DIRTY TAXES: AN ANALYSIS OF THE EXPECTED IMPACT OF ALBERTA'S NEW CARBON TAX

by

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Table of Contents

List of Figures

List of Tables

Introduction

The goal of this essay is to review past trends in fossil fuel consumption in three Canadian provinces; Alberta, British Colombia (BC) and Ontario, and use these trends to predict the impact of a carbon tax on Alberta. Because BC introduced a carbon tax in July 2008, while the carbon tax in Alberta was not implemented until January 2017, there exists an eight-and-a-half-year period in which BC had a carbon tax and neighbouring Alberta did not. This essay will use methods found in literature to attempt to discern changes in BC's fossil fuel consumption and greenhouse gas emissions caused by imposition of a carbon tax by comparing consumption patterns before and after the tax was implemented in BC. The results from this analysis will then be used to predict changes in fossil fuel consumption and greenhouse gas emissions in Alberta.

Ontario is used as a control group in this essay, as the province did not introduce a carbon pricing regime until January 2017 and also lacks the fossil fuel extraction industry found in Alberta (Government of Ontario, 2017). The inclusion of Ontario in this analysis will provide a contrast to the results from Alberta and BC to help differentiate trends caused by a carbon tax from those which would have occurred regardless.

This essay first provides an overview of the carbon tax structures in both Alberta and BC, and discusses the unique challenges facing emissions reduction schemes in Alberta. Next, this essay reviews relevant literature on the subject of carbon taxes and their impact on consumption of fossil fuels, with key concepts being tax salience and the increasing availability of substitutes for conventional energy sources. Data on energy product consumption in Alberta, BC and Ontario is then analysed to determine the relationship between energy prices, carbon tax rates and energy consumption levels. These results are used to predict the impact of Alberta's new carbon tax, using BC and Ontario as reference jurisdictions. Finally, some brief commentary on the expected impact of a carbon tax on various economic sectors in Alberta is provided.

Throughout this essay, special attention is paid to the challenges faced by Alberta to implement a carbon tax; these include Alberta's high per capita greenhouse gas emissions, heavy use of coal to generate electricity and the economic importance of oil and gas extraction to the province. Compared to other Canadian provinces, Alberta's economy is built around many high-emissions activities, so any tax on carbon has the potential to sap the competitiveness of major provincial industries. This means that a carbon tax has the potential to exact a substantially larger economic toll on Alberta than on other Canadian provinces.

In order to capture the full impact of Alberta's carbon tax, provincial energy consumption is divided into three broad areas; natural gas consumption, gasoline and diesel consumption and electricity generation. Each of these areas are analysed to determine the expected impact of Alberta's carbon tax.

This essay finds that natural gas consumption by residential and commercial users in the three provinces analysed is driven almost entirely by outdoor temperature and that there is little or no demand response to changes in price in the short term. In the long term, there is a downward trend in both price and per capita consumption, suggesting that increased heating efficiency is the major driver of reduced natural gas consumption by residential and commercial users, and that a carbon tax will not create a significant reduction in greenhouse gas emissions. This contrasts with industrial natural gas use in Alberta, where bitumen extraction from the oil sands uses over three-quarters of all natural gas consumed in the province, and any increase in the price of natural gas has the scope to cause significant changes in consumption patterns.

Gasoline is generally considered to be a commodity with a low elasticity of demand due to its status as a household necessity, and analysis results confirm this. However, when contemplating the impacts of a carbon tax the theory of tax salience must be considered. Tax salience is a behavioral phenomenon where consumers alter their consumption level by a large amount in response to a relatively small price increase when the price increase is due to the imposition of a highly visible tax. This paper finds that tax salience is a very important concept when predicting the impact of a carbon tax on the gasoline market. However, the low elasticity of demand for gasoline in Alberta, combined with very high provincial greenhouse gas emissions means that a carbon tax is not expected to significantly reduce greenhouse gas emissions from gasoline in Alberta on a percentage basis.

This paper finds that there is a positive correlation between diesel consumption and prices in Alberta. This finding is counterintuitive, as consumption typically falls with higher prices. To explain this, it was hypothesized that diesel consumption increases with high prices because diesel prices are a proxy for oil prices, and Alberta gets a large economic boost from high oil prices as firms invest in oil production. According to this explanation, the demand-dampening effect of high diesel prices is more than offset by increases in commercial activity as the price of oil rises, explaining the positive relationship between diesel prices and demand. If this hypothesis is correct, a carbon tax on diesel may act as a tax on business activity and investment, the desirability of which is questionable.

Finally, this paper finds that the expected phase out of coal as a fuel source for electricity generation in Alberta will lead to a substantial decrease in greenhouse gas emissions in the province. The expected reduction in emissions from the phase out of coal will be far larger than the expected emissions reduction due to the carbon tax on gasoline. It is also expected that the transition to cleaner fuels will increase the price of electricity in Alberta, though the extent of this increase is difficult to predict.

Background

Alberta

Alberta is a province in Western Canada, with a population of 4.25 million people and a GDP of approximately $326 billion.[1] Alberta is the province with the highest emissions of greenhouse gases in Canada, and has the second highest emissions on a per capita basis. Figure 1 plots per capita greenhouse gas emissions in Alberta, BC and Ontario from 2000 to 2015. Over the period studied, annual per capita emissions in Alberta fell 15% from 77.2 to 65.6 tonnes carbon dioxide equivalent (tCO_2e) per capita, while total annual emissions increased by 18% from 232 million to 274 million tCO_2e.

[1] All dollar amounts are reported in Canadian currency.

On May 24, 2016, the *Climate Leadership Implementation Act* was tabled by Alberta's Environment and Parks Minister Shannon Phillips, and was subsequently passed as Bill 20 in that legislature sitting. The bill created two statutes, one of which, the *Climate Leadership Act*, imposed a broad-based carbon tax that came into effect on January 1, 2017. At the 2018 proposed carbon tax rate of \$30/tCO_2e, Alberta's 2015 emissions will yield total tax revenue of \$8.2 billion, if all greenhouse gas emissions are covered by the tax.

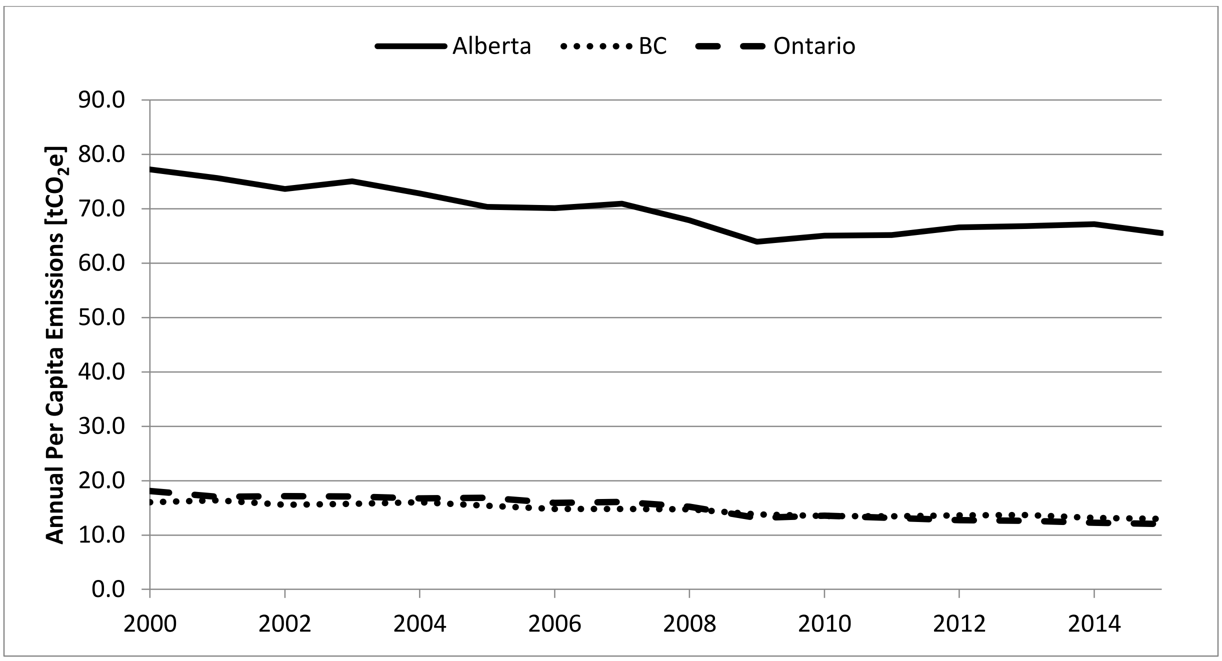

Figure 1 - Annual per capita greenhouse gas emissions by province, 2000 to 2015. Sources: CANSIM table 051-0001, Climate Change Connection (2016).

It is worth noting that Alberta's carbon tax was introduced by Rachel Notley's New Democratic Party (NDP) government, which was elected with a majority in 2015 following 44 years of unbroken majority governments under the Progressive Conservative (PC) party. These 44 years were proceeded by 36 years of Social Credit majority governments, with both the PC and Social Credit parties being classified as right-of-center. Indeed, the NDP is the first left-of-center party to govern Alberta since 1935 (Elections Alberta, 2017). Therefore, some may consider Alberta's decision to implement the tax unexpected, considering that the province, so consistently conservative, is now one of the first jurisdictions in North America to implement a broad-based carbon tax. While there may have been political uncertainty around the longevity of the tax following its announcement, the federal government's climate policy announcement five months after the Alberta carbon tax was announced, in which the federal government mandated that all provinces must implement a carbon price of $50/tCO$_2$e by 2022 has reduced fears of the Alberta tax being repealed following the 2019 provincial election (Harris, 2016).

In addition to its unique political landscape, Alberta's economy is differentiated from that of BC and Ontario by its industrial composition, which is shaped by Alberta's vast oil reserves.

Oil Production

Oil production is a major component of Alberta's economy. As Figure 2 shows, oil production has increased in Alberta over the past two decades, from 6,574,000 cubic metres per month in 2000 to 14,000,000 cubic metres per month in 2015. However, the composition of this oil production has changed greatly in recent years, with 55% of production being conventional crude production and 45% being bitumen extracted from the oil sands in 2000. In contrast, 2015 production was 82% bitumen and 18% conventional oil. This is significant, because relatively large amounts of energy are required to extract bitumen from oil sands. Because this energy is mostly generated through the combustion of natural gas, oil sands production is associated with higher per unit emissions than conventional oil production.

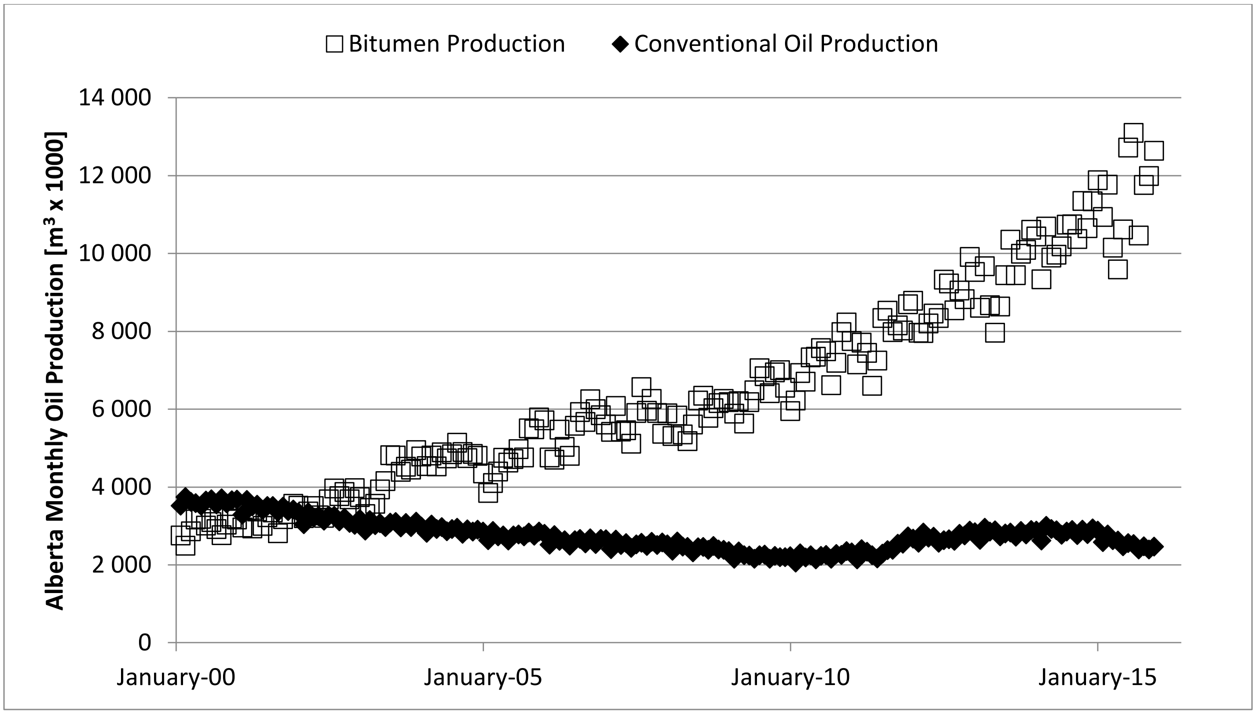

Figure 2 - Monthly oil production in Alberta, January 2000 to December 2015. Source: CANSIM table 126-0001.

Because of the carbon intensity of the oil industry in Alberta, one of the concerns surrounding the implementation of a carbon tax is that there will be severe economic consequences for a large industry within the province. The combined emissions of the Canadian oil and gas industry in 2015 were 189 million tCO_2e, representing 26% of the country's total emissions. With the vast majority of all Canadian oil and gas extraction taking place in Alberta, it is clear that oil and gas emissions are major targets of any expected greenhouse gas reduction resulting from a carbon tax (Environment and Climate Change Canada, 2017).

Using the Western Canadian Select (WCS) oil price forecast from the Alberta provincial budget of $48.30 per barrel in 2017, the upstream oil industry is expected to have gross revenues of approximately $56 billion in 2017.[2] For reference, Alberta produces 14 million cubic metres of oil per month, while all of Canada consumes 6.5 million cubic metres of oil per month, or less than half of Alberta's production (Canadian Association of Petroleum Producers, 2017).

Natural Gas Production

Alberta is also a major producer of natural gas, and the natural gas industry contributes substantially to the provincial economy and regional employment. In 2016, the province produced 136 billion cubic metres of natural gas. With the 2016 Alberta Budget estimating a 2017 natural gas price of $2.80/GJ, this represents annual natural gas production worth $14.5 billion (Government of Alberta, 2015). For comparison, in 2015 Canada consumed a total of 88 billion cubic metres of natural gas, meaning that Alberta produces about 50% more natural gas than the entire country consumes. Therefore, any impact of a carbon tax on this industry will be significant to the provincial economy.

