# Will Carbon Tax Constrain Oil Production in Canada?

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**Abstract.** The article aims to assess how introduction of carbon tax will impact oil production in Canada in the long run. Two oil exporting countries, Norway and Canada, introduced carbon tax in 1991 and 2018 respectively. In Norway carbon tax has not constrained oil production and development of costly hydrocarbon reserves in the Arctic areas. We build a simple econometric model for Canada's oil demand and supply until 2040 in reference and low carbon scenarios. Carbon tax is explicitly inbuilt into the model based on the assumption that producers fully pass costs of carbon tax onto consumers of petroleum products. Demand is modelled bottom-up individually for economic sectors, including road transport, air transport, marine and water transport, industry, commercial sector, etc. On the basis of modelling results we argue that in the projection period carbon tax will have a minor constraining impact on oil production growth in Canada. Demand for petroleum products will contract more deeply compared to crude oil production. The continuously increasing export orientation of the Canadian oil sector will partially shield it from the carbon tax. Given the global advancement of low carbon paradigm, analysis of Norway and Canada experience with carbon tax is crucially important for all large oil producing countries.

**Keywords:** Carbon tax · Canada · Oil production · Oil consumption · Low carbon paradigm · Stranded assets · Unburnable oil

## 1 Introduction

In October 2016 Canada, the sixth largest world oil producer, ratified the Paris Agreement on Climate Change and pledged to reduce greenhouse gases (GHG) emissions by 30% below 2005 levels by 2030. Canada is the second large oil exporting country which imposed carbon tax on oil and gas sector.

Norway introduced carbon tax on oil and gas in 1991 [27]. Almost three decades of experience doesn't confirm that carbon tax puts constraints on oil and gas production in Norway (see Fig. 1). Decrease in oil output since 2002 was caused by exhaustion of recoverable reserves. In 2020–2022 oil output is expected to increase as new reserves will be put into exploitation despite the high level of carbon tax rate.


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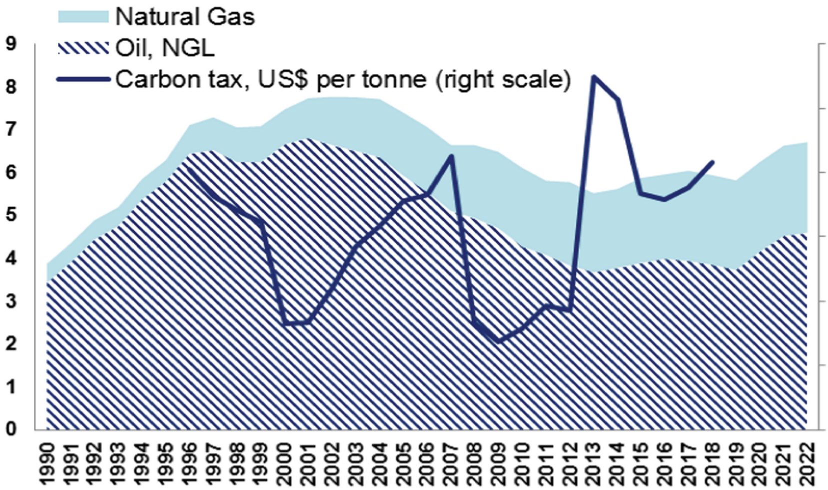


**Fig. 1.** Norway: oil and natural gas output forecast to 2022 (1970–2017: actual production), million barrels of oil equivalent per day and carbon tax rate, US$ per ton of carbon emissions. [18, 19, 21, 25].

Given the relatively high $CO_2$ intensity of oil sands [12], the prospects for Canada's oil production under constraints of low carbon paradigm are widely discussed in the literature. Greenpeace [8] states that increasing use of dirty bitumen from the tar sands will have dramatic negative implications for both the global climate and the economy and lead the international community toward a chaotic and volatile energy future. McGlade and Ekins [16] found that in order to achieve a 2 °C world temperature rise limit scenario by 2050 85% of Canadian bitumen reserves should remain in the ground. Carbon Tracker [4] calculated that in 2 °C scenario a large part of Canadian oil is stranded and 35% of capex planned by oil companies by 2025 is not needed. Taking a different perspective, Boskovic and Leach [1] argue that the cost of emissions policy is unlikely to have a meaningful impact on oil sands growth in the near term. McGlade and Ekins [17] show that oil bitumen production could be supported by Carbon capture and storage (CCS) development.

