allow economic studies at the provincial, state and national levels in both countries.

B.1 Overall Modeling Framework: A Generic Approach

Any activity that leads to increased production capacity in an economy has two components: construction (or development) of the capacity, and operation of the capacity to generate outputs. The first component is referred to as investment, while the second is production or operation. Both activities affect the economy through purchases of goods and services, and labour. Figure B.1 illustrates the overall approach CERI uses to assess economic impacts resulting from these activities.

Figure B.1
Overall US-Canada Multi-Regional I/O Modeling Approach



The first step is to estimate the value of investment (i.e., construction or development expenditure) and production (sales). The total investment or development expenditures are then disaggregated into purchases of various goods and services directly involved in the production process (i.e., manufacturing, fuel, business services, etc.) and labour, using the expenditure shares. In a similar way, the value of total production (or output or sales) from a production activity (i.e., oil sands or conventional oil production, petroleum refinery, etc.) is allocated to the purchase of goods and services, payment to labour, payment to government (i.e., royalty and taxes) and other operating surplus (profits, depreciation, etc.).

The shares across goods and services, and labour, combined with the estimated values of investment and production, are then used to estimate demand for the various goods and services, and labour used in both development and production activities. These demands are met through two sources: (i) domestic production, and (ii) imports. Domestic contents of the goods and services are calculated using Statistics Canada's data and data from the BEA.

It is important to note that investment and operation expenditures are initially determined on a project basis, totaled and allocated to the production type level (i.e. mining and extraction, In Situ, integrated mining, extraction and upgrading and stand alone upgrader). These dollars are used in the model to "shock" the Alberta economy in various sectors (coincident shocks) including the Oil Sands, the Construction, the Refinery, and the Manufacturing sectors. These shocks are considered at the field plant outlet, or to the upgrader outlet for a stand-alone upgrader, and include bitumen and SCO products. The relationship between the Oil Sands industry and the Pipeline and Refining industries is captured in the base economy and thus shocks on the supply side results in impacts on these and other industries. The US sectors are represented in the model as the 14th segment (10 Canadian provinces + 3 territories + US). Investment shocks in Alberta result in impacts to the US economy at the sector level. The BEA data is used to link these shocks on the US sectors to the US state and US industry levels. Thus refinery upgrades to handle oil sand crudes are not directly handled by the model but generic refiner upgrades would be associated with the indirect impact relationship between the investment shocks and the refinery sector (both in Canada and the US). In other words, investment and operating dollar shocks are only done to Alberta industries; no direct shocks are made to the US sectors. Hence, the economic impacts reported herein do not capture the direct investments in US refineries that may be undertaken to process increased crude oil from Canada.

Inter-regional trade flow tables, developed by CERI, are used to derive import or export shares for each type of good and service for all 13 provinces and territories in Canada and the United States. The value of goods and services required by a particular industry and produced in each province or territory of Canada or the US is calculated using the import and export shares. The economic impacts of the production of these goods and services in a particular province or territory of Canada or the US are calculated in the same way as for other provinces and territories.

B.2 CERI US-Canada Multi-Regional I/O Model (UCMRIO)

This section discusses the multi-stage process to build the UCMRIO model. As previously mentioned, CERI developed a Multi-Regional I/O model for Canada, as a part of examining the economic impacts of the Canadian petroleum industry on Canada's provinces and territories. CERI's UCMRIO model builds on the Multi-Regional I/O model for Canada, and is therefore prudent to review it, followed by a discussion of the UCMRIO model. Both approaches are defined in the System of National Accounts (SNA) terminology as industry-by-industry, or "industry technology". The multi-regional tables have the following advantages:

- Compatibility with economic theory;
- Recognizing institutional characteristics in each industry;
- Preserving a high degree of micro-macro link;
- The maximum use of the detailed information in Supply (make) and Use Tables (SUTs);
- Comparability with other types of statistics; and
- Transparency of compilation method, resource efficiency, support for a wider and more frequent compilation of input-output tables internationally.

