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The Canadian oil sands industry under carbon constraints

Gabriel Chan [a], John M. Reilly [b], Sergey Paltsev [b], Y.-H. Henry Chen [b,*]

[a] John F. Kennedy School of Government, Harvard University, 79 JFK St. Cambridge, MA 02138,USA
[b] MIT Joint Program on the Science and Policy of Global Change, 77 Massachusetts Ave, E19-411, Cambridge, MA 02139, USA

HIGHLIGHTS

- ▶ We investigate the impact of climate policies on Canada's oil sands industry.
- ▶ A computable general equilibrium model of the world economy is applied for the assessment.
- ▶ Without climate policy, Canadian bitumen production increases almost 4 fold from 2010 to 2050.
- ▶ With regional policy, bitumen output may drop by up to 68% and upgrading moves to no-policy countries.
- ▶ With global policy, bitumen production is significantly reduced since upgrading abroad is no longer viable.

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ABSTRACT

We investigate the impact of climate policies on Canada's oil sands industry, the largest of its kind in the world. Deriving petroleum products such as gasoline and diesel from oils sands involves significant amounts of energy, and that contributes to a high level of CO_2 emissions. We apply the MIT Emissions Prediction and Policy Analysis (EPPA) model, a computable general equilibrium model of the world economy, augmented to include detail on the oil sands production processes, including the possibility of carbon capture and storage (CCS). We find: (1) without climate policy, annual Canadian bitumen production increases almost 4-fold from 2010 to 2050; (2) with climate policies implemented in developed countries, Canadian bitumen production drops by 32% to 68% from the reference 4-fold increase, depending on the viability of large-scale CCS implementation, and bitumen upgrading capacity moves to the developing countries; (3) with climate policies implemented worldwide, the Canadian bitumen production is significantly reduced even with CCS technology, which lowers CO_2 emissions at an added cost. This is mainly because upgrading bitumen abroad is no longer economic with the global climate policies.

1. Introduction

In this paper, we explore the effects of implementing CO_2 emission reduction policies on Canada's oil sands industry. Bitumen is petroleum based substance that can be extracted from oil sands and upgraded to a synthetic crude oil. From there synthetic crude oil can then be further refined into conventional petroleum products such as gasoline and diesel. The process involves the addition of lighter hydrocarbons, and because the synthetic crude is relatively heavy the refining process generally requires the use of cracking and other advanced refinery operations to generate a product slate with substantial fractions of the higher value petroleum products. Each part of the process involves significant amounts of energy, and that contributes to a high level of CO_2 emissions, and hence the industry would be affected by CO_2 control policies. Addition of carbon capture and storage (CCS) to the process is one strategy that could reduce the CO_2 implications of production but would add to the cost.

Canada has the largest oil sands reserves in the world, with Venezuela the other country with significant known extra heavy oil reserves. Venezuela extra heavy oil may be less degraded then oil sands and thus easier to be extracted. But it also requires substantial upgrading into a crude equivalent. As of 2007, it was estimated that economically recoverable oil sands reserves in Alberta were just over 160 billion barrels, making up over 95% of Canada's total oil reserves of 179 billion barrels. That estimate makes Canada second in the world only to Saudi Arabia's 264 billion barrels of oil reserves. (Government of Alberta, 2009; National Energy Board. Calgary, 2008; Energy Information Administration (EIA), 2008). The oil sands industry prospered, especially as crude oil prices rose in recent years. Although the crude price drop over the last year has slowed expansion of the

* Corresponding author. Tel.: +1 617 715 5432.
E-mail address: chenyh@mit.edu (Y.-H. Chen).

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industry (Healing, 2009), existing oil sands projects may continue as long as world oil prices exceed roughly $35 to $40 per barrel (Levi, 2009). In addition, the oil peak theory (Hubbert, 1956) is another ground that supports the development of Canadian oil sands industry. More pessimistic research often argues that the oil peak of conventional crude production is imminent (Deffeyes, 2001), while even based on more optimistic research, it may arrive within decades, depending on different assumptions such as the rate of exploring new crude reserves, the development of existing oil fields, economic conditions, and climate policies (Brandt et al., 2010; Cambridge Energy Research Associates (CERA), 2006; Energy Information Administration (EIA) (2004a). Moreover, in response to increasing oil imports from politically-stressed regions, many firms and policymakers in the U.S., Canada, and elsewhere are looking to Canada's oil sands as an answer to energy security threats.[1]

However, with potential CO_2 control looming in Canada, the economic viability of the industry and the value of these large reserves may be at risk. Existing studies have found that currently, the GHG emissions from bitumen production and upgrading are higher than those from conventional crude (Charpentier et al., 2009; McKellar et al., 2009). As of 2008, the GHG emissions of Canada have reached 734 megatonnes of carbon dioxide equivalent (Mt CO_2-e), which is already 32% above the Kyoto target Canada once proposed (Environment Canada, 2010).[2] A recent estimate for 2009 has the oil sands industry alone responsible for 41.9 Mt CO_2-e, equivalent to 6.5% of Canada's total emissions and 0.1% of the global greenhouse gas (GHG) emissions (Government of Alberta, 2012).

