A Study of Carbon Pricing Policies and Their Environmental and Economical Effects

Abstract:

Developed amid the 2020 US presidential election, this paper analyzes the environmental and economic impacts of carbon pricing policies implemented in North America prior to 2018. The two carbon pricing policies analyzed are carbon taxes and cap-and-trade systems. On the environmental front, this paper analyzes the impact of the policies' price and extent of emissions covered on absolute emissions reductions and greenhouse gas (GHG) emissions per capita. On the economic front, the paper analyzes the effects of carbon pricing on GDP change.

The results show that high prices and high percentages of emissions covered have miniscule effects on emissions reductions. As shown in multiple cases, factors other than carbon pricing policy, such as adoption of green energy technologies and economic performance, can have a much larger impact on emission reductions. Further, GDP growth appears to be smaller in jurisdictions adopting a carbon price compared to the jurisdiction's country as a whole. With international cooperation, the state of the environment will benefit greatly from a carbon pricing policy supplemented by more aggressive environmental policies.

Key Words: Carbon Pricing, Carbon Tax, Cap-and-Trade Program, Emissions Trading System, GHG Emissions, Emissions Change, Gross Domestic Product, Jurisdiction

Author Biography:

Andrew Cao is the author of this paper. He is a junior in high school and has interests at the intersection of sustainability, economics, and policy. He is an avid follower of environmental policies in the news. He also participates in environmental initiatives and awareness within his community, as he is a member of his school's environmental advocacy club and the Vice President of Project Green Schools' National Youth Council. When he is not exploring his interests in environmental economics and policy, Andrew is an avid golfer and runner. He plays golf competitively throughout the United States, and he enjoys going on long runs in the woods.

Introduction:

With global temperatures on the rise, climate change presents risks to the world's environments, economies, and populations. An increase in the atmospheric concentration of greenhouse gases, such as carbon dioxide, has created a warming effect on Earth. Since the turn of the 21st century, governments and policymakers have increasingly turned to carbon pricing as the primary policy instrument to address the climate crisis. Nonetheless, carbon pricing policies have remained controversial, with critics arguing possible ineffectiveness or negative economic impacts.

The purpose of this study is to do an ex-post analysis of trends in North American carbon pricing schemes. More specifically, the study will analyze all national, regional, and subnational carbon pricing policies that were implemented before 2018. These carbon pricing schemes include:

- Regional Greenhouse Gas Initiative (RGGI)
- California Cap-and-Trade Program

- Québec Cap-and-Trade Program
- Alberta Technology Innovation and Emissions Reduction (TIER) Regulation
- British Columbia Carbon Tax
- Boulder, Colorado Climate Action Plan (CAP) Tax
- Mexico Carbon Tax

The study will try to answer important environmental and economic effects of the carbon prices, as well as the causes for any trends. The study will try to answer the following research questions:

- In general, are carbon pricing policies effective in reducing GHG emissions?
- How do the GHG emissions per capita of a jurisdiction with a carbon price compare with the GHG emissions per capita of the jurisdiction's country as a whole?
- How do carbon pricing policies affect GDP growth?
- What can be done to enhance the effectiveness of carbon pricing policies?

Background:

Carbon pricing incentivizes carbon dioxide emitters to reduce their emissions by charging them for each ton of carbon dioxide they emit. Policymakers decide on the scope of the carbon price through three main factors: the jurisdictions covered, the share of the jurisdiction's GHG emissions covered, and any sectors or fuels covered.

Policymakers' major decision in designing a carbon pricing policy is choosing between two approaches: carbon taxes and cap-and-trade programs (also known as emissions trading

systems). According to the World Bank's Carbon Pricing Dashboard, 64 carbon pricing initiatives that were implemented or scheduled for implementation existed as of April 1, 2021. These 64 initiatives consist of 35 carbon taxes and 29 emissions trading systems, covering 11.65 $GtCO_2e$, or about 21.5% percent of global GHG emissions (*Carbon Pricing Dashboard | Up-to-Date Overview of Carbon Pricing Initiatives*, 2021).

A carbon tax simply sets a direct price for each ton of carbon dioxide that a consumer emits, and this price influences the total emissions reductions in the jurisdiction. A carbon tax offers price certainty, but it offers no guarantee as to how much it will stimulate emissions reductions. In some cases, policymakers can adjust the price of a carbon tax if emissions reductions do not meet expectations.

A cap-and-trade program sets a limit on the amount of greenhouse gases that consumers can emit, and this cap influences the price of each allowance. Governments issue a limited number of emissions allowances each year. Facilities are then able to buy or sell allowances, or allowances are sometimes distributed without cost. In some cases, cap-and-trade systems utilize banking and borrowing, in which consumers can save allowances for a future year or use allowances from future years in the present. Whereas a carbon tax offers price certainty, the limited allowances of a cap-and-trade program offer emissions certainty, or a guarantee that emissions will not be above a certain threshold. However, the varying supply and demand of allowances leads to price volatility for consumers. Price floors and ceilings can be used to limit the price of an allowance within a certain range.

