CLOSUP Student Working Paper Series
Number 70

April 2021

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This paper is available online at http://closup.umich.edu

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April 27, 2021

Abstract

In the face of the urgent and growing climate crisis, policy experts on climate and the economy have pushed for national and other governments to implement a tax on carbon. The Biden administration is considering adopting such a policy (Green, 2020), and Canada adopted a nation-wide tax in 2018. Despite the current level of interest in carbon taxation, there is little literature that reviews the impact of long-standing *existing* carbon taxes on the economy and carbon reductions. The expectation is that a well-designed carbon tax will substantially reduce carbon emissions in its target jurisdiction without severely impacting the overall economy. This paper examined the 2008 British Columbia (BC) carbon tax for a 10-year period (2008-2018) and assessed whether it had noticeable effects on reducing carbon emissions and how it impacted the local economy. Regional green-house gas emissions data, regional GDP and population data, and the stock value of representative companies of British Columbia were compared to the results of the combined rest of Canada. Ultimately, it was found that the British Columbia carbon tax did not price carbon emissions aggressively enough since emissions remain at 2008 levels despite going down in the rest of Canada. It was also found that the tax did not have noticeable effects in the regional wealth of British Columbia or representative private companies, as they performed similarly to the rest of Canada during this period.

Introduction

Human caused climate change is among the gravest concerns facing the international community; its impacts are severe and growing. Extreme weather events are increasing in frequency and strength, biodiversity is decreasing, and the health of major ecosystems is rapidly declining. (IPCC 2014). The accumulated disruption of human life caused by climate change is significant and difficult to estimate; however serious impacts can be observed now. In the United States alone, Texas has endured extreme flooding, several hurricanes, and an unprecedented winter storm while California has contended with persistent droughts and repeated devastating wildfires. It is now routine that each new year will be the hottest on record (*Fountain, 2019*)

Tackling climate change remains perhaps the most daunting challenge facing the international community. The entire world economy needs to shift away from the use of fossil fuels and other greenhouse gas (GHG) emitting resources. Were you to survey climate change experts how to do this now, or even 30 years ago, one of the top recommendations you would have repeatedly head was that governments must price carbon through a tax or other similar methods. The economic theory is simple: by assigning GHG pollution a real monetary cost, it will incentivize economies to efficiently, rapidly, and organically reduce GHG emissions.

To date, only a few national and or regional governments around the world have adopted carbon pricing. This paper shall take an isolated example of an adopted carbon price and examine how the economy and GHG emissions of the region have evolved since the adoption of a carbon price. British Columbia is the chosen target of this case study, as there is a 10-year period from when the province adopted the tax in 2008 and prior to Canada's nationwide adoption of a carbon price in 2018. The economic changes and GHG reductions that occurred in British Columbia during this period can be reasonably compared to the same changes that

occurred in the rest of Canada as a means of accessing the overall impact that carbon pricing has on a region.

Literature Review

To drive the research behind the effectiveness of the BC carbon tax, it is first necessary to examine the existing literature regarding carbon pricing.

The British Columbia Law itself placed a $10 (Canadian) price per metric ton on carbon in 2008. The tax increased by $5 per ton between 2008 and 2012, holding at $30 per ton since 2012. The tax was directly charged on the purchase of fossil fuels. Table 1 below outlines the tax rate on fossil fuels in British Columbia during the studied period of 2008-2018.

Table 1: British Columbia Carbon Tax Rates by Fuel

Type of Fuel	Unit	Tax Rate (2012)
Gasoline	¢/liter	6.67
Diesel	¢/liter	7.67
Jet Fuel	¢/liter	7.83
Natural Gas	¢/liter	5.70
Propane	¢/liter	4.62
Coal – high heat value	$/ton	62.31
Coal – low heat value	$/ton	53.31

A 2015 audit of British Columbia's GHG emissions (Komanoff, 2015) found that the region saw noticeable GHG emissions reductions when compared to the rest of Canada. From 2008 to 2015, British Columbia (BC) saw a net 6.1% GHG emissions reduction compared to the

rest of Canada experience emission *gains* of 3.5%. On a per capita basis, BC experienced a 12.9% reduction compared to the rest of Canada's 3.7%. The paper finds that the statistically significant emissions reduction in British Columbia overall is attributed to the existence of the BC's carbon tax act. However, by the paper's own admission, there several mitigating circumstances that reduce the claims of the effectiveness of the carbon tax within BC. The cost of gasoline in the region barely went up since the adoption of the policy, despite transportation constituting about a third of emissions. Also, unique to BC, most of its electricity production already came from renewables prior to the introduction of the tax. These issues highlight the difficult in accessing the real-world effects that carbon pricing has. Furthermore, this analysis of British Columbia fails to seriously consider how the overall market in BC was affected by the tax.

