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Taha Bouhoun

The effect of the Carbon Tax on GHG emissions

British Columbia, Canada

Introduction:

Externalities are the major reason justifying government interventions in the free market. Basically, when self-interest doesn't align with social good or when goods don't incorporate social costs, the necessity for broad framing arises which then puts the responsibility on policymakers for crafting laws that include external costs in pricing and correct for market failures. This paper analyzes the effect of the Carbon Tax in British Columbia Canada on greenhouse gas emissions (as a negative externality).

Although Canada's commitment to the Kyoto protocol signed in April 1998 to reduce its carbon dioxide emissions by 6% of the 1990 baseline by 2012, its federal government failed to adopt a nationwide law that would put a price on heavy CO_2 emissions, particularly in Alberta and Saskatchewan due to the new field discoveries and the conflict of interest between provinces and the federal government (Jeffrey. S, 2007). The country witnessed a 15% increase in population and over 47% rise in their GDP, however, the toll was Canada missing its Kyoto Protocol's commitment by 34% peak of GHG emissions compared to the 1990 baseline (Duff. D. 2008)

During this period, the US under the department of George W. Bush withdrew from the protocol which spired a bottom-up movement throughout the world to act in favor of climate change under the umbrella of NGO's and environmental initiative. On February 19th, 2008, The local government of British Columbia enacted a bold decision to impose

a flat tax on carbon consumption (10$ per ton of CO_2) which was one of its kind in North America (CTC report, 2010).

This decision spurred many concerns especially in light of the economic crisis that hit the financial system in 2007. The critique ranged from questioning the effectiveness of the tax in reducing GHG emissions as well as the potential threat of hindering economic performance and worsen the market landscape. On the other hand, after experiencing the warmest winter on record back in 2006, British Columbia was determined to act against climate change as they're one of the most vulnerable provinces in Canada due to rising sea level in the west coast (projected 50 cm SLR by 2050 according to The B.C. Ministry of Environment).

The report from the Carbon Tax Center compares per capita GHG emissions in British Columbia to the rest of the Canadian provinces as well as on fossil fuel sales, this paper estimates the effect of the Carbon Tax on CO_2 of BC compared to other Canadian provinces by attempting SCM and DID model based on Statistics Canadian datasets ranging from 1999 to 2017.

Data:

The data used for this paper was extracted from the Statistics Canada website which is a compilation of thousands of metrics in different categories and across all Canadian provinces. The database is managed by the Ministry of Innovation, Science and Economic Development which makes it the basis for all government reports and evaluations, hence, the most reliable source to investigate our research question.
As a panel data, the measurements of relevant covariates are recorded from every year 1999 to 2017 for each of the 13 provinces yielding the following:

- Dependent variable:
    - Total CO_2 emissions [tonnes]: measured every year since 1999, this represents the sum of the household and industries estimated CO_2 emissions for each province and the unit expressed in is Tonnes.
- Explanatory variables:

- Population [units]: The change in habitat of a province impacts the total CO_2 emissions. Based on the population census that Statistics Canada performs every year, it's an estimation of people residing in each province.
- Gross Domestic Product [billion $]: The estimated GDP of each province based on the 2012 USD baseline. Which would have a clear role in predicting the economic activity, hence, GHG emissions.
- Unemployment rate [%]: Since it's an estimation on a monthly basis, the unemployment rates for the panel data is the average rates of the 12 months. The rate is related to economic activity and has a potential impact on GHG emissions.
- Gasoline net sales [thousand $]: Carbon tax has a visible effect on the price of the gasoline in BC and -according to economic theory- we expect the demand to decrease. As a result, the emissions due to the decrease in demand will shape the trend of GHG emissions.
- Motor Vehicle sales [units]: Same reasoning as gasoline sales, we need to control for the number of vehicles circulating in each province as they impact the emission of CO_2.
- Consumer Price Index [unit]: In light of the potential inflation that can bias our results in terms of the CPI for each province, we need to account for the rise in prices for reasons that are not related to the Carbon Tax.
- Transportation expenditure [$]: Showing the government spending on Public transportations per capita for each province.