The following is a brief description of the steps which have been taken in construction of the UCMRIO model, and will be divided into four parts: CERI Multi-Regional I/O Model of Canada, US I/O Model, US-Canada Trade Table and Model Structure and, finally, Disaggregation of National Results to the US.

B.2.1 CERI Multi-Regional I/O Model of Canada

In summary, the multi-regional I/O model consists of 13 provincial and territorial Symmetrical I/O Tables (SIOTS) and a trade flow matrix, the latter of which identifies the trade structure of provinces. The SIOTs are based on national and provincial I/O tables produced by Statistics Canada.[19] More specifically, CERI uses the provincial *Make, Use, and Final Demand* tables to construct the SIOTs for every province and territory in Canada. Each province's SIOT consists of linkages between 31 industries. For that reason, the provincial SIOTs are matrices of 31×31 dimension. There are several methods of constructing the provincial industry-based SIOTs; CERI employed the fixed product sales structures method. The SIOTs are essential in building the new Multi-Regional I/O tables, and conducting I/O analysis.

The provincial (or interprovincial) trade flow table is developed by CERI. Whereas the provincial SIOTs are industry-by-industry elements, the provincial trade flow tables are industry/province elements. Statistics Canada also publishes the provincial trade flow table, but at a small

[19] Statistics Canada, "The Input-Output Structure of the Canadian Economy, 2003-2004," *Catalogue No. 15-201-X*, February 2008.

aggregation level. This table presents the import and export flows among all provinces and territories in Canada, depicting the export of every industry to other provinces and territories in rows and the import of every industry from other provinces and territories in columns. Given there are 13 provinces and territories and each provincial SIOT consists of 31 industries, the provincial trade flow table is a matrix of 403×403 dimension.

The Statistics Canada I/O structure, as mentioned above, consists of three tables (or matrices): (i) "Make" or "Output" matrix, (ii) "Use" or "Input" matrix, and (iii) "Final Demand" matrix. The *Make* matrix presents production of commodities (row) by various industries (column). The *Use* matrix presents consumption or use of commodities (row) by various industries (column). The *Final Demand* matrix presents consumption or use of commodities (row) by various final demand sectors (column), such as household, government, investment, trade and inventory. The CERI Multi-Regional I/O model database combines these three matrices, data from national and provincial accounts, and the provincial trade flow table to form national and provincial social accounting matrices.

B.2.2 US I/O Model

This section reviews briefly the next element of the UCMRIO, the US I/O table. Just as Statistics Canada produces provincial *Make, Use, and Final Demand* tables, the BEA[20] publishes the *Make*, *Use* and *Final demand*.

CERI uses the same procedure explained in the previous section to construct the SIOT for the US. Since this table is going to be merged with the Canadian SIOTs, the structure of the table is designed in such a way that it is compatible with other SIOTs in the model. As such the US SIOT consists of linkages between 31 industries. The classification of industries in both countries is identical. Table B.1 provides a brief description of these aforementioned sectors or commodities.