Another study of a carbon tax, this time the Carbon Climate Levy in the UK, was conducted to determine the impacts of the tax on manufacturing. According to Martin et al. (2016), a carbon tax had appreciable decreases in GHG emissions form the manufacturing industry within the UK. The paper indexed the publicly available data on energy usage in the UK manufacturing industry. They then estimate the amount of energy used by resource type and calculate the associate carbon content emitted by each source. From the findings, there was statistically significant reductions in electricity usage outside of normal trends across different manufacturing plants within the UK. Smaller and less energy-intensive plants reduced their energy demands by 15% and high trade high energy plants reduced their energy usage by as much as 22%. This significantly exceeded the 5% limit for statistical significance. Across the board, manufacturing plants of all size and energy usage made serious efforts to reduce energy

consumption to avoid the carbon levy. Similar analysis would be a useful benchmark for evaluation in British Columbia.

Another useful benchmark for measuring the impact of a carbon pricing is to measure technology innovation per Calel et al. (2016). The paper reviews how the European Emissions Trading System (ETS) impacted technology innovation in green technology, which is defined as technology that has reduced GHG emissions compared to current market solutions. Technology innovation can be measured by recording new green technology patents issued. From their review, the adoption of the EU ETS correlated with a minor spike in the annual rate of green technology patents filed. This occurred with firms both within members of the EU ETS and outside of the EU ETS. The correlation was more significant for firms in the EU ETS, but the existence of a spike in the technology innovation outside of member body suggested that outside firms were responding to new opportunities to compete in areas subject to a carbon tax. However, that does leave open the possibility that there could be a reverse outcome, where high carbon industries might want to get out of performing within regions that are subjected to a carbon price. This paper did not address that issue.

Besides the industry response to carbon pricing, the final major sector of the economy to consider is the consumer level impact. This is very difficult to measure, as consumers will respond to many different pressures. Chief among those pressures are price and political considerations. Consumers may react more positively or negatively to perceived low-carbon emitting firms compared to others. According to Qian et al. (2020), a review of Australia's brief foray into a carbon tax provides significant insight. Qian used Thomas Reuters Eikon database and Australia's stock NGER list to calculate market reactions to businesses that had both public filings and carbon emissions data during the turbulent period in Australia's politics between

2009 and 2014, when Australia started an ETS, adopted, and then repealed a carbon tax. The tax was only briefly law in the nation, and therefore long-term effects of the law could not be calculated. Form the available data, there was no statistically significant correlation between market and carbon performance during the years after the adoptions of the ETS and then the tax. However, pro-active corporations that reduced GHG emissions during these years were rewarded by consumers *after* the carbon tax was repealed in 2014. They concluded that consumers were more conscientious of the environmental impact of their purchases in the absence of government regulation, but that the phenomenon did little to reduce overall GHG emissions.

While the Qian et al. paper acknowledged the carbon tax repel in Australia, it did not offer conclusions as to why there was significant political backlash against it. Insight into how politics and economic anxiety can harm the effectiveness of a carbon tax is provided by Vehmas et al. (1999). They found that significant economic fear over a loss of competitiveness in the global market severely limited the effectiveness of the existing carbon taxes in the Scandinavian countries that they examined. Excessive amounts of special exceptions to Scandinavian carbon prices were allowed for extractive industries, utilities, and other energy intensive sectors. It was relatively easy for most major polluters to avoid paying the tax. These exceptions were motivated by the belief that a carbon tax would severely harm the market competitiveness of these sectors. The carbon tax in British Columbia has much less of these exceptions compared to those that Vehmas studied.

Finally, useful metrics by which to analyze carbon taxes comes from the World Bank. The World Bank (2020) issues an annual report that outlines the broad expected effects of carbon pricing and its market competitiveness. Their assessment comes from a large-scale policy literature review of both theoretical and empirical analysis, consultation with industry experts,

and consultation with an expert advisory group. From their assessment, they have outlined broad, wide reaching conclusions on carbon pricing. These conclusions are outlined in Table 2 below and provide a strong base point for judging the performance of carbon pricing. Its analysis is useful for what metrics a case study *should* examine that would be meaningful, an analysis that can be brought to a study of British Columbia.

Table 2. World Bank Policy Measurements

	Policy Outcome	**Metric**
1.	Carbon Pricing leads to significant GHG reductions	% decrease in GHG emissions
2.	Carbon pricing causes shits to low emission technology	Announcements of industry performing switches to green tech
3.	Concerns that high emission businesses will relocate to areas with low or no carbon pricing are not borne out.	Announcements of high emission industries relocating.
4.	Carbon pricing drives innovation	Indexing of new patent filings in regions with carbon tax
5.	Carbon pricing drives investment in new green tech	Index of stock and creation of green tech companies in regions with carbon pricing

From the literature review conduced above, there is a missing holistic review of the impact of a carbon tax. This begs the questions “what was the combined effect of a carbon tax on a region’s economy and GHG emissions?” This paper investigates the environmental, public

economic, and private economic impact of the carbon tax in British Columbia, and compares the results to the rest of Canada, which has a relatively similar economy and environmental profile as British Columbia but did not have an implemented carbon tax during this time.