Notes:

1. Statistics Canada doesn't specify a dataset with the government spending on green spaces, the budget is included with other irrelevant covariates to the research question, hence, it's ruled out of the panel data.
2. Since the transportation is expressed per capita, the variable "Population" shouldn't be included in the model to avoid correlating covariates. However, it's used to compute GDP per capita.

Methodology:

1. Synthetic Control:

Canada has 13 states, 6 of which are less populated (the northern islands) and most of the population is clustered in the south. Furthermore, most of the covariates in those provinces are missing (refer to the Synth dataset Appx .1). Consequently, the donor pool for the control states is small and if the variance between units is large, then it's challenging to find a synthetic version of British Columbia having provinces outside its convex-hull.

Nevertheless, adding other states from the US (e.g., Washington, Oregon) would cause disparities due to differences in the US and Canadian markets (namely the effects of the housing bubble in the US would bias the credibility of the findings)

Despite the limitations, building a SCM yielded Fig .1 which takes as covariates (GDP per capita, CPI, Unemployment rate, Vehicle sales, Gasoline sales). For the following provinces:

	Treated	Synthetic
GDP	183.3047	183.6784
Gas sales	4505265	4508249
CPI	103.525	104.5013
Unemployment_rate	6.7375	6.77755
Vehicles sales	6259374	5812271

Province	Unit weight
Alberta	.146
Manitoba	.246
Ontario	.198
Quebec	.410
New Brunswick	.0
Nova Scotia	.0

Table 1. Highlighting the result of SCM in terms of the weights associated with each province as well as the comparaison between the mean of the covariates of British Columbia and its synthetic version