[20] http://www.bea.gov/regional/index.htm

Table B.1
Sectors/Commodities in CERI US- Canada Multi-Regional I/O Model

Serial No.	Sector or Commodity	Examples of activities under the sector or commodity
1	Crop and animal production	Farming of wheat, corn, rice, soybean, tobacco, cotton, hay, vegetables and fruits; greenhouse, nursery, and floriculture production; cattle ranching and farming; dairy, egg and meat production; animal aquaculture
2	Forestry and logging	Timber tract operations; forestry products: logs, bolts, poles and other wood in the rough; pulpwood; custom forestry; forest nurseries and gathering of forest products; logging.
3	Fishing, Hunting and Trapping	Fish and seafood: fresh, chilled, or frozen; animal aquaculture products: fresh, chilled or frozen; hunting and trapping products
4	Support Activities for Agriculture and Forestry	Support activities for crop, animal and forestry productions; services incidental to agriculture and forestry including crop and animal production, e.g., veterinary fees, tree pruning, and surgery services, animal (pet) training, grooming, and boarding services
5	Conventional Oil[21]	Conventional oil, all activities e.g., extraction and services incidental to conventional oil
6	Oil sands	Oil sands, all activities e.g., extraction and services incidental to oil sands
7	Natural Gas and NGL	Natural gas, NGL, all activities e.g., extraction and services incidental to natural gas and NGL
8	Coal	Coal mining, activities and services incidental to coal mining
9	Other Mining	Mining of iron, metal, and gold and silver ores; copper, nickel, lead, and zinc ore mining; non-metallic mineral mining and quarrying; sand, gravel, clay, ceramic and refractory, limestone, granite mineral mining and quarrying; potash, soda, borate and phosphate mining; all related support activities.
10	Refinery	Petroleum and coal products; motor gasoline and other fuel oils; tar and pitch, LPG, asphalt, petrochemical feed stocks, coke; petroleum refineries
11	Petrochemical	Chemicals and polymers: resin, rubber, plastics, and fibers and filaments; pesticides and fertilizers; etc
12	Other Manufacturing	Food, beverage and tobacco; textile and apparel; leather and footwear; wood products; furniture and fixtures; pulp and paper; printing; pharmaceuticals and medicine; non-metallic mineral, lime, glass, clay and cement; primary metal, iron, aluminum and other metals; fabricated metal, machinery and equipment, electrical, electronic and transportation equipment, etc.
13	Construction	Construction of residential, commercial and industrial buildings; highways, streets, and bridges; gas and oil engineering; water and sewer system; electric power and communication lines; repair construction
14	Transportation and Warehousing	Roads, railways; air, water & pipeline transportation services; postal service, couriers and messengers; warehousing and storage; information and communication; sightseeing & support activities
15	Transportation margins	Transportation margins

[21] Statistics Canada reports the oil, gas, coal and other mining as one sector due to some confidentiality issues. CERI, uses an in-house developed approach to disaggregate this sector to five sectors: Oil Sands, Conventional Oil, Gas+NGL, Coal and other mining.

Table B.1 (continued)

16	Utilities	Electric power generation, transmission, and distribution; natural gas distribution; water & sewage
17	Wholesale Trade	Wholesaling services and margins
18	Retail Trade	Retailing services and margins
19	Information and Cultural Industries	Motion picture and sound recording; radio and TV broadcasting and telecommunications; publishing; information and data processing services
20	Finance, Insurance, Real Estate and Rental and Leasing	Insurance carriers; monetary authorities; banking and credit intermediaries; lessors of real estate; renting and leasing services
21	Professional, Scientific and Technical Services	Advertising and related services; legal, accounting and architectural; engineering and related services; computer system design
22	Administrative and Support, Waste Management and Remediation Services	Travel arrangement and reservation services; investigation and security services; services to buildings and dwellings; waste management services
23	Educational Services	Universities; elementary and secondary schools; community colleges and educational support services
24	Health Care and Social Assistance	Hospitals; offices of physicians and dentists; misc. ambulatory health care services; nursing and residential care facilities; medical laboratories; child and senior care services
25	Arts, Entertainment and Recreation	Performing arts; spectator sports and related industries; heritage institutions; gambling, amusement, and recreation industries
26	Accommodation and Food Services	Traveler accommodation, recreational vehicle (RV) parks and recreational camps; rooming and boarding houses; food services and drinking establishments
27	Other Services (Except Public Administration)	Repair and maintenance services; religious, grant-making, civic, and professional organizations; personal and laundry services; private households
28	Operating, Office, Cafeteria and Laboratory Supplies	Operating supplies; office supplies; cafeteria supplies; laboratory supplies
29	Travel, Entertainment, Advertising and Promotion	Travel and entertainment; advertising and promotion
30	Non-Profit Institutions Serving Households	Religious organizations; non-profit welfare organizations; non-profit sports and recreation clubs; non-profit education services and institutions
31	Government Sector	Hospitals and government nursing and residential care facilities; universities and government education services; other municipal government services; other provincial and territorial government services; other federal government services including defense