Unless a cap-and-trade program allocates allowances for free, carbon pricing policies generate revenue that can be used in several ways, yielding environmental, economic, and other outcomes. In all cases, revenue use has costs and benefits regarding its impact on fairness, business competitiveness, greenhouse gas emissions, economic growth, public acceptability, transparency, and more. The following methods are the primary ways of reinvesting revenue, but are not limited to:

- Lump-sum payments to households
- Reduction in distortionary taxes
- Green spending methods that reduce emissions beyond the carbon price
- Reduction in government debt
- General spending
- Financial support to industries that are especially dependent on fossil fuels

The point of a regulation of a carbon price determines who must purchase allowances or pay the carbon tax. The carbon price can be levied upstream, where the fewest entities exist, on fossil fuel producers, such as coal suppliers, natural gas processing facilities, and oil refineries. The carbon price can also be levied midstream on the first purchasers of fossil fuels, such as electric utilities. Or, the carbon price can be levied downstream on the end users, such as households and businesses. When the carbon price is upstream, entities often pass the carbon price down to the consumer; in essence, consumers can be responsible for the carbon price, regardless of the point of regulation.

Carbon leakage is a risk that policymakers must consider when designing a carbon policy. It is a situation where the cost of a carbon price induces businesses to shift their production to other regions or countries that have less stringent or nonexistent carbon pricing policies. Carbon leakage most frequently affects energy-intensive businesses. Carbon leakage slows overall global emissions reductions and affects economic activity and business competitiveness. To combat carbon leakage, policymakers often support domestic industries and businesses through initiatives such as issuing more free allowances and investing funds in these areas. Policymakers may also penalize foreign competitors by imposing border carbon adjustments, in which goods must pay a surcharge if they are imported from a country with an unequal or nonexistent carbon pricing.

North American Survey and Methods:

In this study, I analyze all national and subnational North American carbon pricing schemes implemented during or before 2018. These carbon pricing schemes include:

- Regional Greenhouse Gas Initiative (RGGI)
- California Cap-and-Trade Program
- Québec Cap-and-Trade Program
- Alberta Technology Innovation and Emissions Reduction (TIER) Regulation
- British Columbia Carbon Tax
- Boulder, Colorado Climate Action Plan (CAP) Tax
- Mexico Carbon Tax.

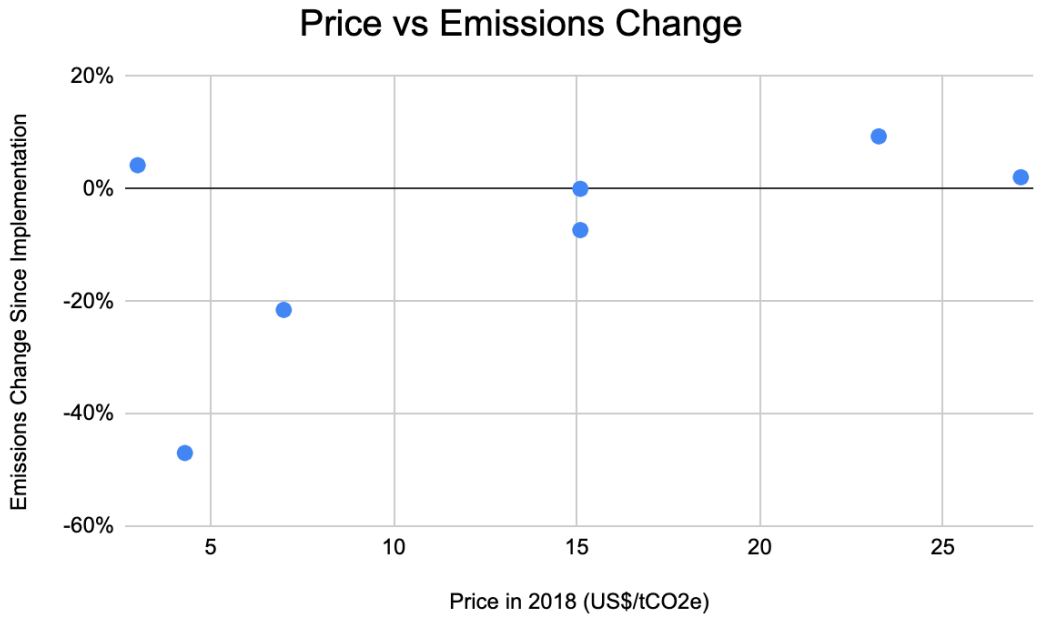
I collect and analyze data on the following attributes of each carbon pricing scheme:

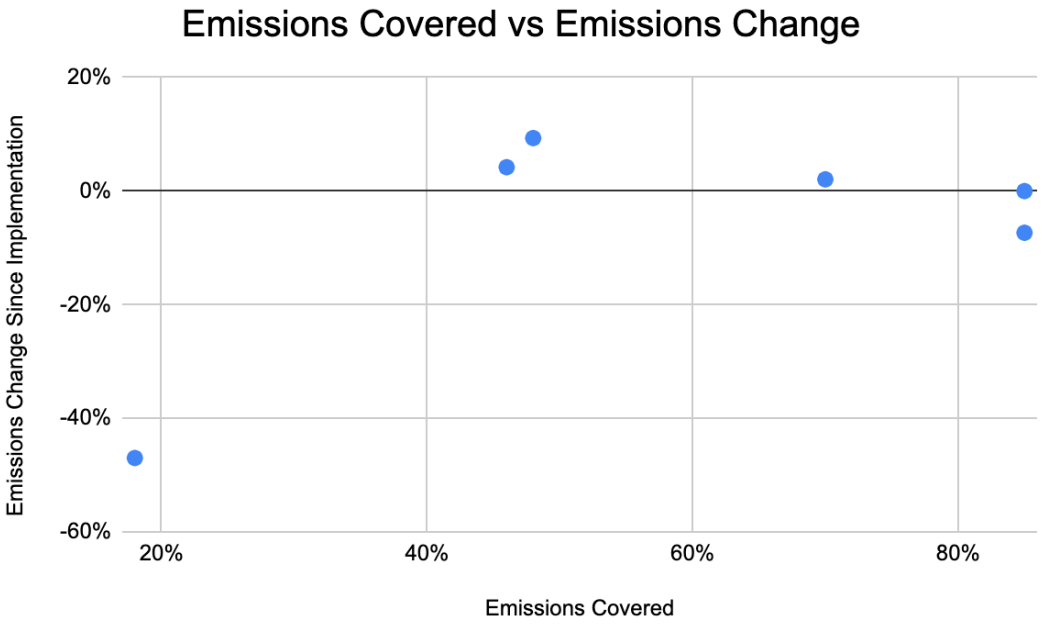
- Type
- Jurisdictions Covered
- Year of Implementation
- Emissions Covered
- Sectors and/or Fuels Covered
- Price in 2018 (US$/tonne$CO_2$e)
- Per Capita Revenues in 2018 (revenue / population)
- Share of GDP in 2018 (revenue / GDP)
- Emissions Reductions Since Start of Program (Until 2018)
- Ratio of GHG Emissions per Capita
- Jurisdiction vs Country less Jurisdiction
- Point of Regulation
- GHG Emissions per Capita in 2018 (Metric tonnes of CO_2-eq. per Capita)
- GDP Change Since Start of Program
- GDP Change Relative to the Rest of the Country
- Revenue Use

Data sources include government and annual reports, databases, the World Bank's Carbon Pricing Dashboard, academic literature, and various other sources as noted in the supporting information.

Results + Discussion

Effects of Price and Emissions Covered on Emissions Reductions:





The above two graphs show that there is no correlation between a carbon pricing policy's price and emissions change of the jurisdiction covered, as well as the percentage of emissions covered and emissions change. For the "price vs emissions change" graph, one would likely expect the greater emissions reductions as the price increases, but many of the jurisdictions with the highest

prices actually saw very little emissions reductions, no change in emissions, or even an increase in emissions. In fact, the jurisdictions with the second and third cheapest carbon prices actually saw the greatest emissions reductions. Similarly, there is no correlation between a carbon pricing policy's percentage of emissions covered and emissions change of the jurisdiction covered. One would likely expect the emissions reductions to increase the percentage of emissions covered increases, but the jurisdictions with the highest percentages of emissions covered saw miniscule or no emissions reductions. The jurisdiction with the lowest percentage of emissions covered had the greatest emissions reductions.