Production of natural gas tends to be associated with large volumes of greenhouse gas emissions. These emissions are created when energy is expended producing, shipping and processing natural gas, as well as from flaring and methane leakage (ICF Consulting Canada, 2012).

[2] WCS is the price paid for oil produced from the oil sands and sold at the terminal in Hardisty, Alberta. While the price received for oil varies based on many factors including viscosity and location, using WCS as a benchmark for sales prices produces a conservative gross sales value figure.

Electricity Production

Another of the major contributors to Alberta's high per capita greenhouse gas emissions is the province's reliance on fossil fuels to generate its electricity, with electricity generation accounting for 14% of the provinces total greenhouse gas emissions in 2014 (Government of Alberta, 2017). In 2015, Alberta produced 90% of its electricity from fossil fuels, with the majority of its electricity coming from coal-fired generating stations.

It is notable that both the Canadian federal government and the Alberta government have mandated that all electricity generation from coal will be phased out by 2030, which along with the carbon tax will place pressure on electrical utilities to find new, cleaner sources of power in the province (McCarthy, Shawn, 2016).

Alberta's Carbon Tax Structure

Alberta's carbon tax came into effect on January 1st, 2017, at a rate of \$20/tCO_2e. The levy is applied to fossil fuels at point of sale, following the rates in Table 1 to achieve a tax rate of \$20/tCO_2e until January 1st, 2018, when the tax will rise to \$30/tCO_2e.

Table 1 - Carbon levy rates for fossil fuel sales, Alberta. Source: Government of Alberta (2015).

FUEL	LEVY AT \$20/tCO_2e	LEVY AT \$30/tCO_2e
DIESEL	5.35 ¢/L	8.03 ¢/L
GASOLINE	4.49 ¢/L	6.73 ¢/L
NATURAL GAS	1.011 \$/GJ	1.517 \$/GJ

Unlike BC's carbon tax, Alberta's carbon tax in not designed to be revenue neutral. To partially offset any negative economic consequences of the carbon tax, the government has lowered the small business tax rate from 3% to 2% (worth $185 million in 2017-2018) and is providing refundable tax credits to low income households worth $435 million in 2017-2018, rising to $590 million in 2018-2019. These transfers will not entirely offset the $1.4 billion expected from the tax in 2017-2018 and the $2.6 billion expected in 2018-2019.

The 2018-2019 revenue projection, while large, falls well short of the $8.2 billion of revenue predicted above if all of Alberta's 2015 greenhouse gas emissions are multiplied by the tariff rate of $30/tCO_2e$. While the tax does allow some exemptions (for example, no tax is applied to agricultural fuels) these exceptions do not appear sufficient to explain this large discrepancy. The application base of carbon taxes in Alberta and in other jurisdictions is a topic worthy of further research.

British Colombia

British Colombia is the province on Canada's western coast, with a population of 4.75 million people and a GDP of approximately $250 billion. The two most significant differences between the provinces for the purposes of this essay is the scale of the energy industry and the difference in their carbon emissions. Figure 1 shows that from 2000 to 2015 BC's annual per capita greenhouse gas emissions fell 19% from 16.1 to 13.0 tCO_2e per capita, with total annual emissions falling by 6% from 64.9 million to 61.0 million tCO_2e. This would mean that if every emission source in BC were assessed at $30/$tCO_2e$, the tax revenue would total approximately $1.8 billion. Contrast this with the $8.2 billion that would be charged to carbon emitters in Alberta with 2015 emission levels, and it is clear that any proposed carbon tax can be expected to have a far larger economic impact in Alberta than in BC.

However, as noted above, Alberta's forecast revenue for 2018/2019 is $2.6 billion, representing a 68% shortfall between total emissions value and the taxed portion of emissions.[3] This contrasts with BC, where the government's 2015 carbon tax revenue of $1.2 billion represents only a 33% shortfall from the total $1.8 billion worth of emissions created at a price of $30/tCO_2e$.

Carbon Tax Structure

A key feature of British Colombia's carbon tax was its gradual phase in, using a series of small tax increases to raise the tax to its final rate over a period of four years. The tax came into force on July 1st, 2008, with a price on carbon of $10/tCO_2e$. The tax was then raised by $5/tCO_2e$ every July 1st thereafter until 2012, when the tax reached $30/tCO_2e$. Considering that a broad-based carbon tax had never before been implemented in North America, it is understandable that the government wanted to gradually increase the tax to ensure that it did not cause unanticipated harm to the economy.

One downside of this gradual tax rate increase is that it makes it more difficult to discern if behavioral changes are due to the carbon tax or due to other factors occurring over the extended timeframe, such as improvements in public transit that allow people to reduce the amount they drive. This gradual phase in served to prevent a difference in differences analysis

[3] While the calculation of Alberta's total emissions uses 2015 values with a 2018 tax rate, the Alberta Budget forecasts emissions in the province to grow during that time, making the taxed emissions versus total emissions discrepancy even larger than calculated above. The tax shortfall is determined by the following equation:

$$\%\,Shortfall = \frac{\left(\frac{\$30}{tCO_2e}\right)(Total\ Emissions) - Expected\ Tax\ Revenue}{(\$30/tCO_2e)(Total\ Emissions)} x100\%$$

from being used in this essay, as the tax introduction was not a single event but a series of tax hikes over a period of four years.

The second key feature of BC's carbon tax is the government's continued pledge that the tax will be revenue neutral. This promise requires the government to offset any revenue raised through the tax with proportional reductions in other taxes, which in 2015 was achieved by reducing personal income taxes by $565 million and corporate taxes by $959 million compared with tax rates before the carbon tax was introduced. This more than offset the $1.2 billion raised through the tax that same year.

A much-touted advantage of the revenue neutrality of BC's carbon tax is that it ensures the government does not face a contradictory incentive to see carbon emissions rise, thus increasing government revenue, since any gains from increased carbon tax revenues must be offset with tax cuts elsewhere. A possibly more compelling benefit is that revenue neutrality makes it easier to convince voters of the merits of the carbon tax. Moreover, commentators continue to debate if BC's carbon tax is actually revenue neutral, since the value of tax reductions directly attributable to the carbon tax versus which tax reductions would have occurred without the carbon tax is a matter of opinion (The Economist, 2014).

Ontario

Ontario is a province in central Canada, and is the most populous province in the country with a population of 14.1 million people and a GDP of $763 billion. As shown in Figure 1, between 2000 and 2015 Ontario's per capita greenhouse gas emissions have fallen 33% from 18.1 to

12.0 tCO_2e per capita, and total annual provincial emissions have fallen 21% from 211 million to 166 million tCO_2e. Clearly, Ontario has experienced a larger drop in emissions during the time period studied than either Alberta or BC. This may be attributable to the economic structure of Ontario, as unlike Alberta and BC, resource extraction does not account for a large portion of provincial GDP in Ontario. Instead, the province has a more diversified economy, with manufacturing and the service sector accounting for relatively larger portions of GDP (Ryan, 2013).

During the time period studied Ontario did not have a carbon pricing scheme in place. The province implemented a cap and trade carbon pricing scheme in January 2017 (the same time as Alberta), presenting an interesting opportunity to predict and study the impact of a carbon price on a province with a different industrial composition.

Literature Review

Carbon Taxes

Carbon taxes are an economic tool commonly favoured by economists to combat the problem of anthropogenic climate change. A carbon tax attempts to internalize some of the externalities associated with fossil fuels into their sales price, thus moving equilibrium towards the socially optimal price level and consumption quantity (Li, Linn, & Muehlegger, 2014). While a great deal of research has been done on the economic impacts of climate change generally and economists have completed analyses on many other emissions reduction schemes, relatively little academic work exists on the expected impact of Alberta's new carbon tax. With climate change a topic of ever increasing importance, made even more prescient by the Canadian federal government's announcement in October 2016 that all provinces must have a carbon price of $50 per t$CO_2$e by 2022, the impact of carbon taxes seems set to be an area of increased academic study in Canada.

<u>Elasticity of Demand</u>

Conventional economic wisdom suggests that household necessities, a category into which transportation fuels and natural gas are typically categorized, face very low elasticities of demand since it is difficult to find substitutes for these products. In addition, evidence has shown that demand elasticities for transportation fuels have been falling over past decades, and that increased volatility in fuel prices experienced in recent years has caused demand elasticities to fall further still (Lin & Prince, 2013). Large amounts of data are available on these elasticities, among which the gasoline and diesel data collected and complied by Carol Dahl at the Colorado School of Mines on the Dahl Energy Demand Database earns mention. However, these elasticity values may not apply to energy price increases caused by the imposition of a carbon tax, as new findings in the field of behavioral economics suggest that consumers respond differently to commodity taxes than to market-driven price changes.

Additionally, there is a growing trend towards the availability of substitutes for conventional fossil fuel energy sources. Public transportation and electric vehicles serve as a substitute for fossil fuel-powered private automotive transportation, with increases in transportation options providing choices to consumers and thus increasing the elasticity of demand for consumption of gasoline and diesel. Adding to consumer choice, increasingly stringent fuel economy standards around the world mean that new cars are ever more fuel efficient than old models, allowing consumers and businesses to cut their gasoline and diesel demand by purchasing new, more fuel-efficient vehicles (Van Benthem & Reynaert, 2015).

Further, the rapidly falling price of small-scale solar panels provides households with the option to generate their own electricity and in many cases the ability to sell this electricity back to the electricity grid through government-mandated power purchase agreements. Small-scale solar panels can be purchased and installed in extremely short timeframes compared to conventional utility-scale electricity projects, thus providing consumers with a substitute for grid-purchased electricity in the event of higher electricity prices (Ministry of Energy, 2012; The Economist, 2017). Finally, government and employer efficiency programs reward consumers with rebates for energy-saving measures such as adding insulation to their homes or purchasing more energy-efficient appliances, again providing what could be viewed as a substitute for consumption of traditional fossil fuel energy sources such as natural gas for heating (Energy Efficiency Alberta, 2017).

These combined trends allow the elasticity of demand for fossil fuel products to rise, as substitutes for their use become increasingly available at a competitive cost. These technological trends provide consumers with a choice where previously they would have had no option but to pay the market rate for the conventional energy source, since the opportunity cost of not buying energy at all is prohibitively high.[4] Thus, improvements in technology and

[4] An example of this high opportunity cost would be a worker deciding not to go to work because she does not want to pay for the gasoline to power her car – the cost of not attending work would be far higher than any conceivable price for the gasoline.

systems (such as public transport) serve to increase the elasticity of demand that consumers exhibit towards conventional energy sources.

This same logic applies to commercial and industrial energy users. As production technologies evolve to become more energy efficient, firms will have the choice to either increase expenditures on energy or to invest in new more efficient technologies.

Salience of Taxes

One of the ideas increasingly prevalent in economics is the theory of tax saliency, which refers to the hypothesis that price shifts caused by tax changes have a substantially larger impact on demand than market-driven price changes. In a 2009 paper, Chetty et al. demonstrate empirically that behavioral responses to commodity taxes differ significantly depending on consumers' level of awareness of the tax, and that consumers become well-informed about a tax when a substantial amount of attention is given to the topic (Chetty, Looney, & Kroft, 2009). Rivers and Schaufele use these findings and apply the concept of saliency to their analysis of BC's carbon tax. In a 2015 paper, Rivers and Schaufele find that a market-driven 5% increase in the price of gasoline in BC leads to a 1.8% fall in demand, a finding consistent with other literature suggesting that demand for gasoline is relatively inelastic. However, the paper goes on to find that a 5% increase in the price of gasoline due to the implementation of a carbon tax causes a 12.5% fall in the demand for gasoline, representing a demand response that is 7.1 times larger than that attributable to market-driven price changes (Rivers & Schaufele, 2015). The authors do not offer a definitive explanation for this difference in consumer behavior, but suggest that media attention for the tax greatly raised consumer awareness of the price increase.

The saliency argument is particularly helpful to policymakers, since it presents an argument that a small carbon levy has the potential to make a significant reduction in carbon emissions.

Summary of Rivers and Schaufele Method

In their paper, Rivers and Schaufele compare price and consumption data for gasoline in BC and Ontario. For their quantitative analysis, Rivers and Schaufele follow the approach of Li, Linn and Muehlegger (2012) and decompose the retail price into two components; the price of gasoline without the carbon tax and the value of the carbon tax, specifying the following linear equation.

$$y_{it} = \beta_1 p_{it} + \beta_2 \tau_{it} + \beta_3 X_{it} + \beta_4 \delta_i + \beta_5 \gamma_t + \varepsilon_{it}$$

Where:

y_{it} → per capita consumption of gasoline in period t, province i
p_{it} → price of gasoline without carbon tax, inflation-adjusted
τ_{it} → carbon tax, inflation-adjusted
δ_i → province-specific fixed effect
γ_t → time-fixed effect
ε_{it} → province and period specific error term
X_{it} → other, potentially relevant variables that vary by location and time

This general concept of treating taxes that receive widespread media attention as separate variables is the basis for determining the impact of carbon taxes on gasoline in this essay.

Loss of Competitiveness

One of the major concerns mentioned by media outlets and politicians is the potential for provinces to lose competitiveness as a result of a carbon tax. This concern appears more valid in the case of Alberta than BC, since Alberta's economy is heavily geared towards extraction of oil and gas, two emissions-intensive activities. In a 2010 paper, Rivers finds that, consistent with the conclusions found in other studies, an aggressive reduction in greenhouse gas emissions will result in a loss of competitiveness in Canada's most energy-intensive sectors (Rivers, 2010). Since the oil and gas extraction industry accounts for 26 percent of all carbon emissions in Canada, with the majority of that occurring in Alberta, it is reasonable to conclude that there will be some loss of competitiveness in the industry with a price of \$30/tCO_2e.

Analysis and Results

The goal of this essay is to predict the impact of a carbon tax on Alberta, using the experience of BC as a reference and Ontario as a control group. To this end, this essay uses data on fossil fuel consumption in all three provinces to calculate expected changes in Alberta's energy demand and greenhouse gas emissions resulting from the government's carbon tax measures.

This essay considers the three categories of emission-generating activities; (1) natural gas consumption, (2) gasoline and diesel consumed for transportation purposes and (3) electricity generation. Because 76% of all oil consumed in Canada is used for transportation purposes, consumption figures for gasoline and diesel serve as a good proxy for oil use in each province and thus for oil's contribution to each province's total carbon emissions (Canadian Association of Petroleum Producers, 2017). Almost 90% of all coal used in Canada is burnt for electricity generation, with the majority of all coal consumption taking place in Alberta, suggesting that the electricity sector analysis done in this essay provides a thorough understanding of the contribution of coal to greenhouse gas emissions in the jurisdictions of interest (Quigley, 2016).