It is important to mention that the base years for the US and Canada is identical, again for compatibility reasons. As the Canadian I/O tables are based on 2003 numbers issued by Statistics Canada, CERI uses the 2003 figures in constructing the US I/O table. The yearly-average exchange rate for the same is used as we needed to exchange the numbers among US and Canadian dollars.

B.2.3 US-Canada Trade Table and Model Structure

This section discusses the construction of the trade flow matrix, an important component to the modeling process. This step connects the US I/O table to CERI's Multi-Regional I/O model for Canada, and depicts a trading pattern between each Canadian province and territory with the US economy. The trade flow table for UCMRIO is a table which depicts the export/import flows of each Canadian province with the US and among each other. In particular, this table shows the import (export) flows of say, Alberta to the US and the other 12 Canadian provinces and territories. It is important to mention that the industry specification of this table is the same as SIOTs, and thus covers the trade flows among all sectors of the economies.

The following is a brief discussion of the modeling.

Based on a standard I/O model notation, and considering total gross outputs vector (GO), final demand vector (FD), and all calculated within multiregional technical coefficient matrixes, the following relationship in Multi-Regional I/O context holds as:

$A \times GO + C \times GO + R' \times GO + FD = GO$

This gives $(I - A - C - R') \times GO = FD$

Rewriting finally yields $GO = (I - A - C - R)^{-1} \times FD$, provided that $(I - A - C - R)$ is a nonsingular matrix.

As is the case for standard I/O models, the impact of an industry, such as the oil sands industry, is calculated by modeling the relationship between total gross outputs and final demand as follows:

$$\Delta GO = [I - A - C - R']^{-1} \times \Delta FD \qquad \text{(Equation I)}$$

Where:

ΔGO Changes (or increases) in total gross outputs of the US and all provinces and territories, at the sectoral level, due to construction and operation of projects (i.e., oil sands). This is a 434×1 vector.

I Is a 434×434 matrix. I is an identity matrix, a matrix with unity for diagonal elements and zero for the rest of the matrix.

A Is a 434×434 block diagonal matrix of technical coefficients at the sectoral level for US and Canada. It is composed of 14 blocks so that each block is a 31×31 matrix corresponding to the US and each province's (or territory) input technical coefficient matrix.[22] An element of such a matrix is derived by dividing the value of a commodity used in a sector by the total output of that

[22] In other words, one can say all 13 provinces' and one US input technical coefficients matrices are stacked together in construction of a diagonal block matrix at the national level.

sector. The element represents requirements of a commodity in a sector to produce one unit of output from that sector.

C Is a 403×403 matrix at the sectoral level for Canada and US. Each of its elements measures the final consumption shares in a sector's total gross output in a province (or territory) and US.

R' Is a 403×403 transposed matrix of multiregional trade coefficients. It includes import and export shares of a sector's total output in US and province or territory. Each element on the row of this matrix measures the share of export to a particular sector in US or province from a given sector in another province or territory or US. [23]

ΔFD Is a 434×1 vector of changes (or increases) in final demand at the sectoral level outputs from Canada and the US resulted from any change in the final demand components in US or any province or territory, including commodity directly demanded (or purchased) for the construction and development of any sector.

The calculation of total impact is based on the multiplication of direct impact and the inverted matrix. Based on the direct impact on a sector, the Equation (I), above, is used to estimate all the direct, indirect and induced effects on all sectors in all provinces, particularly in terms of changes in consumption, imports, exports, production, employment, and net taxes. The direct impact is referred to ΔF in Equation (I). The change in final demand (ΔF) consists of various types of investment expenditures, changes in inventories, and government expenditures. In the current model, the personal expenditures are not part of the final demand and have been endogenized to accommodate the induced impact. Almost 50 percent of the GDP (total final demand) is composed of personal expenditure. Therefore, CERI shocked the final demand by only half of the operating costs.