Methods

While this paper is primarily concerned with the effects of British Columbia's carbon tax, the effectiveness of the tax is very difficult to measure without comparable alternatives according to Seawright and Gerring (2008). Given how few existing carbon pricing initiatives there are around the world and the vast differences of the economies between them, it is more sensible to evaluate the effectiveness of the BC carbon tax against a comparable economy, i.e., the rest of Canada. This paper prepares two unique data sets, one of which is for British Columbia and the other of which is the combined rest of Canada. The goal of this paper is to understand the effectiveness of a carbon tax by examining the economic and emission developments between BC and the rest of Canada from 2008-2018.

The environmental impact of the carbon tax can be calculated by comparing regional data of greenhouse gas (GHG) emissions. The Canadian government through the Environment and Climate Change Canada (ECCC) agency compiles annual regional emissions reports dating back to 1990. This data can be combined with provincial annual census data and gross domestic product data from the Canadian government provided to the public. Table 3 highlights what information is collected and the utility of the data in evaluating the performance of the carbon tax.

Table 3. GHG Emissions Metrics

	Metric	Source	Reasoning
1.	% change in regional GHG emissions	ECCC	Comparing total GHG change provides a benchmark as to whether the carbon tax is aggressive driving down emissions or not
2.	% change in per capita GHG emissions (discounting industry emissions)	ECCC	Comparing per capita data provides a benchmark on whether the carbon tax is decreasing individual emissions.
3.	% change in GHG emissions by sector	ECCC	Comparing GHG emissions by sectors provides a benchmark on which sectors are elastic versus inelastic to carbon pricing.

The next area of interest of this paper is the economic impact of the carbon tax. This paper is interested in the impact the carbon tax had on both public and private economic performance; separate metrics are specified for the different areas of interest. These performance metrics are summarized below in table 3.

Public performance can be evaluated by evaluating the revenue of regional government GDP. The data is available from the Canada Revenue Agency (CRA) and GDP in comparison to the local populations. Additionally, combining the emissions data outlined above, it is possible to calculate the dollar utility out of a unit of GHG pollution.

Finally, the private performance of companies can be evaluated by examining the historical stock data of representative companies during this period. Examination of clean technology companies will indicate whether the carbon tax has boosted their performance. An individual audit of companies listed under the S&P Toronto Stock Exchange Clean Technology Index (2021) will be performed. The historical price data from 2008-2018 for each company shall be acquired from Yahoo Market place which makes this information publicly available for free.

Table 3. Economic Performance Metrics

	Metric	Sector	Source	Reasoning
1.	% change in GDP	Public	CRA	Measuring growth of the total economy is a positive indicator of economic performance
2.	% change in GDP per capita	Public	CRA	Measuring the per capita change of GDP is an effective measure of individual performance. If GDP per capita of BC rises at similar rates as Canada, then the carbon tax is not having an adverse effect on the overall economy.
3.	% change in representative stock value	Private	Yahoo Markets	Stock value is a public indication of the relative value of a company. Higher stock values correlate with investor confidence in a company's competitiveness and the real-world market contributions the company provides. If representative stocks in BC change in similar or better than other Canadian companies, it

				indicates that the carbon tax has low impact to positive impact competitiveness
4.	% change in $ per GHG emissions	Public	ECCC and CRA	Comparing the total economic activity per unit of GHG emissions provides the most useful benchmark of the GHG trend. As economic activity increases, GHG emissions are likely to increase. A successful carbon tax will increase the $ value added to the economy per unit of GHG used.

Data and Analysis

With the research methods now outlined, the review of the carbon emissions of British Columbia versus the rest of Canada from 2008 to 2018 yielded the following results.

By examination of Figure 1, the total percent change of total GHG emissions in British Columbia versus the rest of Canada, it can be concluded that the carbon tax in British Columbia did not monumentally change carbon emissions within British Columbia. The most striking result is that the percent change in emissions did not differ greatly from the rest of Canada until 2016, in which emissions dramatically increased so that by the end of the studied period, the total emissions within British Columbia reached an almost 10% increase from their 2008 levels. While this does not rule out that the tax is yielding positive carbon performance, it does rule out that the BC carbon tax is not reconfiguring the entire market to become carbon neutral.