Bitumen can be produced with surface mining technique when deposits are near the surface or through in situ technique for deposits that are located deeper in the earth. There are varying approaches, in either case, that lead to varying CO_2 emissions per barrel produced.[3] Adding CCS technology increases the cost of production, and would affect the competitiveness of the industry. Canadian CO_2 policy obviously could affect the industry, but policies abroad are also likely to affect the economics of the oil sands resource. Bitumen extraction itself would need to remain near the site of reserves but upgrading could occur abroad. Pressure to move upgrading abroad could result from differential CO_2 control policies, creating a source of "CO_2 leakage." CO_2 leakage refers to an increase in emissions outside of a regulating jurisdiction in response to its CO_2 limits. CO_2 regulation (domestically or abroad) may also affect the overall demand for petroleum products and thus affect the oil sands industry indirectly through the price paid for crude and petroleum products. While the addition of CCS would greatly reduce emissions from energy used in extracting and upgrading bitumen, the petroleum products that are produced would still release CO_2 when finally used as fuel. Production of products from oil sands would be disadvantaged compared with conventional crude oil; as bitumen production is generally a more expensive production process than crude oil extraction, and the addition of CCS would add further to the cost and only get CO_2 emissions per barrel to approach that emitted from conventional crude production.

We investigate the viability of the oil sands industry in the face of Canadian and global CO_2 policies with or without CCS technology. Will it remain profitable to extract these resources? Will there be a demand for the product? Can CCS make the oil sands industry viable and under what conditions? And finally, what is the overall economic impact of climate policy on the Canadian economy, given that it may limit this large and growing industry?

To provide insights in answering these questions, we use a version of the MIT Emissions Prediction and Policy Analysis (EPPA) model, EPPA-ROIL, that includes an elaborated representation of the oil production and refining sectors (Choumert et al., 2006). Like the standard EPPA model, EPPA-ROIL is a recursive dynamic multi-regional general equilibrium model of the world economy. The elaborated treatment of oil production and refining sectors of EPPA-ROIL includes a specific representation of the oil sands industry, with separate production and upgrading activities. While in the original EPPA-ROIL, there is only a single representative bitumen production technology, in our analysis, we modify this representation so that bitumen production from surface mining and in situ projects is now disaggregated into two separate technologies. This extension allows us to take into account the various carbon footprints of different bitumen production projects. In addition to climate policy, we also consider scenarios that include CCS technology on bitumen production and upgrading, and consider cases where biofuels may or may not be the liquid fuels substitutes with low life-cycle carbon emissions. This paper is organized as follows: Section 2 presents the EPPA-ROIL model, Section 3 provides the policy scenarios and simulations, Section 4 analyzes the simulation results, and Section 5 provides the conclusion.

2. Model description

The EPPA-ROIL provides greater disaggregation of the petroleum, refining, and liquid fuels sectors compared to the standard model. As with the standard model, the world economy is simulated through time to produce scenarios of GHG, aerosols, other air pollutants emissions from human activities. The EPPA model is built on the GTAP dataset (Center for Global Trade Analysis, 2012), and is supplemented with additional data for the GHG and urban gas emissions and on technologies not separately identified in the basic economic data (Paltsev et al., 2005, Babiker et al., 2001).

The EPPA model belongs to the class of computable general equilibrium (CGE) models (Dervis et al., 1982; Shoven and Whalley, 1984; Bovenberg and Goulder, 1996; Böhringer and Rutherford, 2009) with two main components in the model: households and producers. Households provide primary factors (such as labor and capital, etc.) to producers and receive factor payments (capital and resource rents and wages) in return. Production sectors are characterized by production functions that represent the technologies in each sector. Production functions transform inputs, including primary factors (labor, capital, natural resources) and intermediate inputs (i.e., outputs of other sectors) into goods and services that are used either as intermediate goods (those used by industrial sectors as inputs) or as final goods (those used by households, government, for capital goods or exports). Imported goods compete with domestically produced goods to supply intermediate and domestic final demands.

The model aggregates the GTAP dataset into 16 regions including the United States (USA), Canada (CAN), Mexico (MEX), Japan (JPN), Australia and New Zealand (ANZ), Europe (EUR), Eastern Europe (EET), Russia Plus (FSU), East Asia (ASI), China (CHN), India (IND), Indonesia (IDZ), Africa (AFR), Middle East (MES), Latin America (LAM), and a Rest of the World (ROW) region. The economy grows as a result of exogenously specified growth in population (and therefore labor) and in labor, energy, and land productivity and through endogenously determined savings and investment. Savings is determined in a Leontief aggregation of consumption and savings in the welfare

[1] From 1993 to 2011, crude oil imports from OPEC countries to the U.S. increase by almost 14%. (Energy Information Administration (EIA) 2012).

[2] Canada has withdrawn from the Kyoto Protocol around the time of the Durban Conference in late 2011. See BBC (2011).

[3] As noted by one reviewer, there is also variation in CO_2 emissions between each mining and in situ project due to different types of energy input. In this study, we use the engineering data from the National Energy Board (2004) and Choumert et al. (2006) to represent oil sands production and upgrading technologies and benchmark the associated CO_2 emissions.