This section will provide an overview of fossil fuel consumption data in all three provinces and will present brief qualitative commentary on the data and its usefulness to the objectives of this essay.

Notes on Data

The data period considered throughout this analysis is January 2000 to December 2015, as this time period is long enough to provide sufficient data points to conduct a high-quality analysis but is still of sufficient compactness so that most of the required data could be found. Almost all of the data used in this section is from CANSIM, Statistics Canada's online database.

Natural Gas

CANSIM table 129-0003 provides monthly consumption and sales price data for natural gas in each Canadian province, with consumption divided amongst industrial, commercial and residential gas users. Monthly sales data was retrieved for Alberta, BC and Ontario in each of these categories for the period from January 2000 to December 2015. The data was then adjusted for population in each province, using population data from CANSIM table 051-0001. Because Statistics Canada estimates population annually every July, the population data was linearly interpolated to get monthly population estimates, since the natural gas consumption data is monthly. Monthly price data was adjusted for inflation using the CPI values for each province found in CANSIM table 326-0020.

A visual survey of the data revealed a substantial seasonal variation that did not necessarily correspond to the price of natural gas, so it was hypothesised that the major driver for natural gas consumption is outdoor ambient temperature.

The validity of this hypothesis has significant scope to alter the outcome of this analysis, as it shows a potential relationship of low outdoor temperatures driving higher natural gas consumption, which would in turn determine the price of natural gas based on supply and demand of natural gas in that market. This is in alternative to the theory postulated in the gasoline section of this paper, where the price of gasoline is the independent variable driving consumption. To test this hypothesis, it was necessary to construct a metric for the amount of heating required in each province, for which a measure known as heating degree days was used. A heating degree day measures the difference between the outdoor ambient temperature and some base temperature which is considered acceptable for a building (typically 18 to 19 degrees Celsius) for a given day (National Oceanic and Atmospheric Administration, 2017).

To construct a provincial average, daily heating degree day data was retrieved from the Environment and Climate Change Canada database from January 2000 to December 2015. The data available on the Environment and Climate Change Canada website contains daily measurements and is city-specific, so the total heating degree day values for each month were summed to create a monthly heating index that could be compared to monthly natural gas consumption. After the data had been converted into a value for each month, the city-specific monthly values were converted into a provincial average. The provincial average for each province was converted using the following city data weighting structure:[5]

- Calgary (50%) and Edmonton (50%) for Alberta
- Kelowna (25%) and Vancouver (75%) for BC
- Ottawa (25%) and Toronto (75%) for Ontario

Once provincial monthly heating values had been calculated, provincial consumption of natural gas was regressed on heating degree days and the price of natural gas separately, and then together to attempt to determine the correlation between outdoor temperature, price and gas consumption. Finally, price was regressed on heating days to determine how reliably price responds to outdoor temperature. The results of these regressions are detailed in Tables 2 to 4.

[5] Calgary and Edmonton are given equal weight since they have similar populations and together account for a majority of Alberta's population. Kelowna is used to represent temperatures in the BC interior, while Vancouver is used to represent costal temperatures, with weightings of 25% and 75% based on approximate populations living in each region. In Ontario, Ottawa is used to represent mid-to-northern temperatures, while Toronto is used to represent more southerly temperatures, with weightings based on approximate populations in each region.

Table 2 - Natural gas monthly data regression results for Alberta. Sources: CANSIM tables 051-0001, 129-0003, 326-0020, Government of Canada (2017).

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Heating Days	0.9549	0.24710	0.00390
		Price	0.0515	-1.89445	0.58972
		Heating Days Price	0.9623	0.25437 0.75953	0.00376 0.12418
	Price	Heating Days	0.0999	-0.00958	0.00209
COMMERCIAL	Consumption	Heating Days	0.9376	0.14673	0.00275
		Price	0.0296	0.83488	0.34686
		Heating Days Price	0.9509	0.14571 0.56081	0.00245 0.07841
	Price	Heating Days	0.0034	0.00183	0.00226
INDUSTRIAL	Consumption	Heating Days	0.1246	0.13502	0.02597
		Price	0.3194	-8.30448	0.87955
		Heating Days Price	0.4947	0.16120 -8.99680	0.01990 0.76462
	Price	Heating Days	0.0125	0.00291	0.00188

Table 3 - Natural gas monthly data regression results for BC. Sources: CANSIM tables 051-0001, 129-0003, 326-0020, Government of Canada (2017).

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Heating Days	0.9447	0.15502	0.00272
		Price	0.4014	-2.27641	0.23369
		Heating Days Price	0.9465	0.16052 0.21668	0.00345 0.08526
	Price	Heating Days	0.3944	-0.02539	0.00228
COMMERCIAL	Consumption	Heating Days	0.9208	0.08728	0.00186
		Price	0.0486	-0.58662	0.18825
		Heating Days Price	0.9210	0.08698 -0.04116	0.00190 0.05567
	Price	Heating Days	0.0460	-0.00733	0.00242
INDUSTRIAL	Consumption	Heating Days	0.1835	0.00707	0.00108
		Price	0.0971	0.08987	0.01988
		Heating Days Price	0.2830	0.00711 0.09097	0.00102 0.01776
	Price	Heating Days	0.0001	-0.00051	0.00415

Table 4 - Natural gas monthly data regression results for Ontario. Sources: CANSIM tables 051-0001, 129-0003, 326-0020, Government of Canada (2017).

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Heating Days	0.9315	0.18282	0.00360
		Price	0.3230	-2.8287	0.29711
		Heating Days Price	0.9317	0.18481 0.08713	0.19369 0.32053
	Price	Heating Days	0.3605	-0.02285	0.00221
COMMERCIAL	Consumption	Heating Days	0.9232	0.10791	0.00226
		Price	0.0709	-0.97101	0.25495
		Heating Days Price	0.9234	0.10844 0.05900	0.00236 0.07674
	Price	Heating Days	0.0856	-0.00901	0.00214
INDUSTRIAL	Consumption	Heating Days	0.7514	0.01530	0.00064
		Price	0.0321	-0.10953	0.04362
		Heating Days Price	0.7660	0.01516 -0.07422	0.00062 0.02155
	Price	Heating Days	0.0045	-0.00194	0.00209

The above monthly data regression is useful for finding short-term trends in natural gas consumption, but a concern with using monthly data is that large seasonal fluctuations in demand hide long-term trends in natural gas consumption driven by price. To assess these longer-term trends, natural gas consumption data was averaged into yearly data (creating 16 data points) and adjusted for year to year differences in temperature by multiplying the average value of heating degree days in the 16-year data set and then dividing by the value of heating degree days for the particular year in question. By adjusting for outdoor temperature, the annual data could be made relatively free of the influence of temperature so that the impact of price on consumption could be deciphered. Tables 5 to 7 detail the regression of annual consumption on price.

Table 5 - Natural gas annual data regression results for Alberta. Sources: CANSIM tables 051-0001, 129-0003, 326-0020.

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Price	0.3706	0.93809	0.32674
COMMERCIAL	Consumption	Price	0.4455	0.59336	0.17691
INDUSTRIAL	Consumption	Price	0.4557	-10.651	3.1110

Table 6 - Natural gas annual data regression results for BC. Sources: CANSIM tables 051-0001, 129-0003, 326-0020.

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Price	0.1396	0.28907	0.19178
COMMERCIAL	Consumption	Price	0.0084	0.04971	0.00226
INDUSTRIAL	Consumption	Price	0.2010	0.10919	0.05818

Table 7 - Natural gas annual data regression results for Ontario. Sources: CANSIM tables 051-0001, 129-0003, 326-0020.

SECTOR	DEPENDANT VARIABLE	REGRESSOR VARIABLE	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
RESIDENTIAL	Consumption	Price	0.2823	0.26377	0.11242
COMMERCIAL	Consumption	Price	0.0034	0.19431	0.14216
INDUSTRIAL	Consumption	Price	0.0914	-0.08728	0.07356

Residential

Looking at the results of the monthly data regression in Tables 2 to 4, there is an extremely high positive correlation between residential natural gas consumption and heating degree days in all three provinces, with R-squared values over 0.90. This leads to the conclusion that outdoor temperature is the main driver of residential natural gas consumption in the short term. This makes intuitive sense, as residential natural gas is primarily used for home heating and thus consumption is directly related to outdoor temperatures. Indeed, most residential buildings have their temperatures controlled by a thermostat that automatically turns on the heat when the building becomes too cold.

Results from price regressions are less straightforward. Regressing residential natural gas consumption on prices yields a negative correlation in all three provinces with varying levels of correlation, indicating that higher prices are associated with lower consumption. This suggests that higher prices drive demand lower, which is contrary to the previously formulated hypothesis that temperature drives demand which in turn drives prices. If temperature-driven consumption serves to determine the price of natural gas, then it would be expected that prices would rise with demand in a positive correlation rather than the observed negative correlation, which appears to show consumption reacting to prices. It should be noted that there is a much weaker correlation with price than there is with outdoor temperatures.

In order to improve the information available to determine the direction of causality, consumption was regressed against both heating degree days and price, which revealed a very weak relationship between consumption and price compared with a very strong correlation between temperature and consumption. This leads to the conclusion that temperature is indeed the main driver of natural gas consumption and that prices do not have much of a short-term impact on residential consumption.

An assessment of the annual data results leads to much the same conclusion as an assessment of the monthly data; annual residential consumption of natural gas is positively correlated with price in all three provinces, although this correlation is relatively weak in BC. The fact that higher prices are associated with higher consumption of natural gas suggests that price is being determined by demand and not the other way around. This suggests an inelastic response in the longer term as well as in the shorter term.

Commercial

The regression of monthly commercial natural gas consumption on heating degree days and price yielded results similar to those observed for residential natural gas consumption in all three provinces. This is likely because commercial natural gas users' primary use of natural gas is for heating purposes, leading to a high degree of correlation between consumption and temperature and little correlation between consumption and prices as heating is a necessity for commercial locations. As a result, this analysis finds that the short-term response of commercial natural gas users is extremely inelastic to changes in price.

The regression of annual commercial consumption data on price yielded a similar result to the annual residential regression, with all three provinces showing a positive correlation between commercial natural gas consumption and price. Over the 16-year period studied there is a downward trend in both per capita natural gas usage and price, suggesting once again that the fall in natural gas usage is due to gains in efficiency rather than a response to price.

Industrial

The major divergence between the provinces occurs in the industrial sector, where natural gas consumption in BC and Ontario tracks temperature fairly closely, while there is almost no correlation with temperature and industrial natural gas consumption in Alberta. This may be because of the large amounts of natural gas used to extract bitumen from the Alberta oil sands, a process that is minimally impacted by outdoor temperatures. In 2016, oil sands producers used 24.6 billion cubic metres of natural gas, over one quarter of the 88 billion cubic metres consumed in Canada and 76% of the 32 billion cubic metres of natural gas consumed in Alberta.

Figure 3 plots monthly industrial natural gas usage and bitumen production in Alberta between January 2000 and December 2015. Regressing bitumen production on industrial natural gas consumption in Alberta yields an R-squared value of 0.8737, indicating a high level of correlation between the two. This figure and close correlation demonstrate the dominance of the oil sands as a customer for natural gas in Alberta.

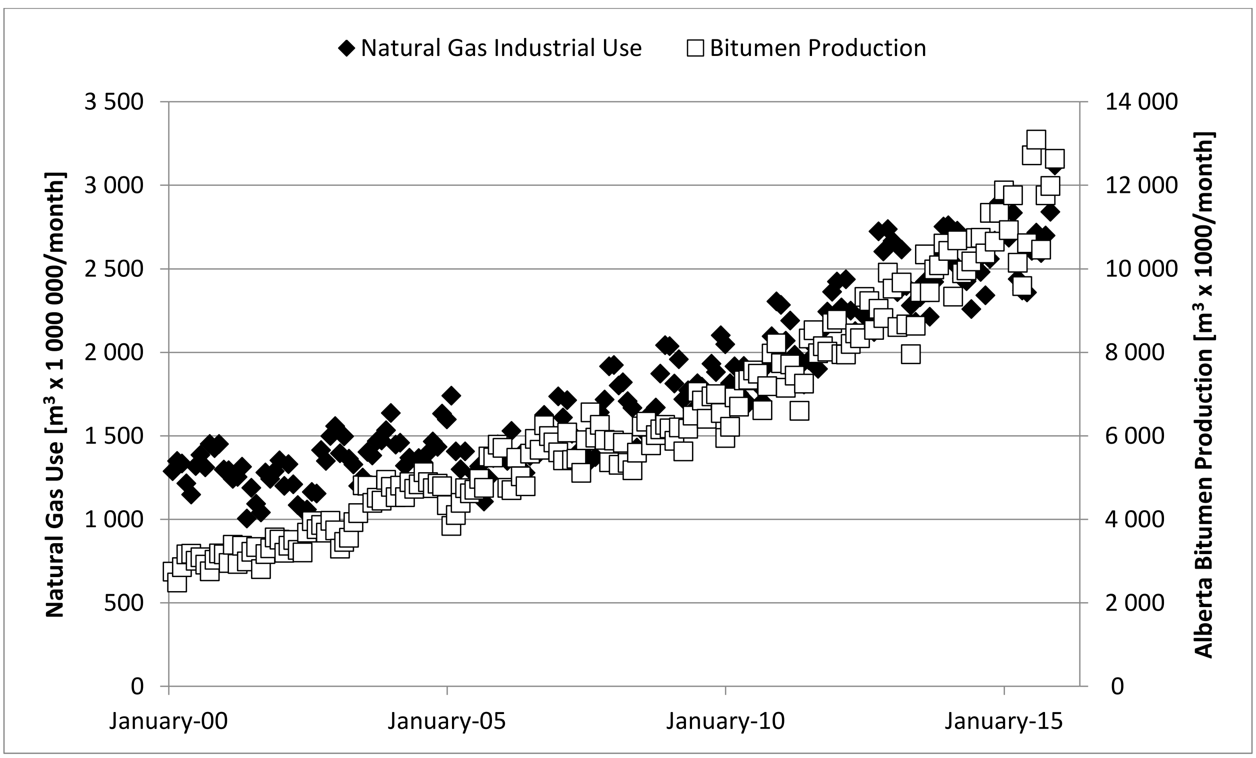

Figure 3 - Alberta bitumen production and industrial natural gas usage, January 2000 to December 2015. Bitumen production is combined crude bitumen and synthetic crude production. Sources: CANSIM tables 129-0003 and 126-0001.