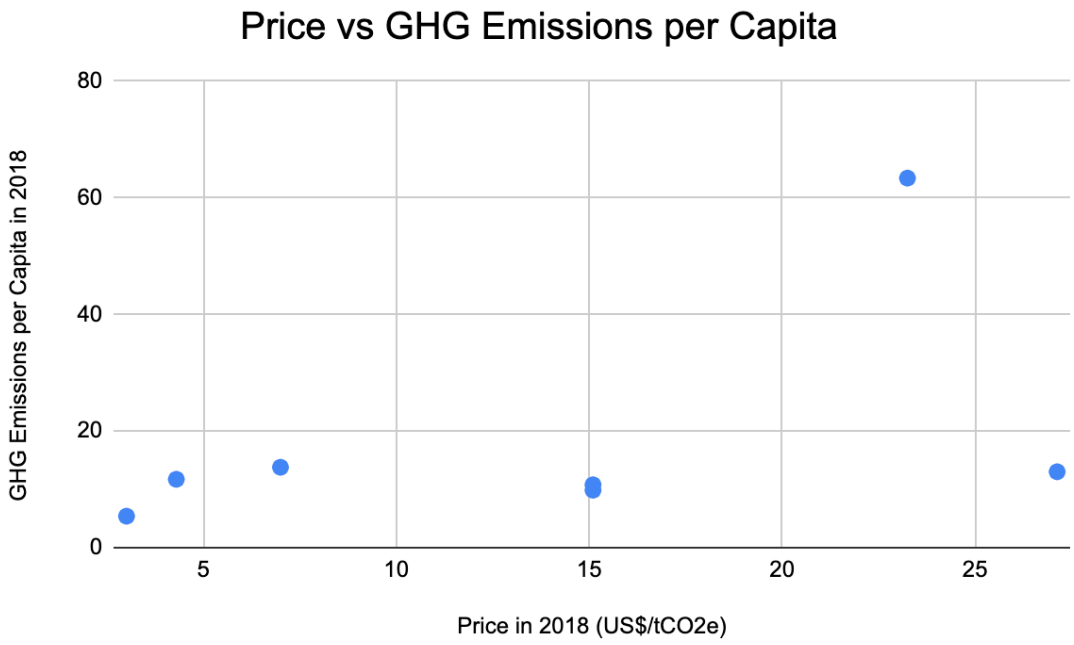
The above observations indicate that many factors, rather than just the design of the carbon pricing policy, must be pushing down emissions in each of the jurisdictions that saw emissions reductions. In the first graph, one would expect the carbon pricing policy with the highest price to induce the greatest emissions reductions, but the GHG emissions actually increased in the jurisdictions with the two most expensive carbon prices. In the two jurisdictions, California and Quebec, with the third highest carbon price, at \$15/tCO_2e, there were very modest or no emissions reductions at all: California emissions dropped by 7.34%, and Quebec saw no emissions reductions at all. As seen in the second graph, out of the five carbon prices that covered the most GHG emissions, at more than 40% each, only one one of those jurisdictions saw emissions fall since the start of the program.

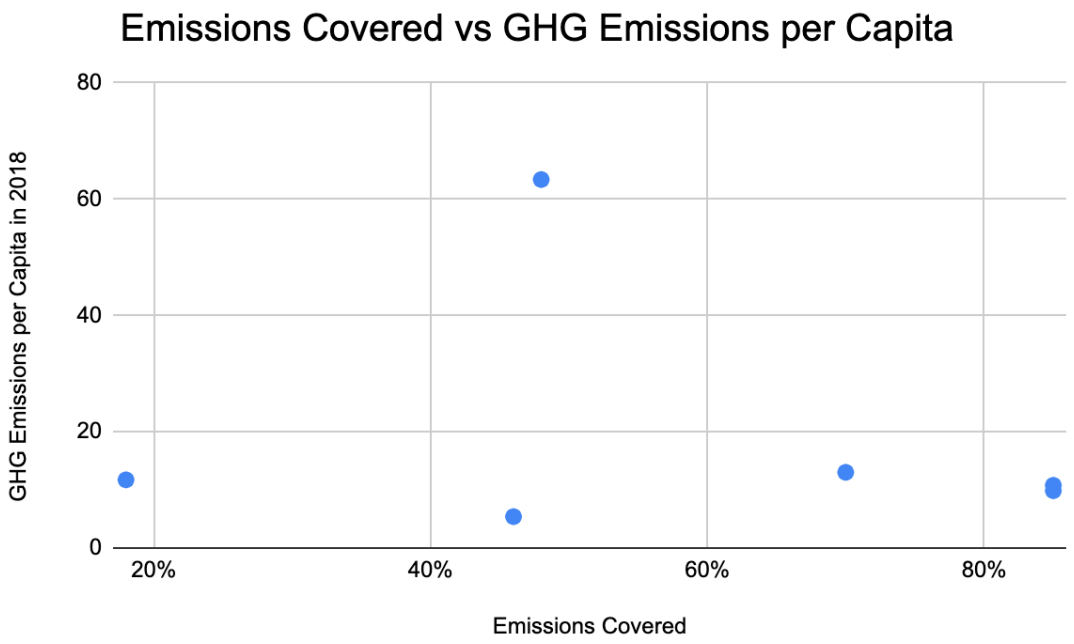
Most surprisingly, the jurisdictions covered by RGGI, the carbon pricing policy that had the second lowest carbon price and covered the least amount of emissions, saw the greatest GHG emissions reductions, at 47% reduction. RGGI had nothing extraordinary or unique about its