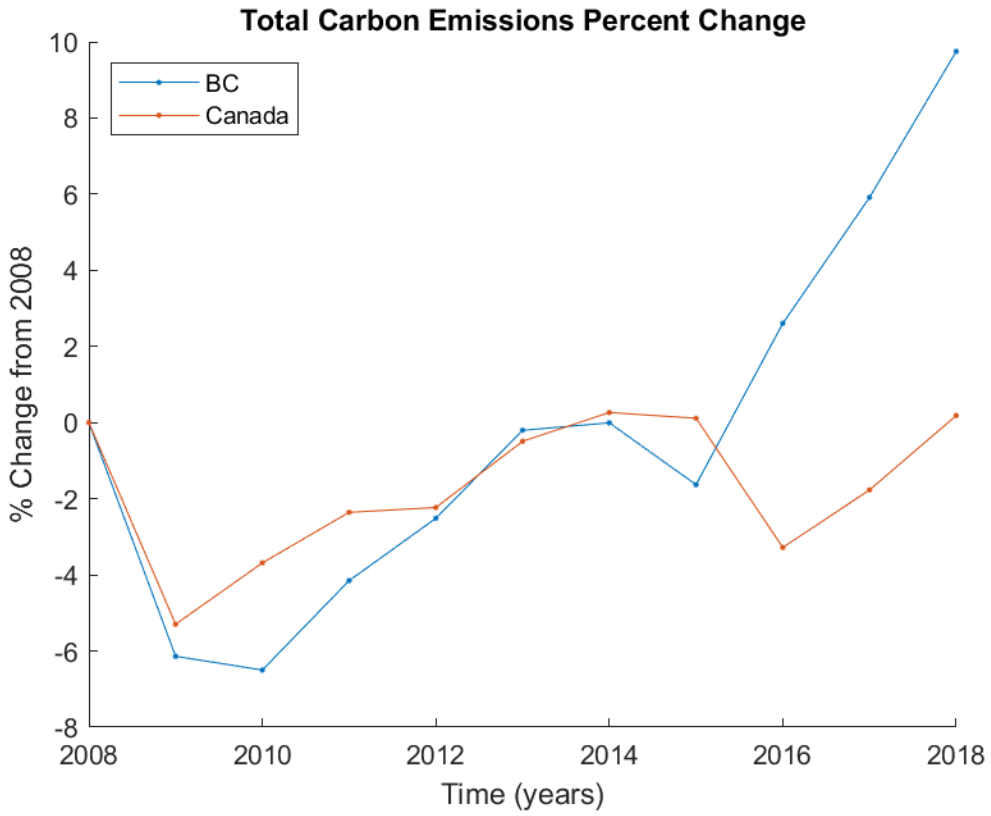

Figure (1) Canadian Carbon Emissions Benchmarked to 2008

The results of the per capita emissions in Figure 2 parallel the results from Figure 1. There is a significant spike in per capita emissions from 2015 to 2018, causing British Columbia to overtake the rest of Canada in percent change from 2008 levels of per capita emissions. The carbon price in BC is not driving historic reductions emissions. It should be noted though that BC per capita emissions remain about 5/8ths the level of the rest of Canada's per capita emissions throughout the entire measured period, much of which may be attributed to the fact that most of BC's electricity generation comes from hydropower over the rest of Canada's which comes from fossil fuels, as noted in Komanoff.

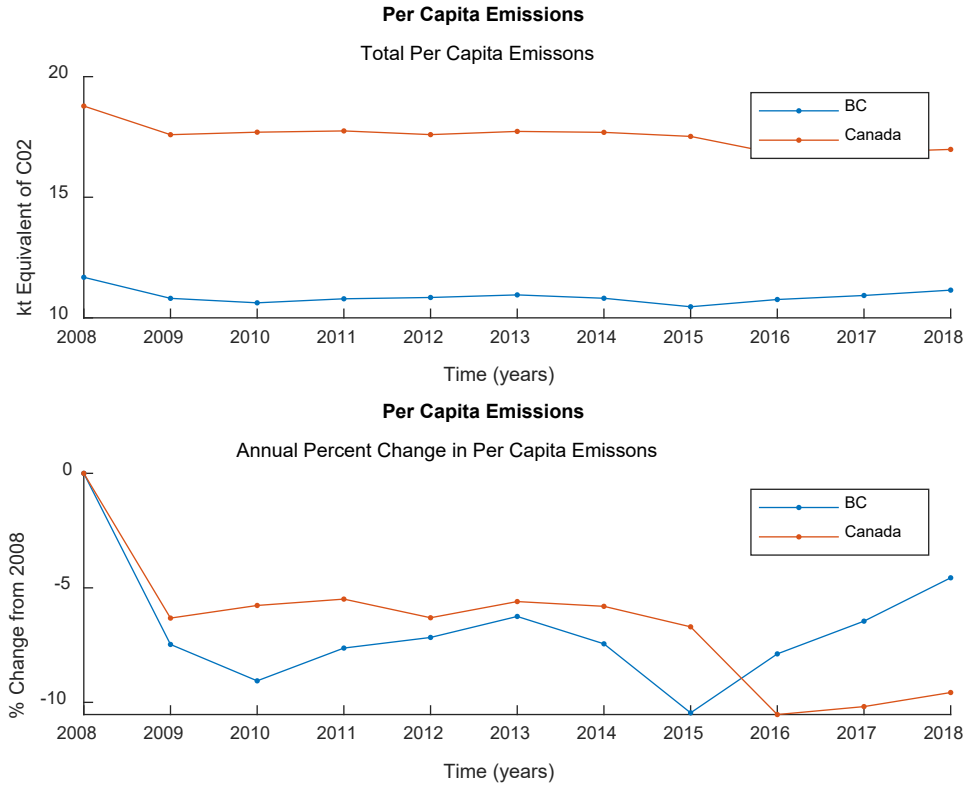

Figure (2) Canadian Per Capita GHG Emissions

While the overall results indicate that the carbon tax is not driving dramatic reductions of GHG emissions, there are interesting developments within emissions by sector within BC compared to the rest of Canada that are outlined below in Table 4.