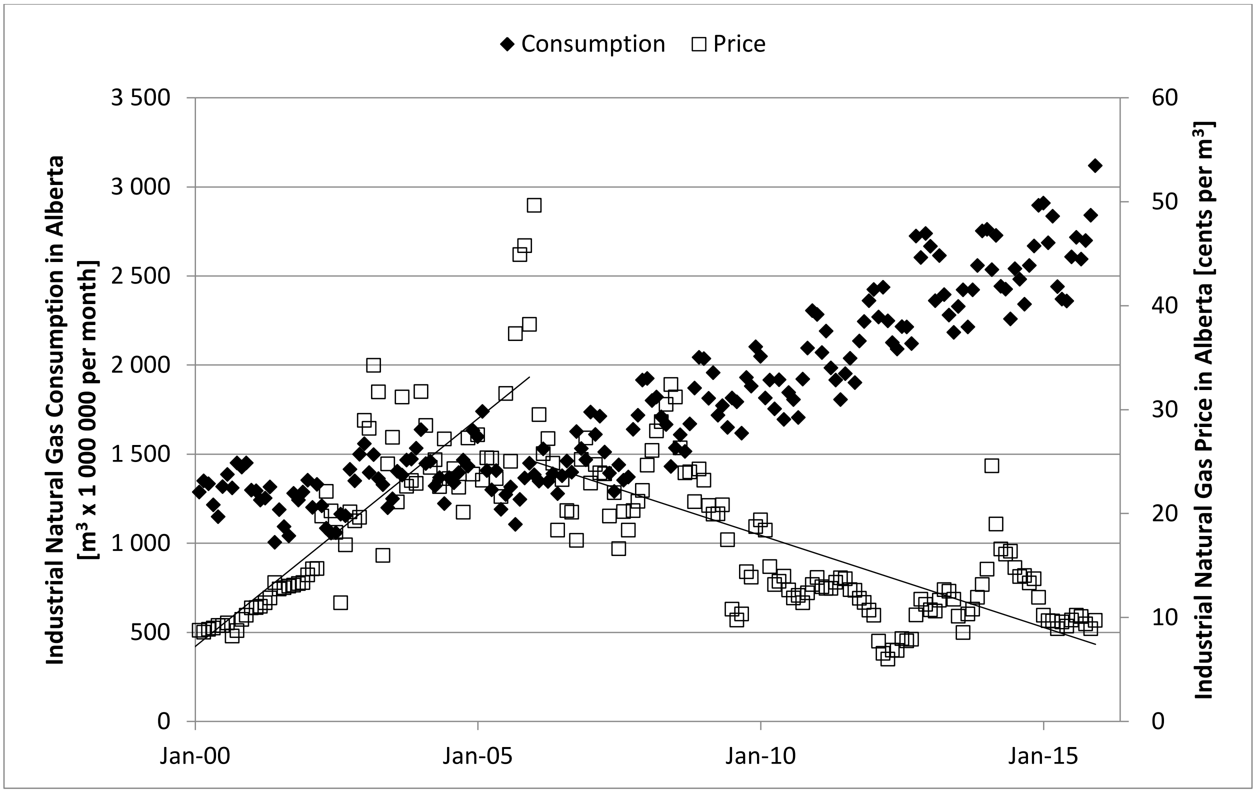

Figure 4 - Natural gas industrial consumption and prices in Alberta, January 2000 to December 2015. Source: CANSIM table 129-0003.

This leaves the question of whether price or some other variable drives industrial natural gas consumption in Alberta. Figure 4 shows industrial natural gas consumption and prices in Alberta from January 2000 to December 2015. A trendline is fitted to the price data from January 2000 to December 2005, and a second trendline is fitted from January 2006 to December 2015. These lines help illustrate a general trend of natural gas price increases from 2000 to 2005, followed by a price decline from 2006 to 2015. Relatively little growth in natural gas consumption can be observed between 2000 and 2005, corresponding with the period of rising prices. Similarly, the period from 2006 to 2015 is characterized by rising industrial natural gas consumption and decreasing natural gas prices. This seems to indicate that there is at least some correlation between industrial natural gas consumption and price in Alberta.

The regression of annual industrial natural gas consumption and price data serves to bolster this point, with industrial natural gas use in Alberta showing a robust correlation and negative relationship over the 16-year time period studied. This contrasts with the annual data for BC and Ontario, which shows almost no correlation between usage levels and price.

Gasoline

To determine the expected impact of the carbon tax on Alberta, gasoline consumption data was retrieved for all three provinces from CANSIM table 405-0003. This database provides monthly province-wide gasoline consumption, with gasoline sales measured on a net basis.[6] Data for all three provinces was retrieved for the time period spanning January 2000 to December 2015.

Provincial net consumption of gasoline was first divided by the driving-age (those aged 15+) population in each province to control for increases in gasoline consumption driven by population increase rather than consumer response to price.[7] The per capita gasoline data showed a large seasonal fluctuation in each province, with gasoline consumption rising during the summer driving season and falling in the winter months. This seasonal fluctuation interfered with analysis of consumer responses to price changes, so the data was adjusted to remove seasonality. To do this, a 12-month average of gasoline consumption was constructed for each month (to create a moving average rate of consumption) then the actual consumption for each month was divided by the moving average consumption. This created an index of how

[6] Net basis refers to gasoline sold without transportation tax applied. Fuel used for agricultural purposes is the main class of fuel sales not captured in the net basis figure.

[7] Driving age was chosen as the divisor population as driving age people are those who have the ability to consume gasoline for automotive transportation.

much a single monthly data point varied from the consumption level during the year around it. Then, an average of this index was created for each month for the entire 16-year data set, to determine how much above or below the yearly average a given month typically was in the 16-year data period analysed. By dividing actual per capita consumption by the average variation observed in a particular month, it was possible to polish the consumption data to reduce the influence of seasonal fluctuations in gasoline consumption.

Monthly price data for regular and premium gasoline was retrieved from CANSIM table 326-0009 for the time period from January 1999 to December 2015.[8] Gasoline price data available from Statistics Canada calculates a price average for each major Canadian city, so it was necessary to convert the city price data into a province-wide price index so that prices could be compared to province-wide gasoline consumption. It was assumed when calculating the index that 25% of gasoline sold was premium and 75% was regular (Kemp, 2016). Then the combined premium and regular gasoline price for each city was used in a weighted average for each province. The provincial price indices were weighed thus, based on prices is metropolitan areas for which Statistics Canada provides a price index:[9]

$$\text{Alberta Price} = 0.5 * \text{P}_{\text{Calgary}} + 0.5 * \text{P}_{\text{Edmonton}}$$

$$\text{BC Price} = 0.25 * \text{P}_{\text{Victoria}} + 0.75 * \text{P}_{\text{Vancouver}}$$

[8] It was necessary to go back an additional year in order to calculate the 12-month weighted lagging price average used later in this paper.
[9] All cities for which a gasoline price index is available from Statistics Canada City weightings are included in the provincial average. Weightings are based on approximate populations in each city, scaled relative to the provincial total.

$$\text{Ontario Price} = 0.25 * P_{\text{Ottawa}} + 0.65 * P_{\text{Toronto}} + 0.1 * P_{\text{Thunder Bay}}$$

To account for inflation, the general provincial CPI value was retrieved from CANSIM table 326-0020, and provincial gasoline prices were divided by their respective provincial CPI values so that prices were in constant-value dollar terms. Finally, a 12-month weighted lagging average was constructed for the price of gasoline in order to smooth fluctuations in price due to external factors, such as seasonal increases in the price of gasoline when refineries shut down after the winter for their yearly maintenance turnaround. The weighted lagging average price of gasoline was calculated using the following equation:

$$12 - \text{Month Weighted Average Price}_t = (12 * P_t + 11 * P_{t-1} + \cdots + 1 * P_{t-11})/78$$

The seasonally adjusted gasoline consumption for each province was then regressed using Stata against the price of gasoline and the price of gasoline based on the 12-month weighted lagging average. The results are detailed in Tables 8 to 11.

Table 8 - Gasoline regression results with raw price data. Price indicates the price of gasoline with carbon and transit taxes subtracted. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.*

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
ALBERTA	Consumption	Price	0.0146	-0.05442	0.03247
BC	Consumption	Price	0.5647	-0.33639	0.02143
		Price* Carbon Tax Transit Tax	0.7639	-0.10436 -1.4580 -2.4538	0.02486 0.19160 0.56344
ONTARIO	Consumption	Price	0.1547	-0.22252	0.03774

Table 9 - Gasoline regression results with raw price data, converted to demand elasticities. Price indicates the price of gasoline with carbon and transit taxes subtracted. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.*

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE(S)	CALCULATION	ELASTICITY OF DEMAND
ALBERTA	Consumption	Price	$-0.054 * \frac{79.41\ cents/litre}{155\ litres/month}$	-0.028
BC	Consumption	Price	$-0.336 * \frac{97.57\ cents/litre}{103\ litres/month}$	-0.318
		Price* Carbon Tax Transit Tax	$-0.104 * \frac{97.57\ cents/litre}{103\ litres/month}$	-0.099 -1.38 -2.32
ONTARIO	Consumption	Price	$-0.223 * \frac{88.65\ cents/litre}{133\ litres/month}$	-0.149

Table 10 - Gasoline regression results with 12-month weighted lagging price data. Price indicates the price of gasoline with carbon and transit taxes subtracted. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.*

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
ALBERTA	Consumption	Price	0.0197	-0.06599	0.03376
BC	Consumption	Price	0.6867	-0.35945	0.01762
		Price* Carbon Tax Transit Tax	0.7679	-0.19136 -1.3848 -0.86688	0.02948 0.18730 0.61363
ONTARIO	Consumption	Price	0.2016	-0.25306	0.03654

Table 11 - Gasoline regression results with 12-month weighted lagging price data, converted to demand elasticities. Price indicates the price of gasoline with carbon and transit taxes subtracted. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.*

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE(S)	CALCULATION	ELASTICITY OF DEMAND
ALBERTA	Consumption	Price	$-0.066 * \frac{79.19\ cents/litre}{155\ litres/month}$	-0.034
BC	Consumption	Price	$-0.359 * \frac{96.80\ cents/litre}{103\ litres/month}$	-0.337
		Price* Carbon Tax Transit Tax	$-0.191 * \frac{96.80\ cents/litre}{103\ litres/month}$	-0.180 -1.30 -0.815
ONTARIO	Consumption	Price	$-0.2016 * \frac{88.31\ cents/litre}{133\ litres/month}$	-0.134

<u>Alberta</u>

The regression of gasoline consumption in Alberta against price yielded almost no correlation for both the actual and 12-month lagging price values, with R-squared values of 0.0146 and 0.0197 respectively. However, a visual analysis of Figure 5, which plots seasonally adjusted per capita gasoline consumption and the 12-month weighted price for gasoline, reveals an inverse relationship between price and gasoline consumption over the longer term. High per capita consumption in the early 2000s coincided with low gasoline prices. As prices rose through the mid-to-late 2000s consumption fell considerably, though this may also be in part due to the 2008-2009 recession which substantially impacted Alberta's oil producers (and hence employment). Between 2010 and 2015 per capita consumption increased, likely due to both the falling price of gasoline and the recovery in Alberta's labour market.

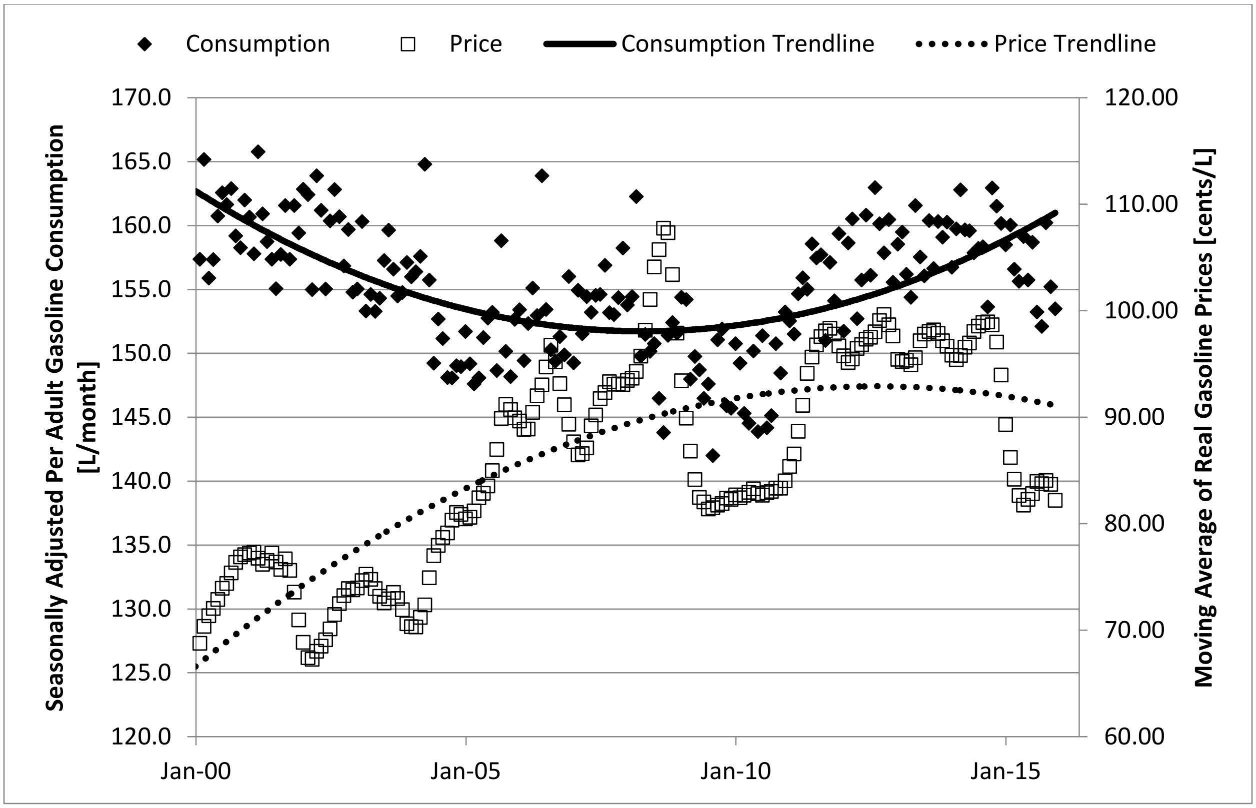

Figure 5 - Per capita gasoline consumption and 12-month weighted lagging price for Alberta with trendlines applied, January 2000 to December 2015. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.

The result is that while a formal regression does not detect a correlation between the price of gasoline and consumption, a visual survey of the data reveals that there is indeed a negative relationship between the two variables. It was considered whether an inverse relationship between gasoline prices and consumption could exist in Alberta, wherein higher oil prices lead to higher gasoline consumption through higher wages due to the economic importance of oil in Alberta. A regression was run to determine if this was true, but no correlation between oil prices and consumption was found. It may be that some of the economic stimulus from higher oil prices serves to offset the consumption-dampening effect of higher gasoline prices, but this is mere speculation. Based on graphical observations, it appears that there is a long-term relationship between higher gasoline prices and lower gasoline consumption, though this relationship is weaker in Alberta than in BC or Ontario.