This article contributes to the literature by explicitly modelling the impact of federal carbon pricing backstop in Canada introduced from the beginning of 2018 on oil demand and supply in the long run. The simple model provides quantitative answers on how pricing of carbon will impact oil production and consumption in Canada by 2040. Direct inclusion of carbon tax into the modelling of oil balances is important not only for Canada, but for all large oil exporting countries, whose economic growth is highly dependent on oil production and exports. To check the relevance of the modelling results we compare them with the Canada's National Energy Board forecast [20], which provides the estimates of oil demand and supply response to different levels of carbon price.

## 2 Modelling Framework

To assess the impact of carbon tax on Canada's oil sector we build a simple econometric model of oil demand and supply until 2040 on a yearly basis in the reference and low carbon scenarios. In the low carbon scenario higher carbon price is modelled after 2022 than in the reference scenario. In 2018 a minimum federal tax of 10 Canadian dollars is collected per ton of GHG emissions. In both scenarios it rises by 10 Canadian dollars each year until reaching 50 Canadian dollars per ton of $CO_2$-eq. in 2022. In the reference scenario carbon price is fixed at this level until the end of the projection period. In the low carbon scenario it continues to increase steadily at 5 Canadian dollars per year before reaching 140 dollars per ton in 2040. The base year of the forecast is 2015.

### 2.1 Data

Historical statistical data for the model was accumulated from the databases of Canada's National Energy Board (NEB), International Energy Agency (IEA), U.S. Energy Information Administration (EIA), the United Nations (UN), International Labour Organization (ILO), International Organization of Motor Vehicle Manufacturers (OICA) and the World Bank.

### 2.2 Exogenous Parameters

The following exogenous parameters are used in the model:

- WTI oil price in constant Canadian 2015 dollars (converted from EIA Annual Energy Outlook 2018, Reference Case [5]);
- carbon price (as explained above to correspond with the NEB Reference and Higher Carbon Price (HCP) Cases [20]);
- GDP forecast built with Solow-Swan production function*;
- population and labor force forecasts (according to the UN World Population Prospects: 2015 Revision, Medium Variant [24] and ILO Key Indicators of the Labour Market (KILM) 2015 [13]);
- vehicle fleet, including passenger cars, trucks, buses and motor cycles forecast built with Gompertz function and linear regressions*;
- passenger and freight traffic forecasts for air, railway, marine and water transport built with regression modelling.

### 2.3 Modelling Algorithms and Assumptions

We assume that oil producers will fully pass costs of carbon tax onto final consumers of petroleum products, thus prices of petroleum products will rise. Changes in stocks of crude oil and oil products are assumed to be zero, refinery losses are forecasted as a fixed share of oil refining output. Future oil production equals forecasted oil demand, including domestic oil product demand and net exports of crude oil and oil products.

Domestic oil demand is modelled bottom-up individually for economic sectors, including road transport, air transport, marine and water transport, railway transport, non-energy use, energy industry own use, industry, agriculture, residential and commercial sector, electricity.

It is assumed that oil consumption is sensitive to carbon price in the following sectors, responsible for 72% of overall oil consumption in Canada (see Table 1):

**Table 1.** Carbon tax impact on oil consumption modelling.

| Sector | Share in Canada's oil consumption, 2016, % | Modelling approach |
|---|---|---|
| Road transport | 43.9 | Short-term and long-term price elasticity of oil consumption by the "composite" vehicle; assumptions on biofuel mandate and transport electrification |
| Air transport | 5.4 | Short-term and long-term price elasticity of oil consumption per unit of passenger and freight traffic; assumptions on biofuel promotion |
| Marine and water, railway transport | 3.2 | Short-term and long-term price elasticity of oil consumption per unit of freight traffic |
| Industry | 4.7 | Price elasticity of oil intensity (consumption per unit of value added) is estimated with linear regression |
| Energy industry own use | 14.4 | Share in overall oil consumption is fixed at 2015 level |

Oil consumption by road transport *($RC_t$)* is modelled taking into account oil consumption by the "composite" vehicle *($U_t$)*, the size and the structure of the vehicle fleet:

$$RC_t = \left(A_t \cdot k^a + Fr_t \cdot k^{fr} + M_t \cdot k^m + B_t \cdot k^b\right) \cdot U_t \quad (1)$$

where $A_t$, $Fr_t$, $M_t$, $B_t$ are the number of automobiles, trucks, motor cycles and buses respectively; $k$ is the weight of each vehicle type correspondingly taking into account the average distance travelled and fuel consumption per 100 km of travel.