Table 4: Percent Change of Carbon Emissions from 2008-2018 by Sector.

Emission Sector	10 year % change BC	10 year % change Canada
Public Electricity and heating	-53.62	-39.80
Petroleum Refining	-16.01	-17.78
Oil and Gas Extraction	24.56	54.55
Mining	-16.76	-18.86

Manufacturing	26.80	-4.82
Iron and Steel	-38.15	10.92
Non-Ferrous Metals	-12.45	-29.11
Pulp and Paper	41.00	0.53
Other Manufacturing	0.94	-16.67
Cement	78.22	-35.55
Construction	-2.49	0.14
Agriculture and Forestry	842.36	18.64
Commercial and Institutional	-16.78	11.05
Residential	-10.56	-3.47
Transportation	21.29	11.35
Fugitive Sources	-23.13	-4.86
Waste	-11.75	-4.57

Of the measured sectors, 6 of the 17 sectors saw net gains of emissions within British Columbia. Besides transportation, the sectors that saw major emissions gains were all industry related. One of the most striking changes is that manufacturing in British Columbia increased by nearly 30% of its 2008 level during this time, whereas the rest of Canada saw a mild decrease in emissions. Other industries like agriculture and forestry and paper and pulp both saw huge percent emissions increase in British Columbia during this period. It seems that the carbon tax is having little to no effect on most production industries within British Columbia given the enormous spikes in emissions. This is contrary to what Marten et al. research suggested about carbon taxes reducing manufacturing emissions. However, this paper did not conduct a by

facility analysis, so the increase in emissions could be due to new factories or increased productions; the overall carbon efficiency of manufacturing in BC is unmeasured in this review.

Uniquely though, oil and gas production emissions, while they increased by roughly 25% in BC, they increased by more than double that in the rest of Canada. Oil and gas production dramatically expanded during this period, but noticeably less in BC than the rest of the country. Moreover, there is a much more significant decrease in emissions related to fugitive sources from methane and other leaks in BC than compared to the rest of Canada. This indicates that the carbon tax is pushing against oil and gas companies in BC, and those that do operate in BC are much more careful about preventing escaped pollution.

Public electricity and heating, residential, commercial, and institutional, and waste sectors all decreased more than the rest of Canada. These sectors tie much more closely to individual behavior compared to the industrial sectors. Conversely though, transportation emissions increased within BC by more than 10% compared to the rest of Canada. This is an unexpected result, as the BC carbon tax is applied directly on gasoline and diesel purchases and therefore the average consumer would most acutely feel the effects of the tax at the gas pump. It seems that the carbon price is motiving individuals to seek greener alternatives for their homes and businesses but are unwilling to make more environmentally conscious choices for their transportation.

A rather striking result is that the sectors that all saw increased emissions from this period accounted for 61.37% of all British Columbia's emission in 2008 but accounted for 71.64 % of all emissions in 2018. Of the emissions increases, transportation and manufacturing account for the largest slices, and both of those sectors increased by 10 and 30 points more than the rest of

Canada. The worst polluters were undeterred by the carbon tax, which suggests that the British Columbian carbon tax was overall ineffective at curbing major polluters.

While the carbon tax has had overall little effect on GHG emissions, it also does not appear to have had adverse effects on the economy. From Figure 3, the GDP and GDP per capita grew at roughly the same rate as the rest of Canada. This strongly suggests that despite the economic fears pointed out in Vehmas et al, carbon taxes do not hurt overall economic performance. Moreover, from Figure 4, the dollar contribution for each kg of emissions released to the economy remains very high: a kg of CO2 earns about $5,500 in British Columbia in 2018 versus only $3,500 in the rest of Canada. The dollar contribution to the economy or overall utility of pollution increased at roughly the same rate for both BC and Canada.