British Colombia

Economic literature discussed in the Literature Review section of this paper indicates that salience is an important consequence of a commodity tax, especially when the imposition of the tax has been highly publicised, as has been the case for the BC carbon tax. It is therefore reasonable to distinguish between the market-dictated price of gasoline (which is taken to include far less controversial taxes such as GST) and highly debated taxes applied to the final retail price of gasoline. To incorporate the theory of tax saliency into this essay, the price of gasoline in BC was broken into three components; the carbon tax, regional transit levies on fuel and the price of gasoline with the aforementioned taxes subtracted from the price.

BC's carbon tax was introduced in July 2008 with a price of $10 per tCO_2e, equating to a price of 2.25 cents per litre of gasoline. This value increased by $5 per tCO_2e every July until a price of $30 per tCO_2e (equivalent to a price of 6.73 cents per litre) was reached in July 2012. The carbon tax is treated as a separate variable in the regression, and is adjusted for inflation using the BC CPI values found in CANSIM table 326-0020.

The theory of tax salience suggests that the phenomenon occurs when a tax is at the forefront of public discourse and there is widespread consumer knowledge (and often resentment) of the tax (Chetty, Looney, & Kroft, 2009). The two largest metropolitan areas in BC have transit levies applied to all gasoline sales within the region; the metro Vancouver region has a transit levy that applies to an area with 2,463,431 people and the Capital Regional District (Victoria plus outlying suburban areas) has a transit levy that covers and area containing 367,770 people. In a province of 4,648,005 people, these two regions cover approximately 61% of the provincial population (Statistics Canada, 2017). Both of these transit levies have received considerable media attention since their introduction, suggesting that tax salience could arise from these levies.

The Vancouver regional transit tax was introduced in 1999 at a rate of 8.0 cents per litre, and was raised in January 2005 to 12.0 cents per litre and again in April 2012 to 17.0 cents per litre (Bader, 2009; Nagel, 2011). The Capital Regional District transit tax was also introduced in 1999 at 2.5 cents per litre and was raised to 3.5 cents per litre in May 2008, a mere two months before the carbon tax was introduced. The transit tax in both regions was adjusted for inflation using the BC CPI found in CANSIM table 326-0020, and treated as a single separate variable in the regression according to the following equation:[10]

$$Transit\ Levy = 0.049 * Victoria\ Transit\ Levy + 0.32 * Vancouver\ Transit\ Levy$$

Since the regional transit levies do not apply to the entire province but instead to the two most urbanized regions, it was necessary to determine what fraction of total gasoline consumption occurred in the two regions covered by the transit levies. To determine this, gas consumption was calculated from levy revenues, as the tax rate per litre is known.

[10] The fractions preceding each municipal levy rate are determined based on the percentage of total provincial gasoline consumption purchased with the transit levy applied.

The 2015 Translink budget (metro Vancouver transit authority) states that revenues from the transit levy on fuels totaled $357 million in 2015, which at a rate of 17.0 cents per litre indicates that the levy was applied to 2.10 billion litres of fuel (both gasoline and diesel) in 2015 (Translink, 2015). According to figures from CANSIM table 405-0002, 4.66 billion litres of gasoline and 1.85 billion litres of diesel were consumed in all of BC in 2015, meaning that 71.5% of all fuel consumed was gasoline. Applying this percentage to the total amount of fuel consumed with the fuel levy applied means that 1.5 billion litres of gasoline was sold with the levy applied in 2015, or approximately 32% of the provincial total.

A similar approach was used for Victoria. In 2011, $11.5 million was raised by the regional levy, representing 329 million litres at a tax rate of 3.5 cents per litre (Victoria Transportation Policy Institute, 2012). In the same year, gasoline consumption accounted for 67% of the provincial fuel total, yielding gasoline use in the Capital Regional District of 220.6 million litres or 4.9% of the provincial total.

Inclusion of the transit levy is prudent for two reasons; it provides an opportunity to demonstrate the theory of tax salience and it reduces omitted variable bias in the regression of consumption on price and the carbon tax. Without the inclusion of the transit levy any changes in consumption caused by the transit tax would be attributed either to variations in the market price of gasoline or changes in the carbon tax rate. This would reduce the accuracy of the regression.

After inclusion of the transit and carbon taxes as separate variables, the regression for gasoline consumption in BC is specified thus:

$$y_t = \beta_1 P_t + \beta_2 C_t + \beta_3 T_t + \varepsilon_t$$

Where:

y_t = consumption of gasoline during month t per driving age person, seasonally adjusted
P_t= price of gasoline with carbon and transit taxes subtracted during month t, inflation adjusted
C_t = carbon tax levied on gasoline during month t, inflation adjusted
T_t = transit levy applied to gasoline during month t, inflation adjusted
ε_t = error term

Tables 8 and 10 detail the results for two different regressions; the former using raw price data and the later using price data calculated with a 12-month weighted lagging average. With the raw data, gasoline has a price coefficient of -0.10, the carbon tax has a coefficient of -1.46, and the transit levy has a coefficient of -2.45. The quality of the results from the raw price data regression is dubious, as there are many factors that can impact the price of gasoline in a given month, creating noise in the data that distorts the true elasticities of demand. Instead, the results of the weighted lagging average should be more accurate.

With the 12-month lagging price data, gasoline has a price coefficient of -0.19, the carbon tax has a coefficient of -1.38, and the transit levy has a coefficient of -0.87. This indicates that a 1 cent rise in the price of gasoline not caused by an increase in tax is expected to reduce per capita monthly consumption by 0.19 liters, while a 1 cent rise in the carbon tax is expected to reduce per capita monthly consumption by 1.38 liters and a 1 cent rise in the transit levy will lower per capita consumption by 0.87 liters per month. These values suggest a saliency factor of 7.2 for any increases in the carbon tax, which is remarkably similar to the results found by Rivers and Schaufele. The transit saliency factor of 4.6 is also significant, but the data is less conclusive on this tax (note the relatively large standard error in relation to the coefficient value for the transit levy).

Figure 6 plots seasonally adjusted per adult gasoline consumption and the 12-month weighted lagging average gasoline price (all taxes included) for BC, with trendlines applied. The vertical line shows when the carbon tax was introduced. Note that after the carbon tax is introduced the rate of decline in gasoline consumption remains constant while the rate of price increase slows. This is a visual indication of the salience of the carbon tax.

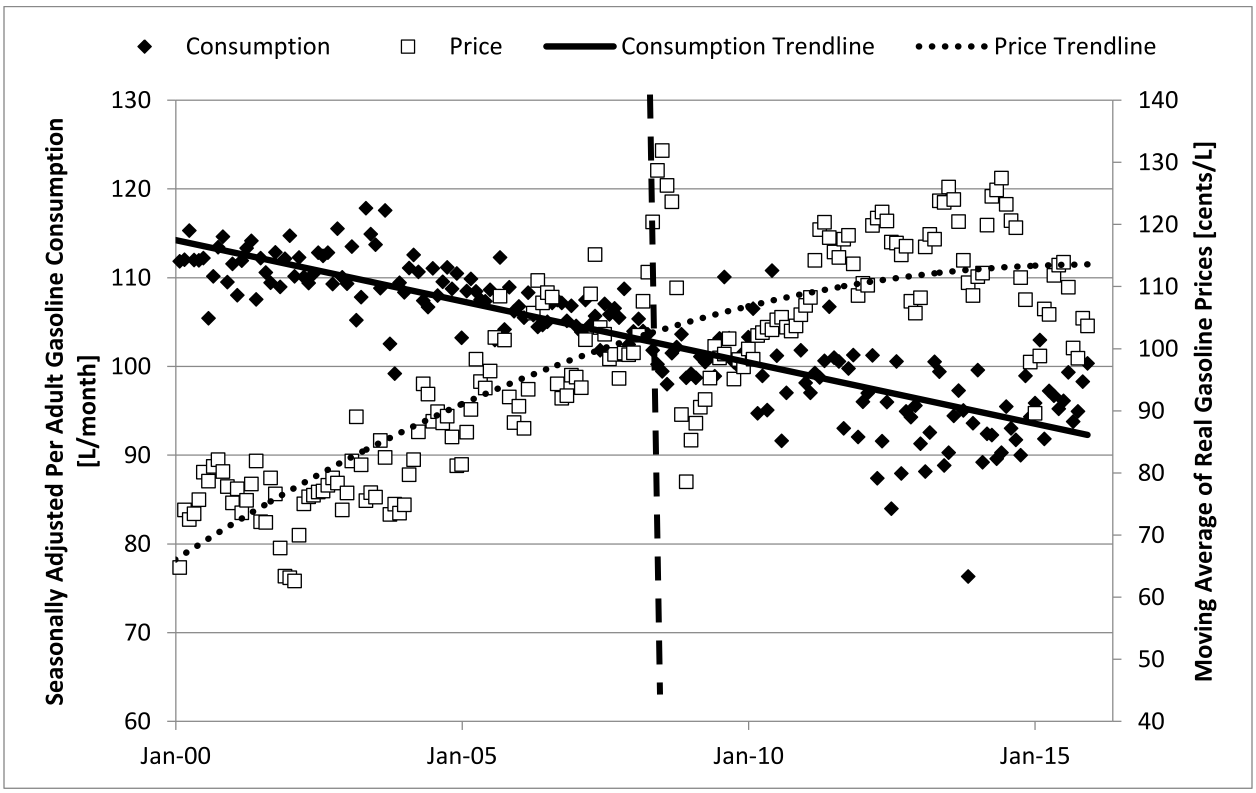

Figure 6 - Per capita gasoline consumption and 12-month weighted lagging price for BC with trendlines applied, January 2000 to December 2015. Vertical line represents introduction of carbon tax. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0003.

Ontario

For the benefit of comparison, gasoline consumption in Ontario was analysed to provide a control group to contrast with the results from Alberta and BC. Ontario was selected as a control as the province did not have a carbon pricing scheme during the time period studied, nor is the Ontario economy reliant on the production of fossil fuels, providing a contrast to BC and Alberta respectively (Ryan, 2013).

The correlation between the price and consumption of gasoline is not particularly good in Ontario, with an R-squared value of 0.15 for the raw price data and an R-squared value of 0.20 with the 12-month weighted price data. However, the 95% confidence interval for the coefficient is -0.30 to -0.15 for the raw data and -0.33 to -0.18 for the 12-month average, evidencing a negative relationship between the price of gasoline and consumption of gasoline in Ontario. Indeed, the calculated 12-month lagging average coefficient for Ontario of -0.20 is remarkably close to the market-driven price coefficient of -0.19 observed for BC. These values (when converted into demand elasticities) are also quite close to gasoline demand elasticity values for Canada found in literature (Nagy, 1993).

This negative relationship is further evidenced by graphical analysis of the data. Figure 7 plots the seasonally adjusted per driving age person consumption of fuel in Ontario against the 12-month weighted average of gasoline prices from January 2000 to December 2015, with trendlines applied to both data sets. Real gasoline prices rise during the time period studied, although there is a noticeable reduction in the rate of price growth in the later years surveyed. This juxtaposes a trend of decreasing gasoline consumption that appears to be trending downward at an increasing rate. Similar to BC, there appears to be an upward tick in consumption corresponding to a downward movement in gasoline prices near the end of the time period.

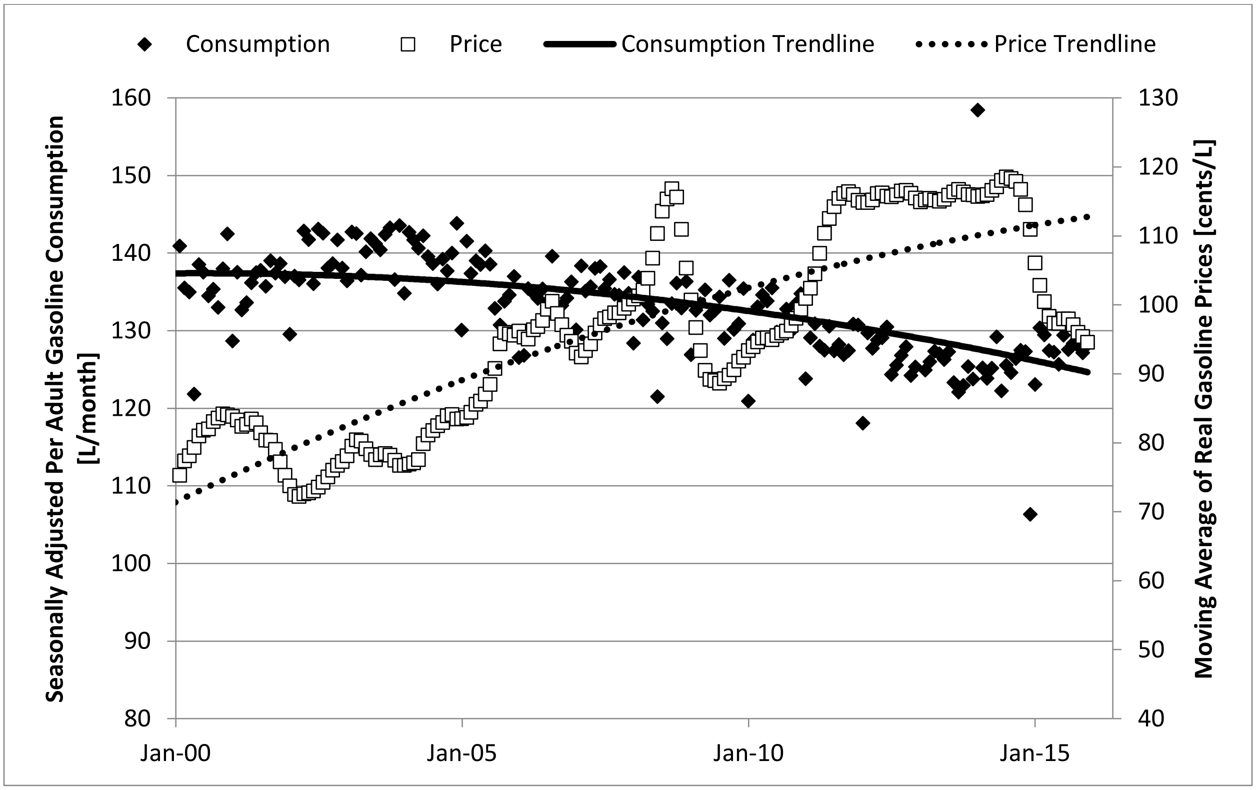

Figure 7 - Per capita gasoline consumption and 12-month weighted lagging price for Ontario with trendlines applied, January 2000 to December 2015. Sources: CANSIM tables 051-0001, 326-0009, 326-0020.