Growth rate of the "composite" vehicle oil consumption *($U_t$)* comprises two components – trend and structural ones. As Canada generally follows the U.S. fuel efficiency standards policy (CAFE), we calculated the trend component *(BE)* from EIA Annual Energy Outlook 2018, Reference Case [5]. The structural component depends on oil price dynamics *($P_t$)* in-built through the short-term *($E^{ST}$)* and long-term *($E^{LT}$)* elasticities:

$$U_t = U_{t-1} \cdot \left(1 + BE + E^{ST} \cdot (P_t/P_{t-1} - 1) + 0.1 \cdot \left(E^{LT} - E^{ST}\right) \cdot (P_t/P_{t-10} - 1)\right) \quad (2)$$

Estimates of fuels demand price elasticities vary significantly in the literature. The range of estimates for Canada is presented in Table 2 [14]. Lawson [14, 15] argues that

taking into account the most recent special studies on Canada and the tendency for elasticities to decline in North America, lower elasticities are more reliable. We use lower elasticities estimates in both reference and low carbon scenarios.

**Table 2.** Price elasticity of oil product demand by Canada's transport sector.

| Assumed elasticities | Road gasoline | Road diesel | Rail diesel | Aviation turbo | Marine diesel | Marine HFO |
|---|---|---|---|---|---|---|
| Higher elasticities | | | | | | |
| Short-term ($E^{ST}$) | −15% | −10% | −10% | −10% | −5% | −5% |
| Long-term ($E^{LT}$) | −60% | −40% | −40% | −30% | −30% | −30% |
| Lower elasticities | | | | | | |
| Short-term ($E^{ST}$) | −5% | −5% | −10% | −10% | −5% | −5% |
| Long-term ($E^{LT}$) | −20% | −20% | −40% | −30% | −30% | −30% |

In the road transport oil faces competition from the promotion of biofuels and transport electrification. In the reference scenario five Canadian provinces which have already introduced biofuel mandates (E5 and B2), are supposed to keep them until the end of the projection period, other Canadian provinces do not introduce biofuel mandates. In the low carbon scenario all Canadian provinces start to implement stricter biofuel mandates since 2025 and achieve E10 and B2 by 2030. Projections of electricity substitution for gasoline and diesel in road transport are taken from the International Energy Agency forecast [10].

Oil consumption by each transport type, including air, railway, marine and water transport, is equal to the product of average oil consumption per ton-km and passenger and freight traffic volume. Growth rate of average oil consumption in each transport sector $\left(UC_t^{TS}\right)$ is modelled through price elasticity (presented in Table 2):

$$UC_t^{TS} = UC_{t-1}^{TS} \cdot \left(1 + E^{ST} \cdot (P_t/P_{t-1} - 1) + 0.1 \cdot \left(E^{LT} - E^{ST}\right) \cdot (P_t/P_{t-10} - 1)\right) \quad (3)$$

We assume that after 2030 oil will face substitution by biofuels in aviation. It is modelled that the share of biofuels by 2040 will reach 1% of total fuel use in aviation in the reference scenario and 5% in the low carbon scenario.

Oil consumption by industry is calculated by multiplying industry value added and its oil intensity. Price sensitivity of industry's oil intensity $\left(UC_t^{ind}\right)$, is estimated using historical data from 1986 to 2015 with the linear regression (4).

$$Ln\left(UC_t^{ind}/UC_{t-1}^{ind}\right) = -0.28 - 0.12 \cdot Ln(P_t/P_{t-1}) \quad (4)$$

In the projection period we fix the share of energy industry own use in total national oil consumption at 2015 level.

Oil consumption in other sectors, such as non-energy use (including petrochemicals), agriculture, residential and commercial, electricity sector, which is responsible for 28% of overall Canada's oil consumption in 2016, is considered insensitive to

carbon price. Oil consumption by petrochemicals sector is fixed in absolute terms at 2015 level. Oil consumption for other non-energy use purposes as well as by agriculture and commercial sector is modelled to decline at their respective 2006–2015 historical rates. Residential oil consumption per capita in the projection period is modelled to decrease at 2006–2015 historical rates. Oil demand in electricity sector is quite low and is projected to reach zero by 2025.