Direct impacts are quantitative estimations that are made up of the main impact of the programs, in the form of an increase in final demand (increase in public spending, increase in consumption, increase in infrastructure investment, etc). The assumption of increased demand includes a breakdown per sector, so that it can be translated into the following matrix notation:

Direct, indirect and induced impacts:

$$\Delta GO = [I - A - C - R']^{-1} \times \Delta F \qquad \text{(Equation II)}$$

Direct and indirect impacts:

$$\Delta GO = [I - A - R']^{-1} \times \Delta F \qquad \text{(Equation III)}$$

[23] In particular, this matrix is a bridge matrix which connects the US, or any province, to other provinces through import and export coefficients.

The difference between Equations (II) and (III) is referred to as the induced impact of any changes in final demand components.

Once the impact on output (change in total gross outputs) is calculated, the calculations of impacts on GDP, household income, employment, taxes, and so forth, are straightforward. In particular, as previously mentioned, the base year for the I/O tables used in this report is 2003. CERI utilized the tax coefficients derived from these tables to calculate the total collected taxes. It is worth mentioning that the disaggregating of the collected taxes to federal and provincial taxes is based on the figures and ratios from the *Finances of the Nation*,[24] where these numbers reflect the tax structure of the Canadian economy in the year 2006. CERI acknowledges that there have been changes to the corporate income tax structure and the goods and services sales tax (GST) since 2006. The new tax regime will result in changes in tax figures and other numbers in the economy since the business will respond to the new incentives. This will be reflected in the upcoming I/O tables released by Statistics Canada.

These impacts are estimated at the industry level using the ratio of each (i.e., GDP) to total gross outputs. Using the technical Multi-Regional I/O table, CERI is able to perform the usual I/O analysis at the provincial and national levels.

B.2.4 Disaggregation of National Results to the US

To report the US economic impacts down to the state level, CERI constructed a series of disaggregating coefficients. This process allows CERI to illustrate the economic impacts of the oil sands developments in Canada on each US state economy.

The BEA publishes detailed information on the sectoral economic variables such as GDP, and employment for the US states.[25] CERI uses the most recent data (year 2007) to establish a series of coefficients to disaggregate the national figures to state levels. For instance, to disaggregate national agricultural GDP among all states, CERI uses a set of 51 share coefficients, one for each state and the District of Columbia, to disaggregate the national numbers.

It is evident that the sum of these coefficients is equal to unity and they depict the share of each state in the GDP of the US economy. The similar sets of coefficients are calculated for each sector of the economy. Following this procedure, we use the GDP coefficients to disaggregate the sectoral GDPs and employment coefficients to disaggregate the sectoral employments. Changes in output, GDP, and employment are among the results that the model produces.

B.3 Data Sources

This section reviews briefly data sources in both the US and Canada.

[24] Treff, Karin and David Perry, Finances of the Nation 2007.

[25] See http://www.bea.gov/regional/gsp and http://ww.bea.gov/regional/spi .

As previously mentioned, the annual US input-output tables are available through the BEA. The *Make, Use and Final Demand* tables are quite detailed at the industry level and are available since 1947. The 85-industry, 365-industry and 596-indusry are a few examples of table formats issued by the BEA. Statistics are in compliance with the definitions of the 1997 North American Industrial Classification System (NAICS).

The *Use* table shows the inputs to industry production and the commodities that are consumed by final users. The *Make* table on the other hand depicts the commodities that are produced by each industry. In this report we use the *Make and Use* table to construct the US symmetric I/O table consistent with the Canadian Multi-provincial I/O tables developed by CERI.