Diesel

In addition to analysing gasoline consumption, trends in diesel consumption are considered in order to provide a more comprehensive analysis on oil products and the transportation sector. While Statistics Canada does not provide monthly Diesel consumption figures for each province, annual consumption data is available from CANSIM table 405-0002. For the analysis of annual diesel consumption data is used for the years 2000 to 2015, with consumption figures provided on a net basis.

While use of annual consumption data certainly reduces the quality of any regression, for the purposes of this essay annual data is likely sufficient to observe macro-level trends in diesel consumption. The major weakness in using annual data is that it is not practicable to separate the carbon and transit taxes in BC from the market price of diesel (as was done for gasoline), since the reduced number of data points would make any observations statistically insignificant. A test run of this regression was attempted, with annual diesel consumption data for BC being regressed against the annualized price, carbon tax rate and transit levy rate. The regression results for carbon tax and transit tax gave extremely poor-quality results, so it was decided that the regression for BC should not use separate variables for a carbon and transit tax. This lack of variable separation is not overly detrimental in the case of diesel, as the impact of tax saliency should not distort the regression outcomes for diesel by as much by as with gasoline. This is because the majority of diesel is used in commercial applications where purchasing decisions are typically made on a cost-benefit analysis, whereas gasoline purchasing decisions are primarily made by consumers who have the negative feelings towards a tax that causes saliency to arise (US Energy Information Agency, 2017).

Monthly price data for diesel in major Canadian urban centres was retrieved from CANSIM table 326-0009 for January 2000 to December 2015. This price data was adjusted to control for inflation using the CPI index for each province from CANSIM table 326-0020, then an average was taken for each year from 2000 to 2015. Annual consumption of diesel was then regressed on the price of diesel in each province, with the results detailed in Table 12.

Table 12 - Regression results for annual diesel consumption and price. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0002.

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
ALBERTA	Diesel Consumption	Diesel Price	0.7007	8.6798	1.5162
BC	Diesel Consumption	Diesel Price	0.4846	1.6392	0.45179
ONTARIO	Diesel Consumption	Diesel Price	0.0963	-0.64821	0.53081

The results are surprising in that consumption is positively correlated with the price of diesel in Alberta, and to a lesser extent in BC. This is strange, as it would typically be expected to see the opposite response since consumption typically falls when the price of a product rises. This result lead to the hypothesis that the positive correlation (particularly in Alberta) between diesel prices and consumption was due to increases in economic activity associated with higher oil prices, and that in the regressions performed above diesel was serving as a proxy for oil prices. Unlike gasoline, which is primarily used by consumers for personal transportation, diesel is predominantly used in commercial applications such as trucking and heavy equipment operation (US Energy Information Agency, 2017). Therefore, it is reasonable to expect that increases in economic activity are correlated with increases in demand for diesel. Further, many of the activities associated with spending on oil production are diesel-use intensive, such as construction oil production facilities or trucking oil from collection batteries to shipping terminals.

To validate this hypothesis, monthly West Texas Intermediate (WTI) oil price data was retrieved from the US Energy Information Agency and adjusted to each province's CPI to account for inflation. These monthly oil price values were then averaged to create yearly price values and converted into Canadian dollars using the average exchange rate for that year.[11] Per capita diesel consumption was then regressed against oil prices, with the results detailed in Table 13.

Table 13 - Regression results for annual diesel consumption, diesel price and the price of oil. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0002, US Energy Information Agency.

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE(S)	R-SQUARED VALUE	COEFFICIENT	STANDARD ERROR
ALBERTA	Diesel Consumption	Oil Price	0.7200	7.7968	1.3000
		Oil Price Diesel Price	0.7351	3.6023 4.8116	4.1774 3.7018
BC	Diesel Consumption	Oil Price	0.4841	1.8343	0.50607
		Oil Price Diesel Price	0.5033	0.94703 0.85689	1.3550 1.2103
ONTARIO	Diesel Consumption	Oil Price	0.0338	-0.3450	0.49332
		Oil Price Diesel Price	0.1819	1.5232 -2.2287	1.3054 1.4523

[11] It is possible to average oil prices and exchange rates in this manner as the production volumes of oil from Alberta do not fluctuate much throughout the year.

Table 14 - Calculation of elasticities of demand for diesel regression results. Sources: CANSIM tables 051-0001, 326-0009, 326-0020, 405-0002, US Energy Information Agency.

PROVINCE	DEPENDANT VARIABLE	INDEPENDENT VARIABLE	CALCULATION	ELASTICITY OF DEMAND
ALBERTA	Diesel Consumption	Oil Price	$7.80 * \frac{61.43\ dollars/barrel}{1143\ litres/year}$	0.419
		Diesel Price	$8.61 * \frac{76.24\ cents/litre}{1143\ litres/year}$	0.574
BC	Diesel Consumption	Oil Price	$1.83 * \frac{65.15\ dollars/barrel}{472\ litres/year}$	0.253
		Diesel Price	$1.64 * \frac{93.02\ cents/litre}{472\ litres/year}$	0.323
ONTARIO	Diesel Consumption	Oil Price	$-0.345 * \frac{63.85\ dollars/barrel}{476\ litres/year}$	-0.046
		Diesel Price	$-0.648 * \frac{85.04\ cents/litre}{476\ litres/year}$	-0.116

The data reveals that oil prices are an excellent predictor of diesel consumption in Alberta, a good predictor in BC, and there is almost no correlation between the price of oil and diesel consumption in Ontario.

Electricity

When the Government of Alberta announced the provincial carbon tax in 2016, they also announced legislation mandating the phase out of coal from Alberta's electricity supply by 2030, with the Federal Government subsequently announcing a similar timeline for the complete phase out of coal across the country (Government of Alberta, 2017; McCarthy, Shawn, 2016). Presently, coal is used to generate over half of all electricity used in Alberta, so the timeline mandated by both levels of government will require a rapid shift away from coal to other energy sources. Given the short timeline for substituting over 50 percent of electricity generation, it seems reasonable to conclude that the mandated phase out of coal will have a greater impact on coal use in Alberta than the carbon tax. Therefore, looking at the experiences of other jurisdictions where similar government-mandated coal phase outs have occurred will provide useful insight into what Alberta should expect over the coming decade.

In 2003, Ontario committed to eliminate all of its coal-fired electricity generation by 2007. In order to maintain a reliable power supply, this deadline was extended to 2014, when Ontario shut down its last coal-fired generating station in Thunder Bay, following the closure of Nanticoke and Lambton generating stations in 2013. This represented a substantial change in the fuel sources for electricity generation in the province, as coal accounted for 25% of all electricity generated in Ontario as recently as 2003 (Ontario Ministry of Energy, 2015). Since the phase out was mandated, coal has comprised a progressively smaller fraction of the total electricity mix in Ontario. Figure 8 uses data from CANSIM tables 127-0007 and 128-0014 to calculate the fraction of electricity generated from coal and natural gas (along with a combined total for fossil fuel power generation) from 2005 to 2015. Data was not available for the years 2000 to 2004. Figure 8 reveals a rapid decline in the use of coal for electricity generation in Ontario, accompanied by a slight rise in the use of natural gas.

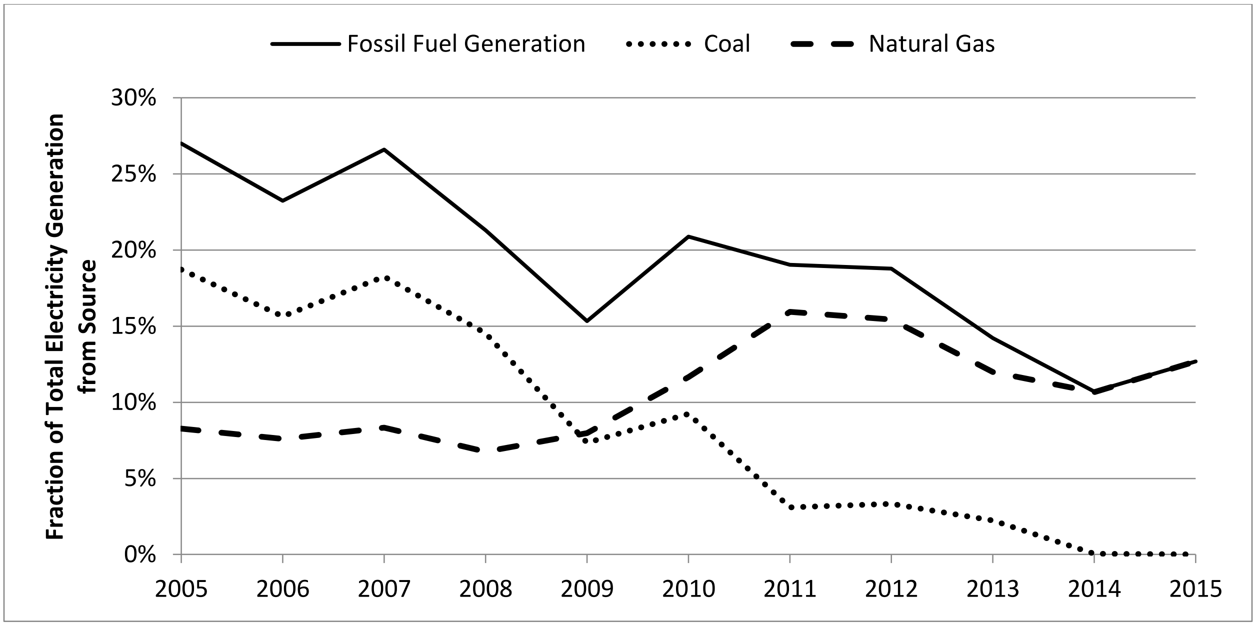

Figure 8 - Percentage of electricity generated from coal and natural gas in Ontario, 2005 to 2015. Source: CANSIM tables 127-0007 and 128-0014.

This contrasts with Alberta, where coal continues to be the fuel source for over 50% of electricity generation in the province. Figure 9 uses the same data sources and methods as Figure 8 to illustrate the share of natural gas and coal used in electricity generation in Alberta. While there has been a shift away from coal to natural gas usage in Alberta, with coal's share of electricity generation falling from 65% in 2005 to 54% in 2015 and natural gas' share increasing from 25% to 38% over the same time period, the overall fraction of electricity generated from fossil fuels in Alberta has remained stable at about 90% for the past decade. This is expected to fall in coming years, as the Government of Alberta has mandated that 30% of electricity must come from renewable sources, such as wind, solar and hydro by 2030 (Government of Alberta, 2017).

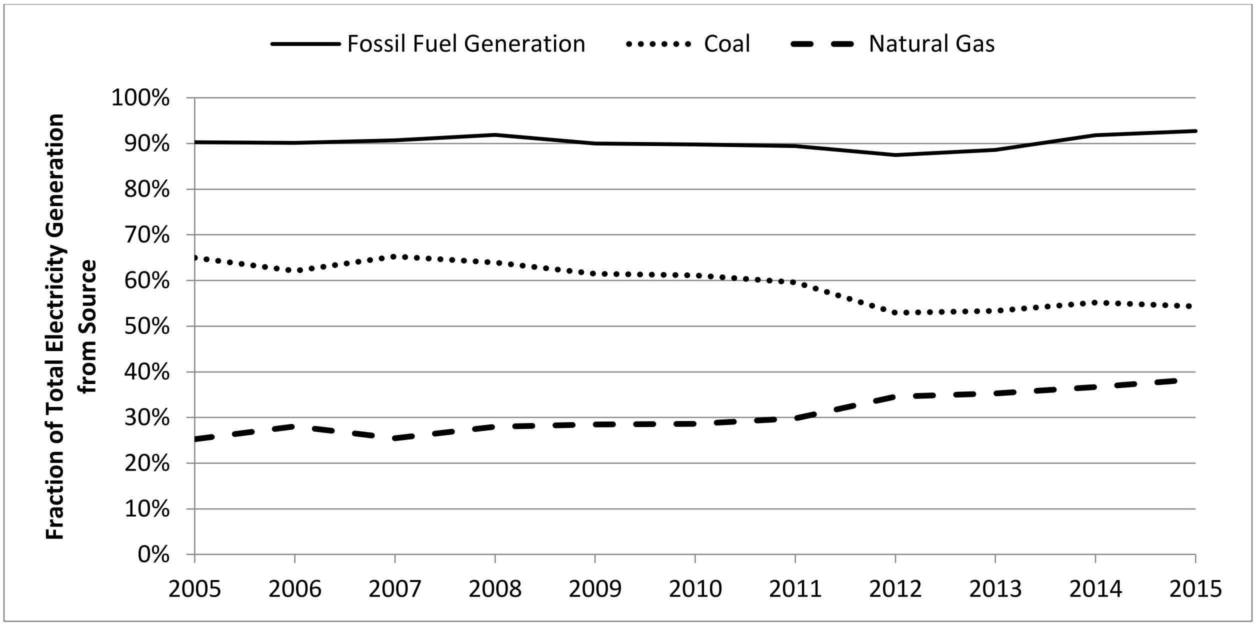

Figure 9 - Percentage of electricity generated from coal and natural gas in Alberta, 2005 to 2015. Source: CANSIM tables 127-0007 and 128-0014.

Finally, in BC approximately 90% of all electricity generated comes from renewable sources, with hydro playing an enormous role in the province's energy supply. Natural gas accounts for approximately 5% of the electricity generated, with BC not using coal for power generation during the 2000 to 2015 time period (Statistics Canada, 2016). While it is true that BC frequently imports electricity from coal-burning Alberta, on an annual basis BC is a net exporter of electricity to Alberta (Government of BC, 2017).

While BC has a fundamentally different power generating network in place than Alberta, Ontario's experience should provide insight into what Alberta can expect during its phase out of coal.

Figure 10 details the price of electricity in Ontario and Alberta from 2006 to 2015, with data retrieved from the Ontario Energy Board and the Alberta Utilities Commission, their respective electricity price regulating bodies. Caution should be exercised when comparing electricity prices across provinces, as delivery and other charges not captured in the energy charge data can substantially alter the final price paid for electricity. However, the data presented in Figure 10 provides useful information on the trajectory of electricity prices in each province. In Alberta, electricity prices have fallen since 2006, coinciding with a rise in electricity usage in the province. In contrast, electricity prices have risen sharply in Ontario while the total quantity of electricity generated has remained flat. The fact that Ontario has experienced an increase in price, which some commentators attribute partially to the phase out of coal and the implementation of renewable energy projects, suggests that Alberta will experience an electricity price increase as it transitions away from coal (Jackson, Stedman, Aliakbari, & Green, 2017).