Exports and imports of crude oil and oil products are projected using the logical assumption, that Canada will maximally utilize its own oil reserves and refining capacities. The share of oil products imports in oil products consumption will reach its 2010–2015 average by 2020 and stabilize at this level until 2040. Oil products exports in the projection period are fixed at their 2015 absolute level under the assumption that incremental demand in the US, the largest market for Canadian products export, will be met by American refineries.

NEB estimates suggest that the share of crude oil imports in the total feedstock requirements stabilized at 27–30% during the last several years [20]. We assume that it will remain at 27% level up to 2040. Taking into account that Canada's crude oil exports almost entirely flow to the US, Canada's crude oil exports are forecasted using the EIA Annual Energy Outlook 2018 [5]. Canadian heavy crude oil competes on the U.S. market with heavy crudes from Venezuela and Mexico [3]. The combined share of these three countries in the U.S. oil imports equaled approximately 60% in 2017 [6]. We assume that Canada's share in the U.S. crude oil imports will increase from 43% in 2017 to 65% in 2040.

## 3 Oil Demand and Output Response to Carbon Tax

The model reveals that Canada's oil demand continues to decrease in both reference and low carbon scenarios (see Fig. 2). Since the middle of the 2020s the decline accelerates, especially in the low carbon scenario. Oil demand is projected to decline by 14% in 2030 compared to 2015 level in the reference scenario and by 19% in the low carbon scenario, in 2040 – by 19% and 28% respectively. In the low carbon scenario oil demand in Canada in 2040 is 0.19 mbd lower than in the reference scenario.

The structure of oil demand response to the federal carbon tax by economic sectors shows that road transport will be the most affected (see Fig. 3). Our modelling reveals that in 2040 75% of the oil demand difference between the reference and low carbon scenarios falls on the road transport.

It is worth noting that oil demand response to the carbon price backstop at the national level could be smoothed because several Canadian provinces, including Alberta, British Columbia, Ontario and Quebec have implemented carbon pricing schemes before the federal government introduced the carbon tax. According to OECD [22], in 2012 Canada priced 43% of its energy related GHG emissions.

Our modelling shows that in the reference scenario oil production in Canada is going to rise significantly up to 2020 (see Fig. 2). In 2021–2030 oil output will remain stable but afterwards start to increase, reaching 6.2 mbd in 2040. Projected oil output in the low carbon scenario does not differ materially from the reference case.

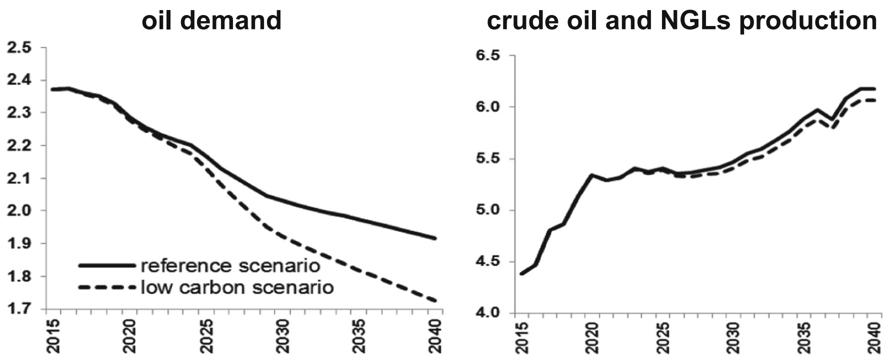


**Fig. 2.** Projections of oil demand and crude oil and NGLs production in Canada in the reference and low carbon scenarios until 2040, mbd.