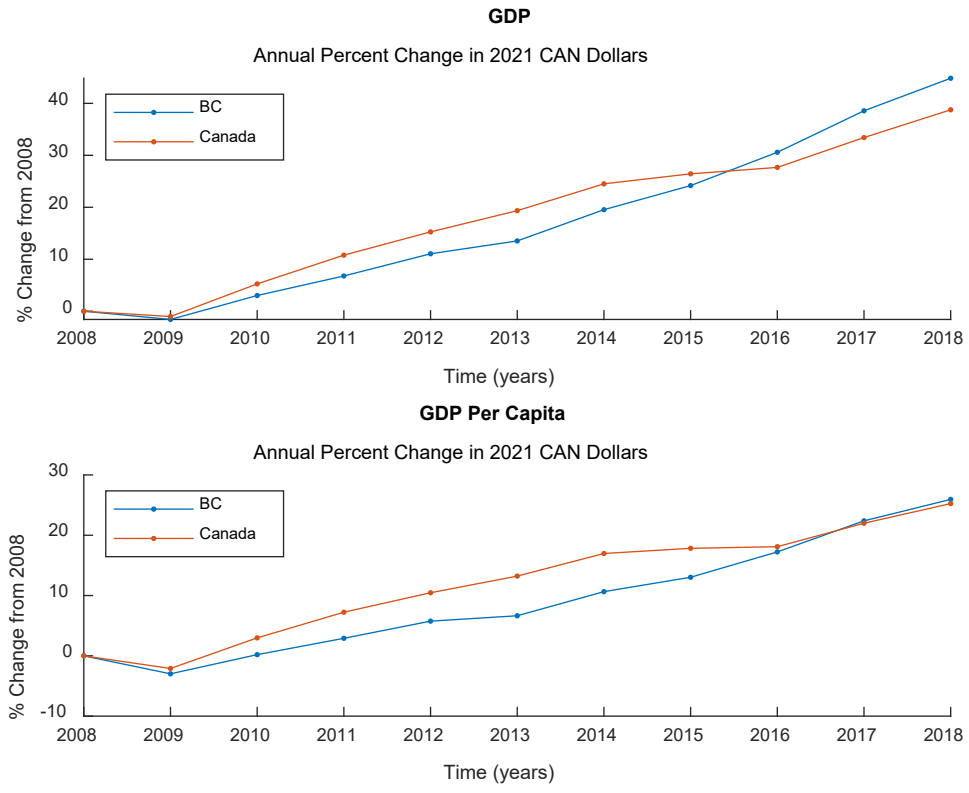

Figure (3) Canadian GDP Data

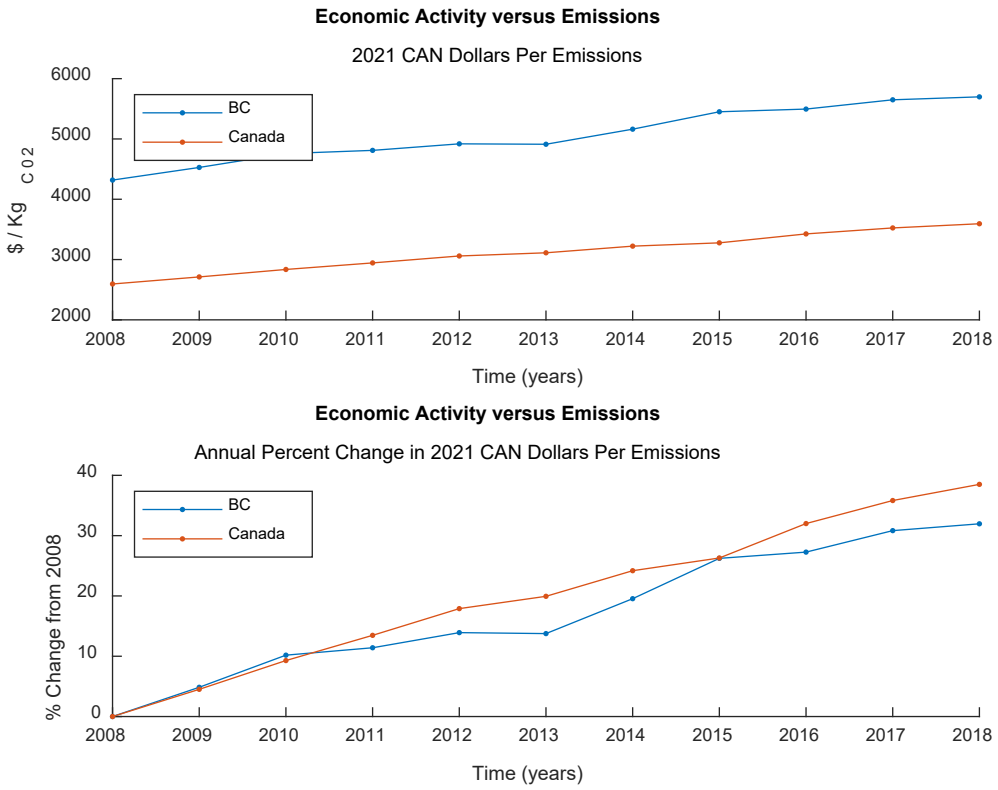

Figure (4) Canadian Economic Activity Per GHG Emissions

Next, as a synthesis of per capita emissions and economic activity associated with emissions, in Figure 5 the cents per Kg of CO2-Person used is plotted. This metric reflects both the increased population and economic activity in British Columbia. The total utility of pollution grew by 40% within BC to only by 35% in the rest of Canada during this 10-year period. It is interesting to note that British Colombia only improved its overall carbon utility performance more than the rest of Canada in 2017, after the major spike in total BC carbon emissions starting in 2015. This indicates that there was a notable but mild increase in carbon performance, or how much utility carbon pollution provided, in BC compared to the rest of Canada at a time when total economic activity BC outpaced the rest of Canada. This suggests that the despite the muted

economic and emissions response to the carbon tax in BC, there was *some* meaningful effects the carbon tax had on reducing emissions.