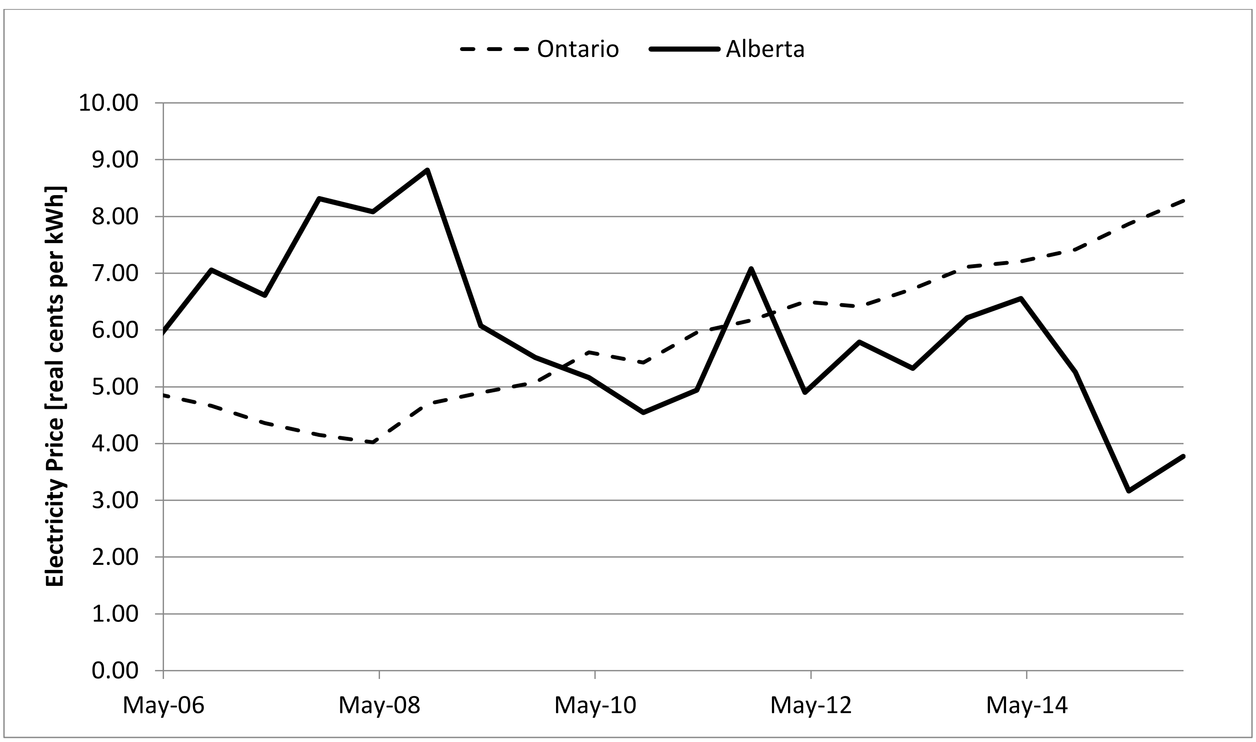

Figure 10 - Electricity prices in Alberta and Ontario, 2006 to 2015. Sources: CANSIM table 326-0020, Alberta Utilities Commission (2017) and Ontario Energy Board (2017).

Discussion of Results

In this section a projection is made for fossil fuel consumption and greenhouse gas emissions in Alberta as a result of the implementation of the carbon tax and other green energy initiatives. The projection uses results from the analysis of the three provinces to project impacts on the major emissions sources analysed in this paper; natural gas, gasoline and diesel and electricity generation.

Natural Gas

Residential

The key observation from the residential natural gas consumption data is the close correlation of consumption with outdoor temperature, indicating that in the short-term outdoor temperature is the independent variable that determines consumption, which in turn determines price. This suggests that in the short term the consumer response to changes in the price of residential natural gas is highly inelastic. This low short-term elasticity is very understandable, as it is difficult and costly for a household to change the type of heating system in their house, and a household cannot simply decide to allow the indoor temperature to be substantially below room temperature because the price of natural gas has increased. Economic theory dictates that the burden of Alberta and BC's carbon tax will fall on the consumer of the natural gas as a result of their inelasticity, which is perhaps a reason why the Government of Alberta is using some of the carbon tax revenue to provide a credit to low income households. The low short-term elasticity of demand for residential heating fuel means that in the short-term implementation of a carbon tax will have little effect on the quantity of natural gas burned, and hence will not cause a significant short-term reduction in carbon emissions. Since the ultimate goal of policymakers who introduce a carbon tax is to reduce greenhouse gas emissions, the short-term results do not bode well for the success of the carbon tax, as the carbon tax on residential natural gas is a regressive tax on a necessity.

In the longer term, households may respond to sustained higher natural gas prices by looking to switch energy sources or to insulate their homes to reduce heating costs. As discussed in the literature review section of this essay, new technologies and government programs are helping to provide alternatives to consumption of conventional energy, which will increase the elasticity of demand shown by consumers to such conventional energy sources. However, the results of the annual data show a positive relationship between consumption and price, suggesting that price does not drive consumption of natural gas. As both prices and consumption have fallen over the period evaluated, it appears that improvements in the efficiency of houses and heating systems are driving down natural gas consumption despite lower prices. While the salience of a carbon tax may serve to accelerate the decrease in per capita consumption, there is evidence in the data that the consumer response to price is highly inelastic (approaching zero), if there is a response to price at all. This means that the carbon tax on residential natural gas is merely serving as a tax on home heating without causing meaningful changes in behavior.

Commercial

The trends observed in commercial consumption of natural gas are very similar to those observed in residential consumption. The close correlation of monthly natural gas consumption to outdoor temperature suggests that most commercial use of natural gas is used for space heating, and that short-term elasticity of demand is extremely low. This makes sense, as commercial spaces such as retail stores and service industry businesses have little choice but to heat their facilities regardless of the price of natural gas. A similar lack of responsiveness to changes in natural gas price is observed in the yearly analysis, and with an overall downward trend in both consumption and price it is reasonable to conclude that factors other than price are the main drivers of long-run trends in commercial natural gas consumption.

Industrial

As mentioned previously, there is a high degree of correlation between industrial natural gas use in Alberta and bitumen production, with bitumen-extracting processes accounting for the vast majority of natural gas consumed in the province. This is because it takes three barrels of water turned into high temperature steam to produce one barrel of bitumen from a typical steam assisted gravity drainage (SAGD) oil sands operation. This requires a great deal of energy, which is derived from natural gas (Alberta Energy, 2016). However, knowing of this correlation does not mitigate the difficulty in determining the causality of the negative relationship observed between industrial natural gas use and price in Alberta. Fundamental changes in technology (such as hydraulic fracturing) have greatly increased the supply of natural gas in recent years, and it is not certain lower natural gas prices have driven the increases in bitumen production or if increases in bitumen production have driven the increase in natural gas usage (US Energy Information Agency, 2016). The two possible explanations are as follows:

The first explanation is that high oil prices led firms to invest in bitumen extraction facilities, which in turn caused an increase in the industrial demand for natural gas in Alberta. In isolation, this increase in demand should have caused the price of natural gas to increase, but increases in natural gas supply external to this essay's model (likely due in large part to improvements in natural gas production technology) outweighed the increases in demand, and instead caused the price of natural gas fall over this time period. According to this explanation, the price of natural gas has little overall impact on its consumption level by industry in Alberta.

The second explanation is that the decreasing price of natural gas between 2006 and 2015 caused the expected cost of operating a bitumen extraction facility to fall, which made these plants a more attractive investment. This lower cost of natural gas was responsible for the increase in both industrial natural gas usage and bitumen production in Alberta. According to this explanation, the price of natural gas is closely linked to its consumption level.

Essentially, the difference between these explanations is whether the lower price of natural gas was a required condition for the increase in bitumen production to occur, or if the increase in production would have occurred regardless of the observed decrease in the price of natural gas.

In order to determine which case is correct, it is useful to know how significant the cost of natural gas is in the overall cost of oil sands production. A report by the Canadian Energy Research Institute (CERI) released in February 2017 breaks down typical bitumen production costs in Alberta, including fixed capital costs and allows for a 12 percent return on investment. The report concludes that in-situ bitumen production costs total $43.31 per barrel and mining costs total $70.08 per barrel. Of this, natural gas costs represent $5.87 per barrel or 13.6% of in-situ costs and $2.68 or 3.8% of mining costs. While these fractions are certainly not insignificant, it seems unlikely that they are determinative of the rate of investment in Alberta's oil sands.

However, the percentage increase in the price of natural gas due to the carbon tax will be significant, as industrial natural gas prices in Alberta averaged 9.60 cents per cubic metre in 2015, and with a $30 per tCO_2e carbon tax rate (as of 2018) of $1.517 per gigajoule or 5.65 cents per cubic metre, the cost of industrial natural gas will increase by 59% as a result of the carbon tax. It must be noted that the price of natural gas in 2015 was exceptionally low, having fallen from 28.38 cents per cubic metre in 2005, but the increase in price due to the carbon tax is nonetheless significant. This increase also needs to be considered in the context of a low oil price environment. Therefore, the impact of the carbon tax on oil sands production is difficult to determine, as it will greatly depend on the sensitivity of investment by oil-producing firms to the higher cost of natural gas. Additionally, there are many other pressing factors that determine investment decisions for oil sands producers, such as pressure from environmental groups to invest in less carbon-intensive energy projects and lack of access from Alberta to international oil export markets (The Economist, 2014; Bakx, Kyle, 2017).

Natural gas use in BC and Ontario appears to fluctuate in accordance with temperature, suggesting an inelastic response. In contrast, industrial natural gas use in Alberta correlates more with price (certainly in long-term decisions) making the response to changes in price more elastic, hence a carbon tax can be expected to not simply be borne by the consumers of the gas but will cause modifications of behavior. While decisions on industrial investment in Alberta certainly consider many factors besides the price of natural gas, the relative elasticity of the response suggests that a carbon tax in Alberta will cause a larger reduction in emissions than the same tax would from industrial emitters in BC or Ontario. The desirability of this response by industry is a matter of debate, as it has the potential to both greatly reduce greenhouse gas emissions and to reduce investment in a major industry in Alberta.

Gasoline

The results from the 12-month weighted lagging average price regression with BC produced results remarkably similar to those found in literature, with this essay finding a saliency factor of 7.2 for the BC carbon tax compared to a saliency factor of 7.1 found by Rivers and Schaufele. The similarity of this essay's results serves as independent affirmation of the findings on saliency by Rivers and Schaufele, as the data for this essay was prepared without reference to the specific data preparation methods used by Rivers and Schaufele. Therefore, it appears quite well-founded to conclude that the salience factor for the BC carbon tax is in the range indicated in both papers.

One difference between this essay's analysis of the BC gasoline market and the analysis done by Rivers and Schaufele is that this essay considers the regional transit levies applied to fuel sold in the metro Vancouver area and the Capital Regional District. This was done because these transit levies have received considerable media attention, and thus would also be subject to the increased consumer awareness that Chetty et al. discuss as exacerbating changes in consumer behavior. Failure to include the transit tax as a variable would raise the problem of omitted variable bias, as changes in consumer behavior due to the transit tax would be inaccurately attributed by the regression to other variables.

The analysis conducted in this paper found the salience factor for the BC transit taxes to be 4.6, which is certainly a significant finding. However, the results from the transit tax are somewhat less convincing than those from the carbon tax. This lack of precision is evidenced by the relatively large standard deviation for the transit tax, along with a 95 percent confidence interval that spans from -2.08 to 0.34 compared with a confidence interval of -1.75 to -1.02 for the carbon tax.

One issue with analysing the transit tax as a separate variable is the consumption data for gasoline used in this essay are for the entire province, while the transit tax applies only to certain regions of the province and there is no way of measuring with the utilized data whether the fluctuations in consumption occurred within the regions covered by the transit tax. Additionally, there is a large gap between each time the transit tax is raised, with the result that media attention dies down and the tax falls out of the public discourse as people become accustomed to paying the tax. This may have the effect of diluting the salience of the tax, as the principle of salience requires that the public be aware of the tax and it is this awareness that drives the disproportionate response in behavior. Indeed, this same phenomenon may begin to cause consumers to pay less attention to the carbon tax, as the BC carbon tax has not increased since July 2012 and media coverage of the tax has fallen. An interesting point of future research would be whether media coverage of the federal carbon tax impacts the salience of BC's carbon tax, even though the federal tax will not impact BC until 2021.[12]

A positive outcome of the analysis is the similarity in the coefficients of Ontario and BC, with coefficients being determined as -0.20 and -0.19 respectively, equating to demand elasticities of -0.134 and -0.180. While the price regression for Ontario did not produce the best correlation, yielding an R-squared value of 0.2016, visual analysis of Figure 7 shows that there generally exists a negative relationship between price and consumption, suggesting that the low R-squared value may be due to short-term fluctuations in the relationship.

Given the low correlation between price and consumption in Alberta, it is difficult to use the results from Ontario and BC to project a change in consumption in Alberta due to the imposition of a carbon tax. In order to apply the concept of tax saliency, it is necessary to have a market-price demand elasticity so that the saliency factor can be applied and the ultimate change in consumption can be predicted. While there is graphical evidence that gasoline consumption in Alberta has a negative relationship to price, without an estimate of market-price demand elasticity it is challenging to project changes in demand accurately.

One approach would be to use the demand elasticity range found in the regressions for BC and Ontario (-0.180 and -0.134) and those in literature (-0.21) to make a projection for Alberta. If this method were applied using elasticities of -0.134 and -0.21 (lowest and highest), the predicted outcome of the carbon tax is that monthly per adult gasoline consumption will fall by

[12] The federal carbon tax mandates a minimum carbon price of \$10 per tCO_2e in 2018, rising by \$10 per year until a final price of \$50 per tCO_2e is reached in 2022. As of 2021, BC's carbon tax will need to be raised to meet the federal minimum.

between 13.6 to 21.2 litres per month or 163 to 255 litres per year. This equates to a per adult emissions reduction of 0.38 to 0.59 tCO_2e per year, which is a province-wide reduction of 1.3 to 2.0 million tCO_2e. On a percentage basis, this is a 0.47% to 0.74% reduction in total provincial greenhouse gas emissions. However, these assumptions represent an optimistically large response to the carbon tax, as the analysis done in this essay suggests that Alberta has a smaller response to changes in price than other jurisdictions studied.

The broader implication of this paper's findings is that the high saliency observed with the imposition of a carbon tax on gasoline means that prices on carbon are potentially an effective tool for reducing carbon emissions from gasoline. Traditional economics suggests that a tax on a product with a low demand elasticity (a category into which gasoline is typically placed) will fall on the seller and the buyer in proportion to their elasticities of supply and demand. Because consumers are assumed to have a low elasticity of demand for gasoline, the previously expected result is that the cost of any tax imposed on the product will fall heavily on the consumer while eliciting little change in consumption levels. The finding of a high level of tax salience suggests that these taxes are in fact relatively effective at changing behavior, since tax saliency in effect increases the elasticity of demand which in turn means that less of the cost of a tax falls on the consumer, and the change in consumption level is greater.