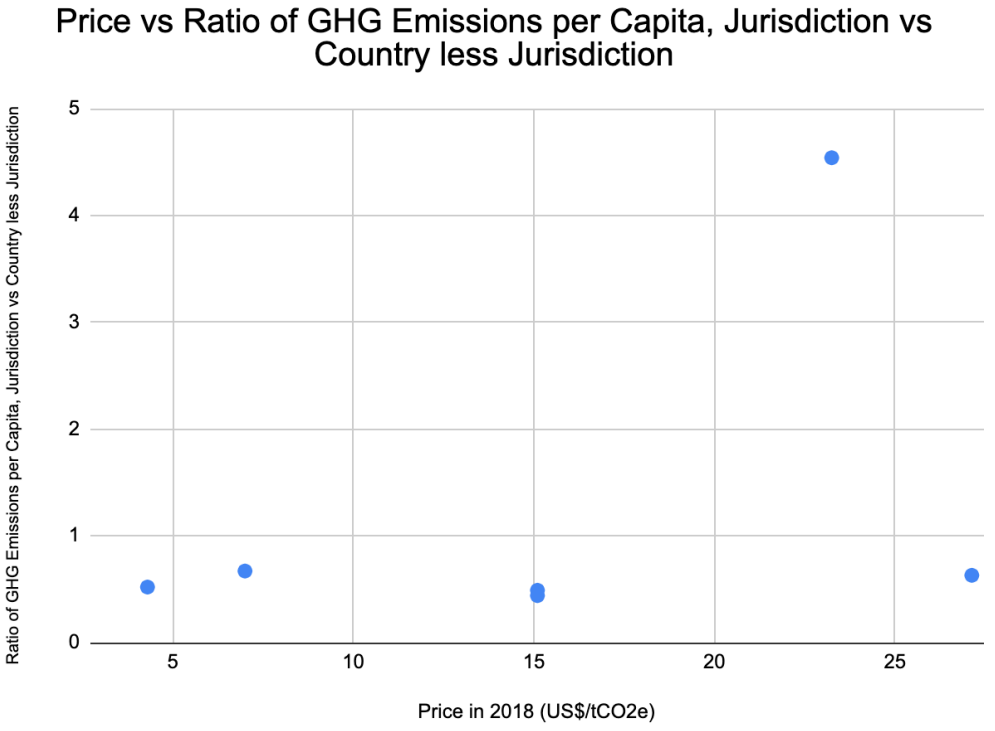
policy design that the other carbon pricing policies omitted. The emissions reductions in RGGI's covered jurisdictions are unrelated to the implementation of RGGI but rather several other factors:

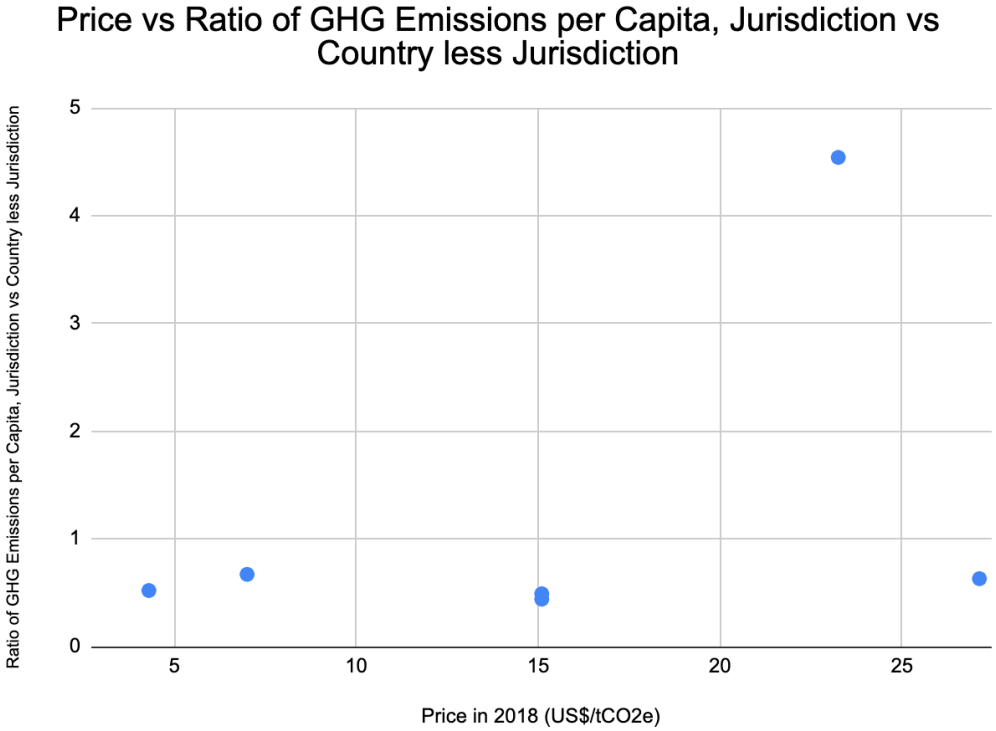
- The biggest contributor has been the region's decades-long trend of fuel switching from high-emitting power sources to cleaner, highly efficient natural-gas-fired generation. For example, natural gas fueled just 15% of New England's electricity in 2000, but fueled 48.5% in 2019. Natural gas generally outcompetes oil- and coal-fired generators in terms of market price.
- Tighter emissions controls on coal-fired resources
- Increasing reliance on renewable and zero-emission energy sources, such as wind and solar
- Increasing reliance on cheaper imported electricity, which does not count toward the region's emissions
- Decreasing demand for electricity

Effects of Price and Emissions Covered on GHG Emissions per Capita:






Price vs Ratio of GHG Emissions per Capita, Jurisdiction vs Country less Jurisdiction
Ratio of GHG Emissions per Capita, Jurisdiction vs Country less Jurisdiction
0
1
2
3
4
5
5
10
15
20
25
Price in 2018 (US$/tCO2e)