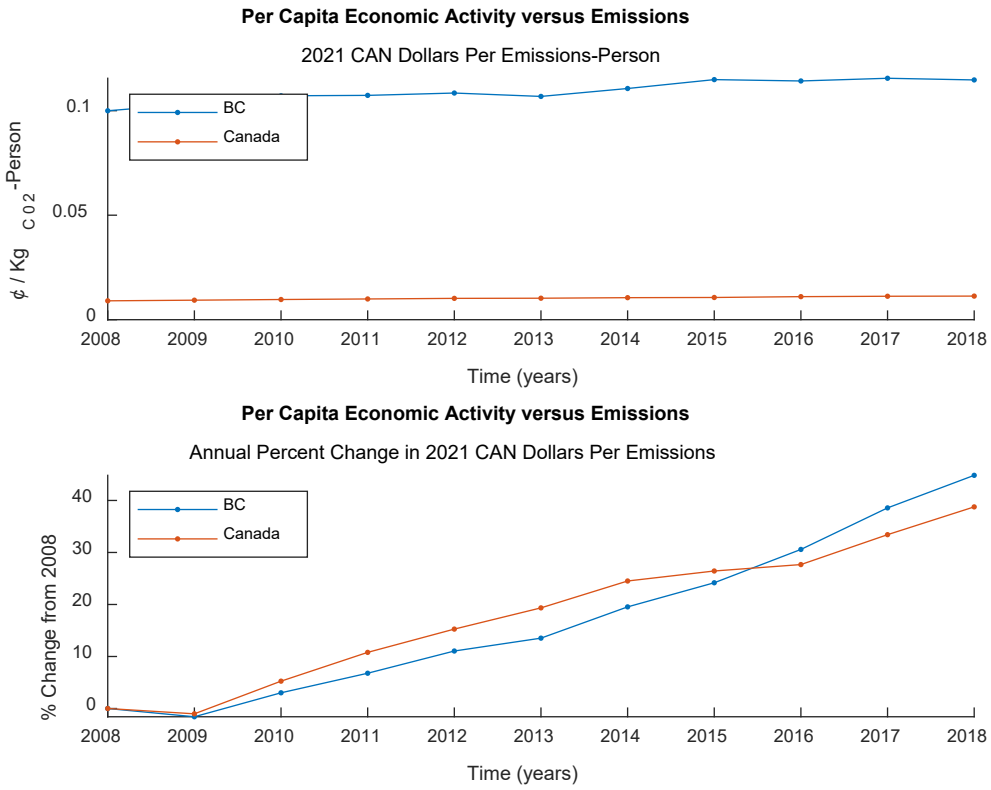

Figure (5) Canadian Per Capita Economic Utility of GHG Emissions

Finally, this paper examines how representative stocks changed during this period. In Figure 5 below, the averaged percent change in stock prices for companies listed under the S&P's Renewable and Clean Technology Index in British Columbia versus the rest of Canada is plotted. The averaged response for companies stationed in BC did not differ noticeably from the rest of Canada, with the average company stock in both regions at about 60% improved price since 2008 by 2018. The British Columbia price oscillated more than the relatively stable prices for the rest of Canada, but that is most likely the result of the bigger sample size for non-BC companies smoothing out the trend. Therefore, it can reasonably be concluded that the BC

carbon tax did not have a meaningful impact on new investment in clean technology nor uniquely improve the market competitiveness of renewables or clean technology. This collaborates Qian et al's conclusion that consumers and investors are unlikely to take into consideration environmental performance for companies while it is perceived that meaningful environmental regulations are in place but contradicts the finds of Calel et al's findings that carbon prices' incentivize meaningful increases in new clean technology investment.