It may be tempting to argue that a province-wide emissions reduction of 0.47% to 0.74% in Alberta is not large enough to warrant the possible economic fallout from imposing a carbon tax. However, the achieved emissions reduction is small on a percentage basis because Alberta's greenhouse gas emissions are so high. The same 1.3 to 2.0 million tCO_2e fall in emissions would equate to a 2.1% to 3.3% emissions reduction in BC, a province with a similar population to Alberta. The emissions reduction is material, but in relation to Alberta's overall emissions level the expected reduction in emissions from gasoline due to the carbon tax is small.

Other Error Sources

Another source of error is the fact that gasoline prices are only available for the major urbanized regions and do not necessarily reflect the average price paid for gasoline in the province. For example, in BC gasoline prices are available only for Vancouver and Victoria, which represent 32 and 4.9 percent of total provincial gasoline consumption respectively. This means that the majority of the gasoline purchased in BC is not purchased in regions where a price index is available, hence there may be some inaccuracy in constructing the provincial price index.

One additional source of error is that changes in technology are not factored into the regressions. Ontario provides generous government incentives for electric and hybrid cars, and US regulations (which spill over into the Canadian auto market) have required car makers to produce increasingly efficient vehicles (McCarthy, 2012). Falling per capita consumption of gasoline may be due in part to consumers purchasing more efficient vehicles which reduces demand for gasoline while not altering consumers' driving behavior. While it could be argued that some consumers purchase new vehicles to reap the benefits of higher fuel efficiency, there are doubtless many consumers for whom the increased fuel economy is not a major factor in their purchase of a new vehicle. The reduction in consumption achieved in these cases is not due to price considerations, adding error to the above model which assumes that price is the only motivating factor for reductions in consumption.

Diesel

The results of the diesel consumption analysis largely speak to the relative dependence of each province's economy on resources, and specifically each province's dependence on oil production. When the price of oil is high in Alberta, this stimulates economic activity which in turn raises the demand for diesel, as diesel is overwhelmingly used in commercial applications such as trucking and heavy equipment operation. Alberta's diesel consumption coefficient of 7.8 indicates that for every dollar the average annual price of a barrel of oil increases the per capita consumption of diesel fuel rises by 7.8 liters in the province. On a percentage basis, this works out to be a demand elasticity of 0.42. This is far more than in neighbouring BC, where a one dollar increase in oil prices translates into a much more modest diesel consumption increase of 1.8 liters per capita per year, translating into a demand elasticity of 0.25.

The correlation in BC is more difficult to explain as BC produces little oil, so it is strange that increases in the price of a product that is largely imported into the province causes a rise in diesel consumption, which is treated here as a proxy for economic activity. However, many economic pundits have observed global commodity prices tend to move together, based on global economic growth (The Economist, 2017). BC is a major exporter of many natural resources, so increases in the price of oil could merely coincide with increases in the prices other resources that BC does produce in large quantities, explaining the increase in diesel consumption as investment in production of those resources rises (BC Stats, 2017).

Finally, Ontario's low correlation indicates that the economy does not rely on resource exports to fuel economic growth. This makes intuitive sense, as most economists consider Ontario to have a highly diversified economy, and Ontario has essentially no domestic oil production (Ryan, 2013; Statistics Canada, 2017).

The results of the diesel consumption analysis cast doubt over the wisdom of applying a carbon tax to diesel in Alberta, as the results indicate that diesel is a product purchased as part of investment in oil-producing infrastructure, so it could be argued that the carbon tax is essentially a tax on investment. Further, since diesel is primarily used for business-related applications, a tax on diesel raises the input costs for business, which also serves to deter investment and reduce economic activity. This is not to say that the introduction of a carbon tax on diesel in Alberta will not lead to a reduction in diesel consumption, as the mere existence of a positive relationship between diesel consumption and price does not mean that the tax will not cause businesses and consumers to change their behavior and purchase less diesel. The issue is whether the tax will cause changes in behavior (particularly by businesses) that will have an outsized negative impact on the economy. This is certainly a topic that merits further research.

Electricity

With the phase out of coal-fired electricity generation mandated at both the federal and provincial level, Alberta looks set to retire all of its coal-fired electricity generating stations by 2030. As coal currently serves as the fuel source for 54% of Alberta's electrical energy, this shift looks likely to cause a major change in the way that Alberta generates its electricity. Emissions from electricity generation currently account for 14% of Alberta's total greenhouse gas emissions, and since coal is the heaviest emitting power source, any move away from coal to other fuel sources will result in a reduction in greenhouse gas emissions. The most likely replacement for coal is natural gas, as natural gas is abundant and cheap in Alberta, and natural gas power plants can be built and become operational on a relatively short timeline (Alberta Utilities Commission, 2017).

The Alberta government has also mandated that 30% of electricity used should come from renewable sources, such as wind, solar, hydro or geothermal. These sources produce no marginal emissions for every unit of energy generated. Therefore, it would be reasonable to expect that 30% of Alberta's energy will come from non-emitting sources and the remaining 70% will be generated using fossil fuels by 2030. By utilizing this information and electricity use projections for Alberta, it is possible to forecast the reduction in emissions in Alberta due to the phase out of coal.

Emissions Reduction Calculation

According to the US Energy Information Agency, burning enough natural gas to generate one million British thermal units (Btus) of thermal energy releases 53 kilograms of CO_2. The CO_2 emissions released from burning coal vary based on the quality of coal, but generally fall in the range of 93 to 104 kilograms of CO_2 per million Btu (US Energy Information Agency, 2017). Therefore, the chemical difference between natural gas and coal allows natural gas to emit approximately half as much CO_2 compared with generating the same about of heat from burning coal. This is a large emissions reduction in itself, but the increased efficiency of natural gas generating stations adds to the emissions reduction gained by switching to natural gas.

The newest combined-cycle natural gas electricity generating stations are capable of a heat energy to electrical energy conversion rate of 60 percent, meaning that 60 percent of the thermal energy of combusting the natural gas in converted into electrical energy (Siemens, 2017). Alberta's existing combined cycle natural gas plants have efficiencies between 46 and 49 percent, and existing coal plants have thermal efficiencies between 23 and 38 percent (JEM Energy, 2004). Before the introduction of the carbon tax, 12 of Alberta's 18 coal-fired generating stations were slated to retire by 2030 before the mandatory closing legislation was passed (Government of Alberta, 2017). Only the newest plants (with the highest efficiency) were to be kept open, so an energy conversion rate of 38% will be used for calculating the efficiencies of coal-fired power plants in the baseline scenario.

In 2015, total electricity generation in Alberta (including on-site electricity generation by industrial facilities) totaled 80,257 GWh. It is projected that electricity generation in Alberta will reach 94,304 GWh by 2030, an 18% increase since 2015 (Alberta Electric System Operator, 2017). Using this information it is possible to project two scenarios for the future of Alberta's electricity generating industry and measure the associated reduction in emissions between the two scenarios. The first scenario represents emissions from electricity generation without the phase out of coal, and the other represents emissions from electricity generation if the industry adheres to the coal phase out mandate and the province achieves its goal of 30% of electricity coming from renewable sources by 2030.

Baseline Scenario

This baseline scenario projects what greenhouse gas emissions from electricity generation will be in 2030 without the coal phase out or the 30% renewable mandate. In the baseline scenario, it is assumed that no new coal-fired plants will be constructed in Alberta. This seems reasonable, as the carbon tax and regulatory uncertainty would likely deter investment in new coal stations that have decades-long payout periods. However, the baseline scenario projects that the six coal-fired power plants scheduled to remain open after 2030 remain active and producing electricity at 2015 output levels. These plants are Genesee 1 and 2 (3,297 GWh total annual output), Genesee 3 (3,955 GWh), Sheerness 1 and 2 (5,500 GWh) and Keephills 3 (3,729 GWh) for a combined total of 16,481 GWh (Capital Power, 2012; TransAlta, 2017).[13]

In 2015, Alberta generated 7,710 GWh of electricity from renewable sources.[14] Under this baseline scenario, the remaining 86,594 GWh of electricity will be generated from fossil fuel sources in 2030. The six remaining coal power plants are assumed to generate 16,481 GWh of electricity, natural gas power plants built prior to the coal phase out announcement will generate 32,215 GWh, and the remaining 37,898 GWh of power will be generated by new high-

[13] TransAlta does not publish the total annual generation figures for Keephills 3. The annual power output was calculated based on the ratio of installed capacity to total generation (86%) at Genesee 3, as these power plants are similar in age.
[14] For the purposes of this essay, biomass generation is considered a renewable electricity source.

efficiency combined cycle natural gas power plants.[15] The greenhouse gas contribution of each of these sources can be calculated using the following equations.

Coal contribution:

$$(16{,}481\ GWh)\left(\frac{1}{0.38}\right)\left(\frac{0.099\ tonnes\ CO_2}{million\ BTU}\right)\left(\frac{3{,}410\ million\ BTU}{1\ GWh}\right) = 14.6\ million\ tCO_2e$$

Pre-phase out natural gas plant contribution:

$$(32{,}215\ GWh)\left(\frac{1}{0.47}\right)\left(\frac{0.053\ tonnes\ CO_2}{million\ BTU}\right)\left(\frac{3{,}410\ million\ BTU}{1\ GWh}\right) = 12.4\ million\ tCO_2e$$

New combined-cycle natural gas plant contribution:

$$(37{,}898\ GWh)\left(\frac{1}{0.60}\right)\left(\frac{0.053\ tonnes\ CO_2}{million\ BTU}\right)\left(\frac{3{,}410\ million\ BTU}{1\ GWh}\right) = 11.4\ million\ tCO_2e$$

In the baseline scenario, the total emissions from electricity generation in Alberta will be 38.4 million tCO_2e in 2030.

Coal Phase Out and Renewables Scenario

The above baseline scenario can be contrasted with the predicted greenhouse gas emissions in Alberta with implementation of the coal phase out and 30% renewable energy mandate. Given the target of 30% of electricity coming from renewable sources by 2030, it can be projected that with the green energy mandate fossil fuels will be used to generate 66,013 GWh of

[15] 32,215 GWh is the assumed output of the natural gas power plants built prior to 2016 as this was the total amount of electricity they generated in 2015.

electricity in 2030, a 10% drop from the 73,593 GWh generated from fossil fuels in 2015 (Government of Alberta, 2015). In this scenario, it is assumed that all coal capacity phased out between 2015 and 2030 is replaced by high-efficiency natural gas turbines, and that pre-phase out natural gas plants continue to operate at 2015 output levels. The total emissions from these high-efficiency turbines can be calculated according to the following equation:

$$(33{,}798\ GWh)\left(\frac{1}{0.60}\right)\left(\frac{0.053\ tonnes\ CO_2}{million\ BTU}\right)\left(\frac{3{,}410\ million\ BTU}{1\ GWh}\right) = 10.2\ million\ tCO_2e$$

Total emissions in this scenario are 22.7 million tCO_2e, which represents a 41% reduction in greenhouse gas emissions compared to the baseline scenario. This equates to a 5.8% reduction in total provincial emissions in Alberta. It is notable that the expected emissions reduction from the clean electricity mandate will result in a far larger reduction in emissions than the carbon tax on gasoline.

Expected Trends

Many have argued that the transition away from coal will cause the price of electricity to rise significantly in Alberta. While it is true that Ontario has experienced a rapid increase in electricity prices in recent years, many experts argue the main driver of this increase was the large capital expenditures made on the Ontario electricity transmission infrastructure, which required significant amounts of investment after many years of underinvestment. Commentators also point to the generous subsidies for wind and solar energy as being major drivers of the price increases in Ontario (Morrow & Cardoso, 2017). Alberta intends to make similar investments to Ontario in replacing coal-fired generating capacity and adding renewable power sources, but will not be making the same capital expenditures on its electricity transmission grid. It is therefore difficult to predict exactly how much the price of electricity will rise in Alberta, aside from predicting that prices will increase somewhat. What is certain is that the proposed coal phase out and increased use of renewables will produce a very large greenhouse gas emissions reduction in Alberta.

Conclusion

The goal of this essay is to contribute towards the understanding of carbon taxes and other green energy policies in Canada. In particular, this essay seeks to assess the expected impact of Alberta's Carbon tax and associated emission reduction programs, with reference to the experiences of BC and Ontario. To that end, this essay has detailed several expected changes in greenhouse gas emissions due to imposition of a carbon tax resulting from trends in three major types of emission sources; natural gas, gasoline and diesel, and electricity generation.

Natural Gas

Residential and commercial consumption of natural gas was found to be highly inelastic to changes in price in the short and long term, with outdoor temperature dictating price in the short-term and long-term reductions in natural gas use (possibly due to improvements in efficiency) coinciding with lower prices. This suggests that the effectiveness of a carbon tax at lowering greenhouse gas emissions from natural gas by residential and commercial users is limited. On the other hand, there may be a connection between higher natural gas prices and reductions in industrial consumption of natural gas in Alberta, as natural gas is required in such large quantities for oil sands extraction. The desirability of the impacts of this reduction is a subject of debate.

Gasoline

This essay serves to confirm that while the overall elasticity of demand is low for gasoline, tax salience can greatly amplify the consumer response to changes in price due to the imposition of taxes. This allows a small carbon tax to cause a relatively large reduction in greenhouse gas emissions. However, because of the high level of greenhouse gas emissions produced in Alberta, the expected reduction in greenhouse gas emissions from gasoline due to the carbon tax is small on a percentage basis.

Diesel

This analysis found that diesel consumption in Alberta is positively correlated with diesel prices, which is the opposite of the normal response to higher prices. A relatively robust hypothesis is that a high oil price coincides with high diesel prices, and high oil prices boost economic activity in Alberta which in turn increases demand for diesel in commercial applications. The presence of this relationship brings the wisdom of a carbon tax on diesel into doubt, as it may be serving as a tax on investment and commercial activity.

Electricity

It is expected that the mandated phase out of coal and increased use of renewables in Alberta will serve to provide a significant reduction in greenhouse gas emissions. Based on the experience of Ontario, it would be rational to expect that electricity prices will rise in Alberta due to this shift in energy sources, but the extent of the analogy between the price rises observed in Ontario and the same price rises occurring in Alberta is unclear, as Alberta faces different challenges and strengths in its shift away from coal towards renewable energy sources.

Future Research

With climate change an ever more prescient topic, there is room for a great deal of research on the topic of economic policies designed to reduce greenhouse gas emissions. While some may disagree with the effectiveness or efficiency of certain policies designed to reduce climate change, there is no doubt that a great deal of creative and thoughtful policy is needed in order to prevent catastrophic changes to the global environment.

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