The National Accounts and I/O tables in Canada were also developed at the conclusion of the Second World War. Tables in the present format, however, were first published in 1969 for the base year 1961. The I/O accounts are one of four main accounts that are published by the CSNEA, the others being income and expenditure accounts, financial and wealth accounts, and balance of payments accounts.

The I/O accounts are calculated at the national, provincial and territorial level, but on an annual basis only.[26] These tables are available at different levels of aggregation[27] on the Canadian Socio-Economic Information Management System (CANSIM) Tables 381-0009 to 381-0014. Provincial I/O data are also available on an occasional basis.

The framework of both the US and Canadian I/O system is complementary and consists of the following three basic tables:

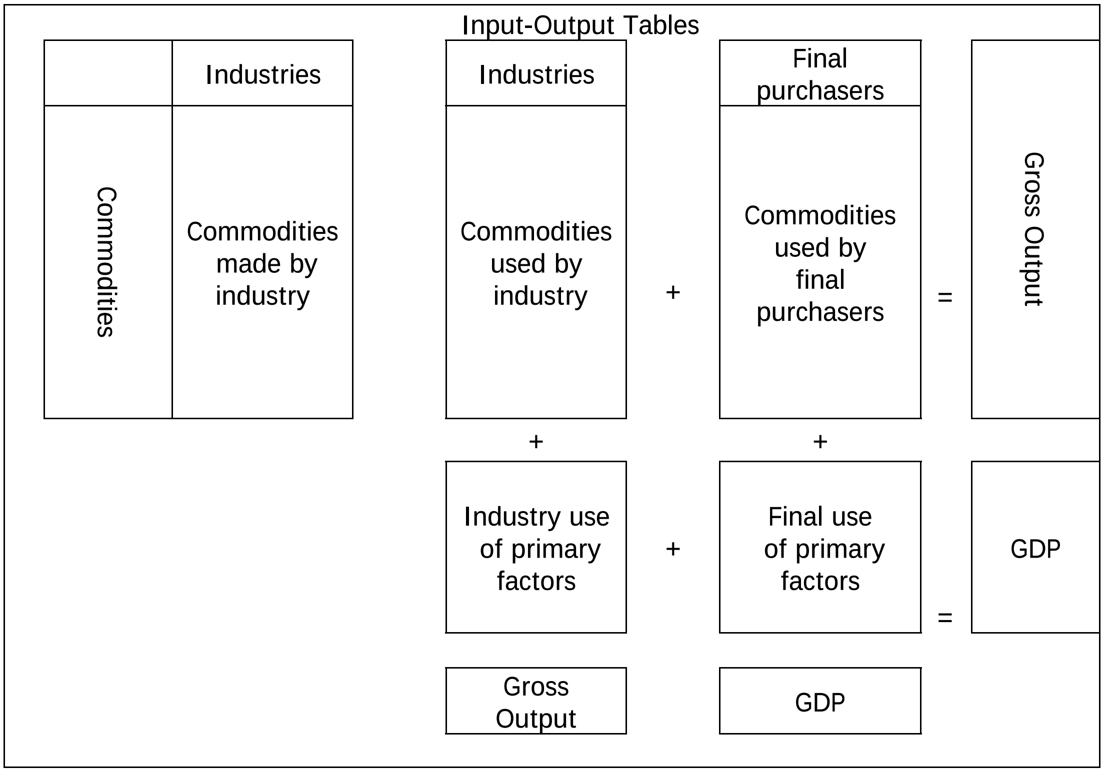
- Gross output of commodities (goods and services) by producing industries;
- Industry use of commodities and primary inputs (the factors of production, labour and capital, plus other charges against production such as net indirect taxes); and
- Final consumption and investment plus any direct purchases of primary inputs by final demand sectors.

Figure B.2 is a schematic of the I/O system, and combines features of both the US and Canadian system and the more traditional single matrix presentation.