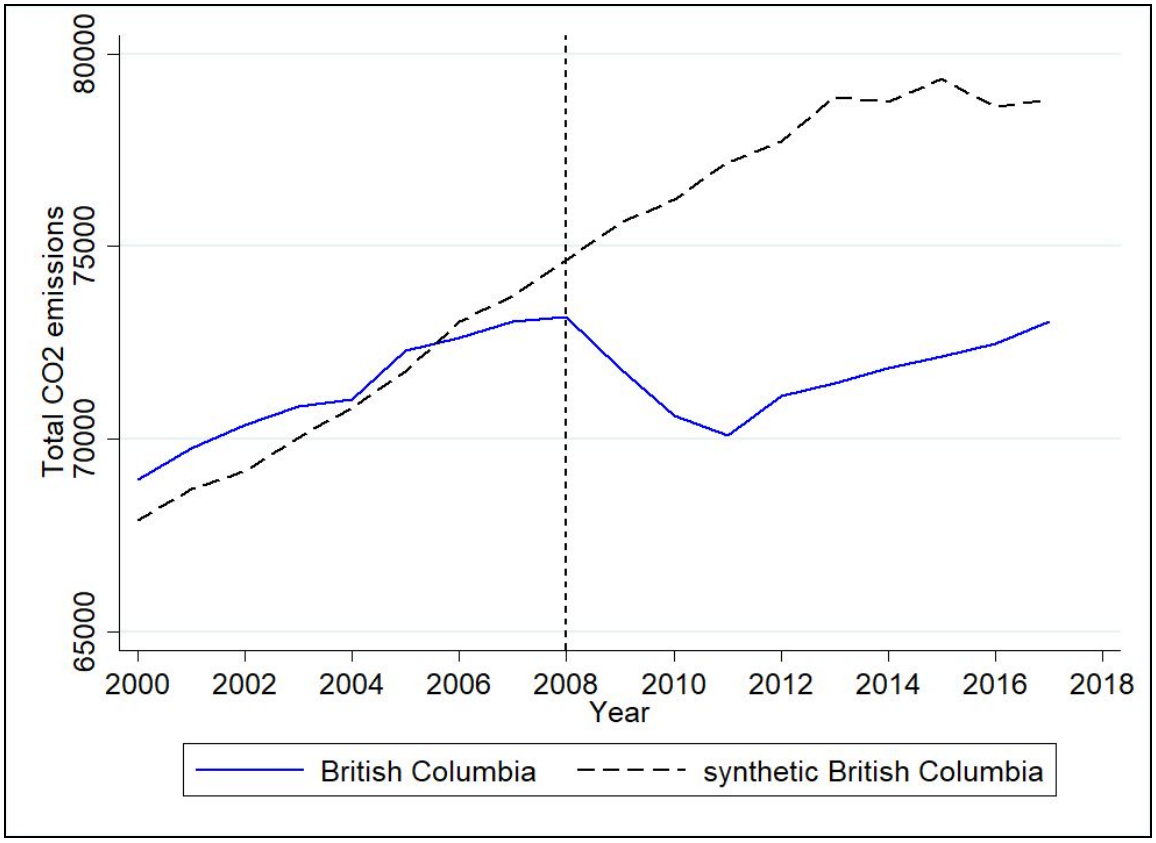

Fig .1 Synthetic Control of British Columbia generated from other Canadian provinces using Stata software [source code: Appx .1]

Remarks:

Although attempting to add as many covariates relevant to the research question, we can still recognize the poor fit of synthetic BC prior to the treatment year as well as potential spillover effects of neighboring provinces. Since the goodness-of-fit prior to the treatment is the selling point for the credibility of the SCM, we can't be confident about the estimates in the context of the Carbon Tax effect.

2. Difference-in-differences model

Narrowing down the donor pool to provinces that are more similar to BC in terms of the parallel trends of the GHG emissions during the pre-treatment period (1999-2008). Difference-in-Differences model was the alternative to investigate the effect of the Carbon Tax keeping in mind the following assumptions:

I. Stable Unit Treatment Value Assumption (SUTVA):

The adoption of the Carbon Tax in British Columbia shouldn't affect the control unit in terms of the outcome (GHG emissions) or the covariates (outsourcing industries from BC to a control province because of CO_2 restrictions). This can also be referred to as Spillover Effects, meaning that there shouldn't be an external effect of the Tax on other neighboring provinces.

II. A parallel trend in outcome between the treated unit and the control unit: considered the most important assumption for the DID method because it ensures the internal validity of the model. The challenge is to find a control unit that has the same outcome trend overtime prior to treatment.

Upon examining the outcome trends, Quebec has a clear parallel trend of CO_2 emissions pre 2008 as highlighted in Fig 2 contrary to Alberta and Ontario.