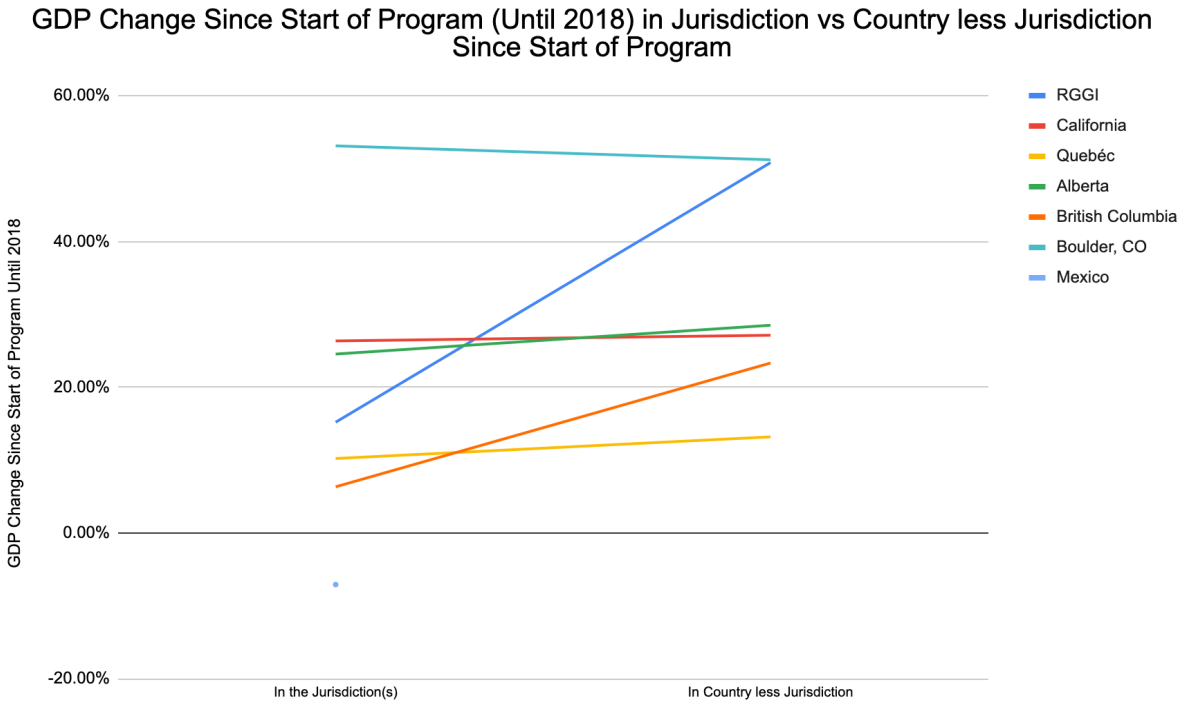

Price vs Ratio of GHG Emissions per Capita, Jurisdiction vs Country less Jurisdiction
Ratio of GHG Emissions per Capita, Jurisdiction vs Country less Jurisdiction
0
1
2
3
4
5
5
10
15
20
25
Price in 2018 (US$/tCO2e)

The first two of the above four graphs indicate that the GHG emissions per capita are very similar among the jurisdictions, regardless of factors like price and emissions covered. The last two of the above four graphs similarly indicate that the jurisdictions all have GHG emissions per capita that are smaller than those of their countries. A ratio of less than one of GHG emissions per capita in the jurisdiction to the GHG emissions in the country, not including the jurisdiction, indicates that the jurisdiction emits less GHG per person.

The one outlier in all four graphs is Alberta. Surprisingly, if Alberta was a nation, it would be one of the highest GHG emitters per capita in the world, as its per capita emissions are three times those of the largest nationwide polluter per capita, Saudi Arabia. Alberta's abnormally high GHG emissions per capita are due to its rich availability of natural resources. Alberta produces most of its energy from fossil fuel combustion, whereas other Canadian provinces like British Columbia generate electricity largely through hydropower. Alberta also generates emissions through its intensive mining, oil, and gas industries, as it has a heavy reliance on oilsands, heavy oil production, while other provinces have fewer large industrial emitters. The trends of the above four graphs suggest that carbon pricing policies do not differentiate jurisdictions significantly in terms of GHG emissions per capita. While these jurisdictions commonly perform better than their countries as a whole, their GHG emissions are still relatively high at around 15 metric tons of CO_2e per person.

Effects of Carbon Pricing Policies on GDP Growth

Carbon Pricing Scheme	In the Jurisdiction(s) (Until 2018)	In Country less Jurisdiction Since Start of Program
Regional Greenhouse Gas Initiative (RGGI)	15.20%	50.81%
California Cap-and-Trade Program	26.35%	27.13%
Québec Cap-and-Trade System	10.22%	13.19%
Alberta Technology Innovation and Emissions Reduction (TIER) Regulation	24.55%	28.50%
British Columbia Carbon Tax	6.34%	23.32%
Boulder, CO Climate Action Plan (CAP) Tax	53.11%	51.20%
Mexico Carbon Tax	-7.07%	N/A



The above table and graph show that every jurisdiction, with the exception of Boulder, CO, saw a GDP change since the start of its program that was smaller than the GDP change of the jurisdiction's country. Because Mexico is a country, it simply has a dot to represent its GDP change, rather than a line. Furthermore, because Boulder, CO is a city, the GDP Change in Boulder is compared with the GDP change in Colorado less Boulder.