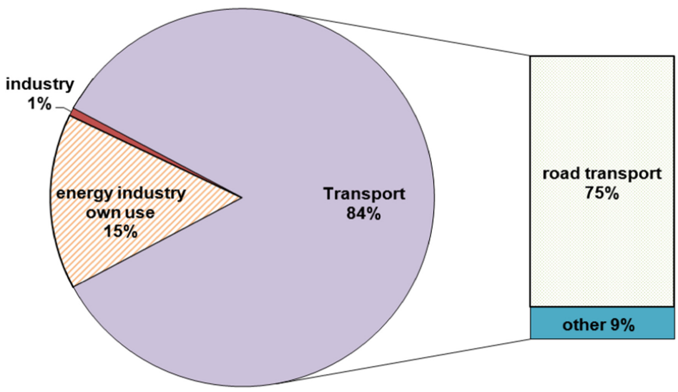


**Fig. 3.** Breakdown of oil demand difference between low carbon and reference scenarios in 2040 by economic sectors.

Oil production in Canada in the medium term could be supported by the projects that have been launched before oil price collapse in 2014–2016 and are going to be put into operation in the upcoming several years. They include Fort Hills with the peak oil production of 195 kbd, Horizon (phase 3) – 80 kbd, Christina Lake (phase G) – 50 kbd and Kirby North – 40 kbd [9]. In November 2017 ExxonMobil started production at Hebron field, which could produce up to 150 kbd of oil at peak [7]. Also, shale formations Montney and DuVernay are expected to increase oil production. After 2020 oil production in Canada could be affected by sharp capital expenditures reduction in 2015 and 2016 due to the oil price collapse.

In order to check the modelling results for robustness we use the higher levels of short-term and long-term price elasticities of demand in transportation sector provided by Lawson [14, 15] (see Table 2). The use of higher price elasticities of fuels demand does not crucially change the modelling results (see Figs. 4 and 5).

Also, we compare our modelling results with projection of the Canada's National Energy Board reference scenario (NEB-reference) and high carbon price scenario (NEB-HCP) [20]. Both the National Energy Board's reference and high carbon price scenarios of future demand for oil are more optimistic than our projections (see Fig. 4). Projection of oil consumption in the NEB reference scenario compared to our reference scenario is 0.35 mbd higher in 2030 and 0.4 mbd higher in 2040. Federal carbon tax impact on oil demand is more pronounced in our model compared to the NEB scenario. NEB projects that by 2030 demand for oil in the Canadian economy in the high carbon price scenario will drop only by 1% relative to 2015 level and by 6% in 2040.

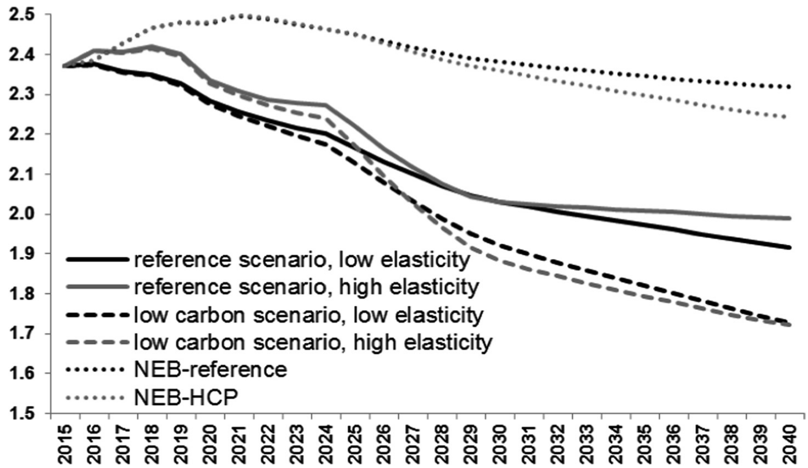


**Fig. 4.** Projections of oil demand in Canada until 2040, mbd.

Until 2021 our projections of oil production dynamics are close to the NEB scenarios (see Fig. 5). After 2021 the NEB scenarios become more optimistic. In relative terms NEB projections assume much stronger constraining impact of the federal carbon tax on oil production dynamics than our scenarios. As we assume that oil producers fully pass costs of carbon tax onto consumers of petroleum products, that is an expected modelling outcome. NEB forecasts of oil production are significantly higher compared to projections in all our scenarios. By 2030 the gap in the reference scenarios reaches 1.4 mbd. Such a large difference in modelled results is partially explained by the gap in production volume in the forecasts base year. We rely on the International Energy Agency data, while NEB uses its own estimates. However, the main explanatory factor behind such wide difference in output projections is oil export assumptions. NEB does not provide projections of crude oil export from Canada, but implicitly it is very optimistic about future export growth in its both scenarios. Our assumptions about export potential of Canadian oil are more modest.