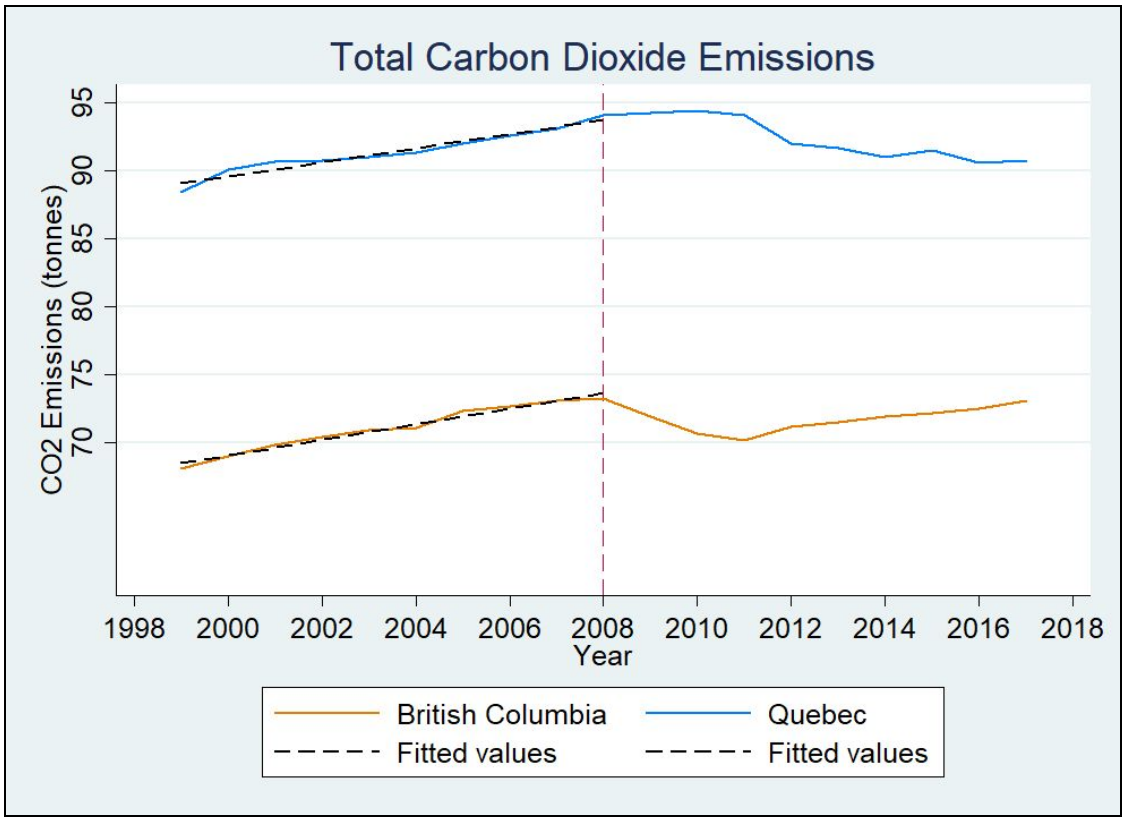

Fig 2. Illustrating the parallel trend between British Columbia and Quebec in terms of GHG emissions prior to the adoption of the Carbon Tax in 2008. Best fit lines were included to clearly visualize the slopes of the trends.

Besides the parallel trend condition, Quebec is four provinces apart from British Columbia which leaves a little window for spillover effects due to the introduction of the Carbon Tax

Time fixed effect:

Since we have panel dataset, we need to account for the fixed effect of time using the command "`xtset`". In other words, we want Stata to recognize the observations as measurements of two different units throughout a defined period of time.

The interaction term $treat \times postpre$ would generate a binary variable representing the difference-in-Differences between British Columbia and Quebec, hence, the estimate of the ATE (average treatment effect).

The functional form of the model:

$$Y = \beta_0 + \beta_1 \times [postpre] + \beta_2 \times [treat] + \beta_3 \times [postpre \times treat] + \beta_4 \times [cov] + \xi$$

Results:

DID design is inherently a regular regression that accounts for the conterfactual by considering the control group as the alternative scenario given the similarity of the outcome trend prior to the treatment. The regression using Stata yielded the following:

DIFFERENCE-IN-DIFFERENCES ESTIMATION RESULTS

VARIABLES	Total CO2
DID (ATE)	-2,571***
	(990.1)
Treat	-16,609***
	(3,350)
Post_pre	3,014***
	(654.8)
Gas	0.00160**
	(0.000811)
CPI	-291.9***
	(104.6)
GDP per capita	0.729**
	(0.283)
Vehicle sales	0.00690
	(0.00819)
Transport expenditures	-3.091**
	(1.214)
Unemployment rate	-1.871
	(229.2)
Constant	79,885***
	(9,057)
Number of stateid	2

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. The estimate of the treatment effect of the Carbin Tax on the Total CO_2 emissions of British Columbia.

The findings suggest that the DID Average treatment effect of introducing the Carbon Tax is estimated to be a decrease by 2571 tonnes of the total CO_2 emissions with a significance level of 0.01 (p-value). We can also interpret that Quebec had an increase in GHG emissions by 3014 tonnes.