There's no evidence that a carbon price stalls GDP growth, as almost all jurisdictions saw GDP growth regardless of the rate of their carbon price. Unexpectedly, the carbon price that stalls GDP growth the most is the cheapest one. Mexico's GDP decreased because of sluggish industrial output, especially in construction and oil, falling business investment, and a slowdown in services and employment.

It is important to note, however, that while the GDP of all jurisdictions covered by a carbon price grew, they grew less than the jurisdiction's country, not including that jurisdiction. With the exception of the Boulder, Colorado Climate Action Plan (CAP) Tax, all subnational and regional jurisdictions had GDP growth that was smaller than the GDP growth of the country, not including those jurisdictions.

Though each revenue's share of GDP is less than 0.5%, all jurisdictions with a carbon price, with the exception of the Boulder, Colorado CAP Tax, saw GDP growth that was more than 0.5% less than the GDP growth of the country minus jurisdiction either the carbon price is stalling GDP growth beyond the 0.5% of GDP that its revenue covers, or there are other unrelated factors hampering GDP growth.

Conclusion and Future Work

In this paper, I examine the environmental and economic effects of the two major carbon pricing schemes, cap-and-trade and carbon tax. The main takeaway of the research is that carbon pricing schemes on their own are insufficient to significantly reduce GHG emissions. Rather, the greatest emissions reductions are seen when carbon pricing schemes are paired with other factors.

A carbon pricing policy likely has a smaller effect on emission reductions than other factors, such as a downturn in the economy, fuel switching, or a shift from heavy to light manufacturing. If policymakers want to make a carbon pricing policy more effective at reducing emissions, they

will need to pair it with additional policies, such as subsidizing green technology research, development, and deployment, that decrease a jurisdiction's reliance on fossil fuels and invest in greater energy efficiency.

Two interesting cases are Alberta and RGGI. The TIER Regulation in Alberta is doing little to reduce emissions, due to Alberta's heavy reliance on fossil fuel combustion and intensive oilsands and heavy oil production. In the case of RGGI, its carbon pricing policy had the second lowest carbon price and covered the least amount of emissions, but saw the greatest GHG emissions reductions. Future research will explore these two regions and examine other significant factors that are inhibiting emissions reductions in Alberta and accelerating emissions reductions in the states covered by RGGI. Future research will also explore the reasons why the GHG emissions per capita decrease was smaller in Québec, British Columbia, Alberta, and Boulder than in their respective countries. Any country-wide policies or initiatives that are effective in reducing GHG emissions per capita should be investigated and potentially implemented to a greater degree.

Bibliography

2017-DE-GHG-Inventory.pdf. (n.d.). Retrieved August 9, 2021, from https://documents.dnrec.delaware.gov/Air/Documents/2017-DE-GHG-Inventory.pdf

2017_GHG_Inventory.pdf. (n.d.). Retrieved August 9, 2021, from https://portal.ct.gov/-/media/DEEP/climatechange/2017_GHG_Inventory/2017_GHG_Inventory.pdf

Bureau, U. C. (n.d.-a). *2018 National and State Population Estimates*. The United States Census Bureau. Retrieved August 26, 2021, from https://www.census.gov/newsroom/press-kits/2018/pop-estimates-national-state.html

Bureau, U. C. (n.d.-b). *American Community Survey 5-Year Data (2009-2019)*. The United States Census Bureau. Retrieved August 26, 2021, from https://www.census.gov/data/developers/data-sets/acs-5year.html

Bureau, U. C. (n.d.-c). *State Intercensal Tables: 2000-2010*. The United States Census Bureau. Retrieved August 26, 2021, from https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-state.html

Bureau, U. C. (n.d.-d). *State Population Totals: 2010-2019*. The United States Census Bureau. Retrieved August 26, 2021, from https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html

Canada, E. and C. C. (2007, January 9). ***Greenhouse gas emissions*** **[Research].** https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

Canada, E. and C. C. (2021a, April 12). ***Greenhouse gas sources and sinks: Executive summary 2021*** **[Program results].** https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html

Canada, E. and C. C. (2021b, April 12). ***Greenhouse gas sources and sinks: Executive summary 2021*** **[Program results].** https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html

Canada_GHG_emissions_trend_by_-province_1990-2013.pdf**. (n.d.). Retrieved August 26, 2021, from** https://climatechangeconnection.org/wp-content/uploads/2014/08/Canada_GHG_emissions_trend_by_-province_1990-2013.pdf

Carbon Pricing 101**. (n.d.). Resources for the Future. Retrieved July 4, 2021, from** https://www.rff.org/publications/explainers/carbon-pricing-101/