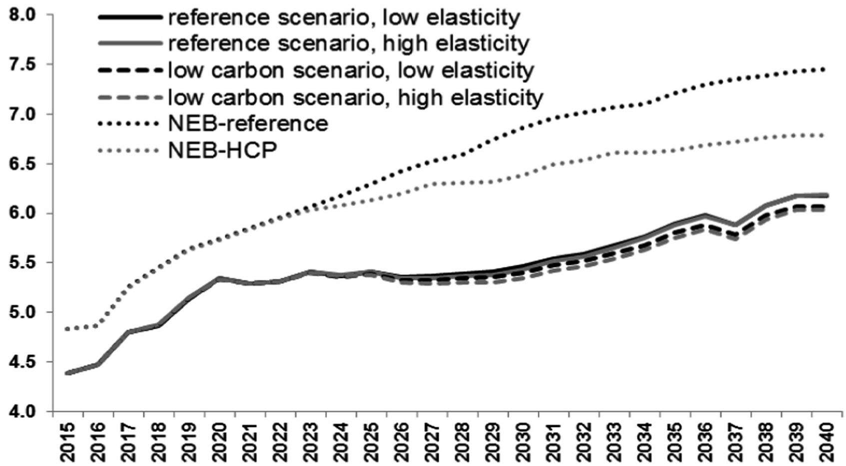


**Fig. 5.** Projections of crude oil and NGLs production in Canada until 2040, mbd.

## 4 Increasing Export Orientation of Canadian Oil Production

Shale revolution in the US led to unprecedented growth of U.S. light sweet crude oil production and at the same time created a strong demand for Canadian oil, as U.S. refineries have been modernized to process heavy crudes. The mix of light tight oil with relatively cheap heavy crudes strongly increases margins for American refineries. Because of this complementarity the demand for Canadian crude oil exports to the U.S. increased in parallel with rising U.S. tight oil production. Share of Canada in the U.S. crude oil imports went up from 20% in 2008 to 43% in 2017, squeezing out Venezuela's and Mexico's heavy crudes. Canada could continue to increase crude oil exports to the U.S. on the one hand by further squeezing out Venezuela's and Mexico's crudes, on the other hand by meeting growing appetite for heavy feedstock from the U.S. oil refineries.

We estimate that in absolute terms Canada's crude oil exports will grow by 0.7 mbd to 4 mbd in 2020 and reach 4.9 mbd in 2040. It is worth noting that pipeline and railway exports infrastructure is capable to transport these volumes of Canadian crude. IEA estimates reveal that in 2018–2020 due to the lack of sufficient pipeline infrastructure oil producers in Canada will switch to the alternative railway transport, which is capable to transport up to 1 mbd of crude oil per year [9]. By the end of 2019 pipeline takeaway capacity will expand by 0.5 mbd due to Enbridge Line 3 optimization and replacement. Also, Trans Mountain pipeline is probably to be expanded by 0.59 mbd by 2021, and the most controversial Keystone XL project, if implemented, could add 0.83 mbd of takeaway capacity [9]. Nationalization of Kinder Morgan oil pipeline system by Canadian government [2] with plans to extend the pipeline to the Pacific coast with the goal to increase oil exports to the Asia Pacific show that there are intentions to expand the country's oil exports capacity and diversify oil exports beyond North America after 2020.

## 5 Conclusions and Discussions

The major conclusions from the modelling of the Canadian oil demand and production until 2040 are the following. First, in the projection period carbon tax will minimally constrain future oil production growth in Canada. Such a conclusion is of a particular importance given the high dependence of economic growth in Canada on oil revenues. Second, under the assumption that producers fully pass costs of carbon tax onto consumers of petroleum products demand for petroleum products will contract more substantially compared to crude oil production. Third, the continuously increasing export orientation of the Canadian oil sector to the US market with limited pricing of carbon will partially shield the former from the impact of the carbon tax.

The assumption that oil producers fully pass costs of carbon tax onto consumers of petroleum products is a strong one. More detailed research modelling the sharing of carbon price among oil producers and consumers is required. Also, oil companies in Canada's oil sector, reacting to the introduction and increase of carbon tax, could follow heterogeneous strategies. In 2016–2017 some international oil companies sold oil exploration and production projects in Canada to local companies, possibly reacting to the risks associated with the federal carbon tax introduction. If this tendency continues it would be difficult to attract capital investment into the Canadian oil sector, sufficient to ensure oil output growth in the long run.

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