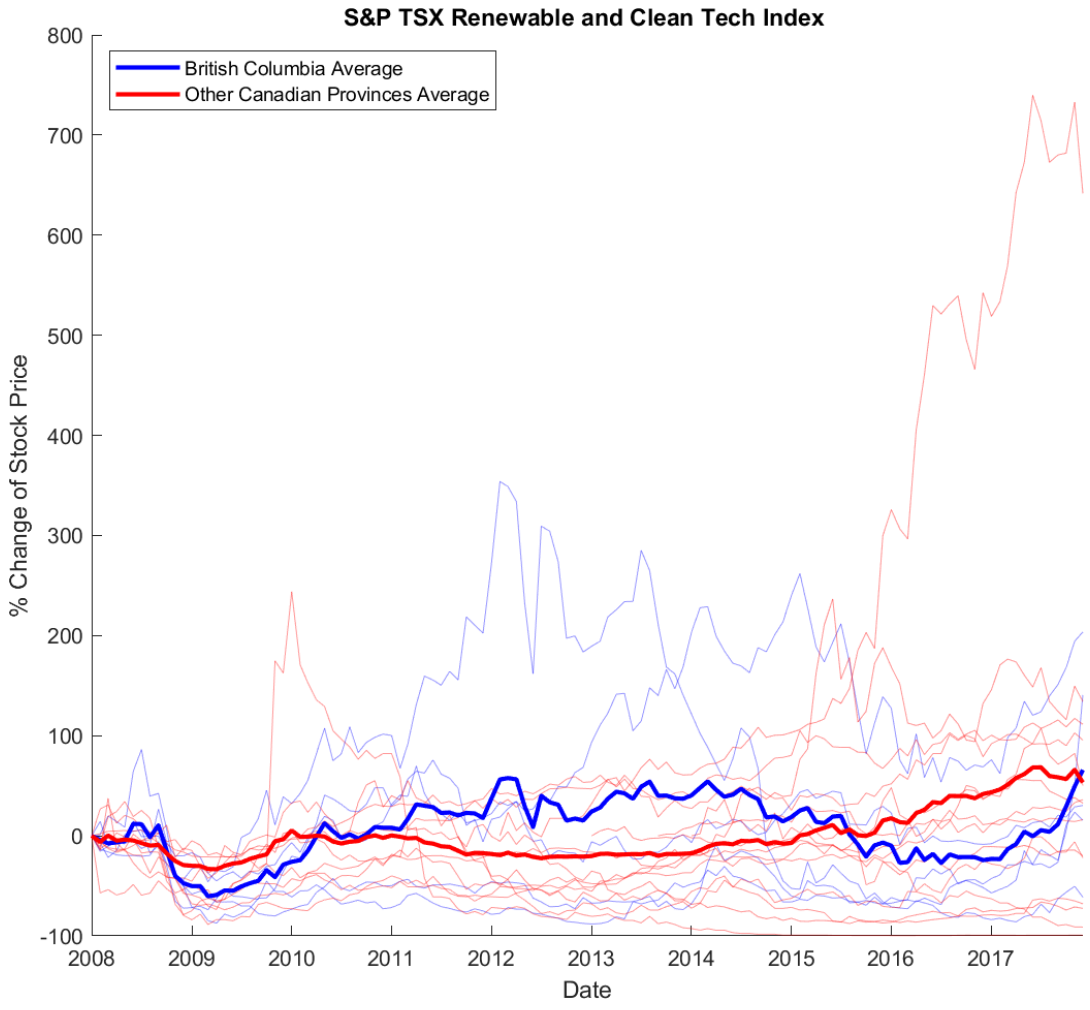

Figure (6): S&P TSX Renewable and Clean Tech Index Component Companies Stock Performance (The bolded lines in front are the averaged stock price change by region, the transparent lines behind are each individual stock's performance)

Limitations and Future Work

This paper was able to draw meaningful conclusions about the emissions and economic effects of the British Columbia carbon tax but was limited by insufficient access to economic data. This paper would have benefited from a larger examination of private companies' performances in more sectors such as oil and gas, manufacturing, and transportation industries. It would have been useful to compare each sectors emissions data with relevant metrics of economic performance in British Columbia and the rest of Canada.

However, much of that information is tightly controlled and requires paid terminal access. Efforts on behalf of the author to access this information for free (this paper had no operating budget) from the Toronto Stock Exchange Failed. Furthermore, even gathering and parsing the relatively small data set of 10 years of stock data form the companies in the S&P Toronto Stock Exchange Renewable and Clean Energy Index was time and labor intensive. The manufacturing and oil and natural gas sectors on the Toronto Stock are each several times larger than the examined data, and many of those companies operate in multiple Canadian provinces and internationally, so further data parsing would be needed to properly attribute which activity was limited to British Columbia and which activity was elsewhere in Canada. Future work required for this paper is a full economic and emission comparison on a sector-by-sector basis. Finally, this paper would have benefited from a contributor with more expertise in statistics. In the future, more sophisticated statistical analysis comparing the emissions and economic data should be pursued.

Conclusion

While it is difficult to access the holistic impact of a price on carbon, in the case of British Columbia, the effect of it has been mild. British Columbia improved its carbon performance slightly more than the rest of Canada by the end of the studied period and there was little indication that the tax meaningfully impacted the economy of BC. Noticeable emissions reductions were sustained in some sectors, but the worst polluters: manufacturing, transportation, and oil and gas extraction saw significant increases during the studied period, though oil and gas extraction increased much less than the rest of Canada. When examining the utility of GHG pollution per capita, it increased by 5% more in British Columbia than in the rest of Canada. This is a positive indication that the carbon tax is applying pressure on reducing emissions, but the pressure is minimal. This is likely tied to the fact that the price of carbon is relatively un aggressively priced at only $30 per ton, which translated to gasoline only being taxed at an increased 6.67 cents per liter. Given that there is *some* improvement in carbon performance and no adverse economic reaction to the carbon tax, the policy implication is that higher carbon tax rates can be applied to regions with developed economies without shocking the economy and improving the carbon emission performance.

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