Carbon Pricing Dashboard | Up-to-date overview of carbon pricing initiatives**. (2021, April 1).** https://carbonpricingdashboard.worldbank.org/map_data

Climate Mitigation Actions, Sustainability, Maine Department of Environmental Protection**. (n.d.). Retrieved August 9, 2021, from** https://www.maine.gov/dep/sustainability/climate/mitigation-actions.html

Community GHG Emissions | City of Boulder. (n.d.). Retrieved August 26, 2021, from https://bouldercolorado.gov/boulder-measures/community-greenhouse-gas-emissions

Current California GHG Emission Inventory Data | California Air Resources Board. (n.d.). Retrieved August 26, 2021, from https://ww2.arb.ca.gov/ghg-inventory-data

Final 2019 CO GHG Inventory Report.pdf. (n.d.). Google Docs. Retrieved September 5, 2021, from https://drive.google.com/file/d/1TxyoktxCOLFd6CaUKZzeqsKgEIHMjdqt/view?usp=drive_open&usp=embed_facebook

GDP by State | U.S. Bureau of Economic Analysis (BEA). (n.d.). Retrieved August 26, 2021, from https://www.bea.gov/data/gdp/gdp-state

GDP (current US$)—Canada | Data. (n.d.). Retrieved August 26, 2021, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CA

GDP (current US$)—Mexico | Data. (n.d.). Retrieved August 26, 2021, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=MX

GDP (current US$)—United States | Data. (n.d.). Retrieved August 26, 2021, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=US

GHG Emissions and Mitigation Policies | Mass.gov. (n.d.). Retrieved August 9, 2021, from https://www.mass.gov/info-details/ghg-emissions-and-mitigation-policies

Ghg-emissions-inventory-16.pdf. (n.d.). Retrieved August 9, 2021, from http://www.dem.ri.gov/programs/air/documents/ghg-emissions-inventory-16.pdf

Ghg_inventory_trends_00-18.pdf. (n.d.). Retrieved August 26, 2021, from https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2018/ghg_inventory_trends_00-18.pdf

Government of Canada, S. C. (2012, December 14). *Gross domestic product (GDP) at basic prices, by sector and industry, provincial and territorial*. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048701

Government of Canada, S. C. (2017, February 8). *Population and Dwelling Count Highlight Tables, 2016 Census*. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/Comprehensive.cfm

Greenhouse Gas Emissions Inventory. (n.d.). NH Department of Environmental Services. Retrieved August 9, 2021, from https://www.des.nh.gov/climate-and-sustainability/climate-change/greenhouse-gas

Greenhouse Gas Emissions Inventory- Rhode Island -Department of Environmental Management. (n.d.). Retrieved August 9, 2021, from http://www.dem.ri.gov/programs/air/ghg-emissions-inventory.php

Greenhouse Gas Inventory Data Explorer | US EPA. (n.d.). Retrieved August 26, 2021, from https://cfpub.epa.gov/ghgdata/inventoryexplorer/#allsectors/allsectors/allgas/gas/all

Greenhouse-Gas-Inventory. (n.d.). NYSERDA. Retrieved August 10, 2021, from https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Greenhouse-Gas-Inventory

MD 2017 Periodic GHG Emissions Inventory Documentation.pdf. (n.d.). Retrieved August 10, 2021, from https://mde.maryland.gov/programs/Air/ClimateChange/Documents/MD%202017%20Periodic%20GHG%20Emissions%20Inventory%20Documentation.pdf

NJDEP | Climate Change | NJ Climate Data. (n.d.). Retrieved August 10, 2021, from https://www.nj.gov/dep/climatechange/data.html

Population, total—United States | Data. (n.d.). Retrieved August 26, 2021, from https://data.worldbank.org/indicator/SP.POP.TOTL?locations=US

Revenue recycling | Climate Change Connection. (2016, September 22). Climate Change Connection | Connecting Manitobans to Climate Change Facts and Solutions. https://climatechangeconnection.org/solutions/carbon-pricing/revenue-recycling/

The Regional Greenhouse Gas Initiative: Ten Years in Review. (n.d.). Acadia Center. Retrieved August 26, 2021, from https://acadiacenter.org/resource/the-regional-greenhouse-gas-initiative-ten-years-in-review/

Total greenhouse gas emissions. (n.d.). Our World in Data. Retrieved August 26, 2021, from https://ourworldindata.org/grapher/total-ghg-emissions

U.S. Bureau of Economic Analysis. (2001, January 1). *Total Gross Domestic Product for Boulder, CO (MSA)*. FRED, Federal Reserve Bank of St. Louis; FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/NGMP14500

U.S. Census Bureau QuickFacts: California. (n.d.). Retrieved August 26, 2021, from https://www.census.gov/quickfacts/CA

_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2017_Final.pdf. **(n.d.). Retrieved August 9, 2021, from https://dec.vermont.gov/sites/dec/files/aqc/climate-change/documents/_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2017_Final.pdf**