The model also accounts for the time fixed effect by using the "`xtreg`" command as mentioned in the code source (Appx)

VARIABLES	Household CO_2	Industries CO_2
DID (ATE)	-1,512*	-1,477
	(836.8)	(1,630)
Treat	-12,978***	-16,434***
	(2,831)	(5,514)
Post_Pre	757.3	605.7
	(553.4)	(1,078)
GDP per capita	-0.0687	1.371***
	(0.239)	(0.466)
Gas sales	0.000383	-0.00135
	(0.000685)	(0.00134)
Vehicles sales	0.000913	-0.0102
	(0.00692)	(0.0135)
CPI	50.81	-201.6
	(88.42)	(172.2)
Transpot expenditures	0.468	-4.800**
	(1.026)	(1.999)
Unemployment rate	-187.9	525.4
	(193.7)	(377.4)
Constant	24,679***	39,348***
	(7,654)	(14,910)
Number of stateid	2	2

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. The estimate of the treatment effect of the Carbin Tax on the CO_2 emissions of households and of industries in British Columbia.

The outcome in this section was replaced by the estimated GHG emissions dependent on the source.
Household emissions seem to decrease by 1512 tonnes with a significance level of 0.1 (p-value). On the other hand, the emissions attributed to industries show a similar decrease (1477 tonnes) but the results are not significant.

The Interpretation:

The economic theory suggests that rising prices (in the form of a tax) would decrease the consumption if a given good. In the context of the Carbon Tax, there was a clear decline in the GHG emissions for British Columbia compared to Quebec which confirms that the policy indeed had an effect on reducing the total share of BC air pollution.
As of Table 3. The estimation shows a decrease of 1512 tonnes for households which suggest that the price of gasoline shaped their consumption behavior to consider other mobility alternatives or minimize their travel unless necessary. It's noteworthy to mention

that the average household emissions prior to the treatment is 14963 tonnes, therefore, the decrease represents roughly 10.1% of the usual average.

Strengths and limitations:

"If an omitted variable does not change over time, then any changes in the outcome over time cannot be caused by the omitted variable" - Donald, S. G. and K. Lang (2007)
DID model relies on a comparison that is based on a natural control unit rather than a generated simulation of the counterfactual of BC in the absence of treatment.
Furthermore, this simple method takes into account the change due to factors other than the intervention. As a result, the estimate of the effect can be inferred using observational data conditioning that the assumptions are met. On the other hand, finding a perfect control unit can be challenging especially if many covariates need to be matched.
The mechanism of correcting for externalities spurs a clear change in consumer behavior, but other factors like awareness of climate change and the environmental cause can also reshape the habits of people which might be hard to disentangle.

Conclusion:

The effect of the Carbon Tax is meant to be seen in the long term, but primary results show a clear cut in the GHG emissions of British Columbia. The fact that internalizing social costs can cause a significant shift in consumer behavior would policymakers to craft laws with a broad framing.
Further investigation would be on the effect of reducing CO_2 emissions on the economic performance to compile an argument that we can grow green especially in light of climate change warnings that transcend the market dynamics and put our existence as human beings in stake.

Appendix:

Data source:

Statistics Canada (2018). Multiple covariates by province from 1993 to 2017. Retrieved from: https://www150.statcan.gc.ca

Google Drive compiling all the datasets extracted from the website:
https://drive.google.com/open?id=18FvPHn5KTxeq-MjC7C-udgczqUr8WRuH

The dataset used for SCM:
https://drive.google.com/open?id=1CyL9wq8SsJUgxQ5wh8E7H5ZlzkSKpuAO

The dataset used for DID model:

https://drive.google.com/open?id=1U-Ov44GrMQi7rkYB2wS5o3opoIItohO5

Stata Code [SCM and DID]:

https://gist.github.com/Tahahaha7/ee1ba78d57126ffef8547f2316094d3c

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