[26] The I/O tables and models, published annually by Statistics Canada, are entitled "The Input-Output Structure of the Canadian Economy". This document covers the basic concepts related to the I/O tables. Each year, two years of data are reported; the latest year is considered preliminary and the previous one is considered final. There are also many documents which are available on request from the I/O division.

[27] The I/O Tables of this publication are stored in CANSIM at the Small (S) level, Medium (M) level and Link (L) level of aggregation.

Figure B.2
Schematic of the Input-Output System



Source: A User Guide to the Canadian System of National Accounts, Statistics Canada, Catalogue No. 13-589E, November 1989.

B.4 Assumptions and Limitations

The main assumption of any I/O analysis is that the economy is in equilibrium. Despite partial equilibrium analysis, it is assumed in the general equilibrium (GE) approach that the economy as a whole is in equilibrium. This is a realistic assumption in the long run, as it is difficult to imagine an economy remaining in disequilibrium for a long time period.

A second important assumption in I/O analysis is the linear relationship between inputs and outputs in the economy. Each sector uses a variety of inputs in a linear fashion to produce various final products. Though the form of the production function is simple, this could be viewed as an approximation of the real world's production function. A very interesting aspect of this assumption is the constant return to scale (CRS) property of the production function, which turned out to be a proven property in the real world economy. Though the linearity of the production function gives a constant average and marginal products, these are justified if the analysis focuses to the long-run rather than the short-run.

Although the I/O approach has been widely used around the world for economic impact assessment, there are certain limitations that should be noted. I/O matrices are limited to the estimation effect on demand, rather than supply. Therefore, they do not take into account important objectives such as lasting effects on productive potential. Most effects on supply, which are likely to lead to a sustainable increase in the growth rate of assisted sectors (or provinces/states) and enable them to catch up with more developed sectors (or provinces), are completely disregarded. Some of these overlooked points include: the creation of new productive capacity, improvement of the training and education of the workforce, construction of infrastructure, productivity gains throughout the economy, spread of technological progress, and intensity of high-tech activities in the productive sector. All these effects on supply can transform productive capacity in a lasting and irreversible manner. These cannot be estimated using this multi-regional I/O tool.

In particular, several other well-known limitations of the I/O approach are discussed below:

Static relationships. I/O coefficients are based on value relationships between one sector's outputs to other sectors. The relationship and, thus, the stability of coefficients could change over time due to several factors including:

- Change in the relative prices of commodities;
- Technological change;
- Change in productivity; and
- Change in production scope and capacity utilization.

Since these attributes cannot be incorporated in a static I/O model, these models are primarily used over a short-run time horizon, where relative prices and productivity are expected to remain relatively constant. Hence, over a longer period, static I/O models are not the best tools for economic impact analysis. GE models or macroeconomic models accounting for the factors mentioned above could be more appropriate. Moreover, I/O models and other static macroeconomic models and general equilibrium models do not account for sectoral dynamics and adjustment in an economy.

Unlimited resources or supplies. The I/O approach simplistically assumes that there are no supply or resources constraints. In reality, in the short run, increasing economic activities in a particular sector of the economy may put pressure on wages and salaries. However, in the long run, the economy adjusts through the mobility of the factors of production (i.e., labour and capital).

Lack of capacity to capture price, investment and production interactions. An I/O model is incapable of representing the feedback mechanism between price change, investment and production. For example, an increase in oil price provides a signal to investors to increase investment. The increase in investment would add productive capacity (more drilling) and also the production. However, this type of interaction cannot be modeled in a simple I/O model.

About CERI

The Canadian Energy Research Institute (CERI) is a co-operative research organization established through an initiative of government, academia, and industry in 1975. The Institute's mission is to provide relevant, independent, objective economic research and education in energy and related environmental issues. Related objectives include reviewing emerging energy issues and policies as well as developing expertise in the analysis of questions related to energy and the environment.

For further information, see our web site: www.ceri.ca