Impacts of Carbon Pricing Policies on Manufacturing Sectors: A Further Investigation of the BC Carbon Tax

by

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ABSTRACT

This paper investigates the impacts of the British Columbian (BC) carbon tax on the manufacturing sector in BC. I estimate that the policy has a statistically significant 3.7 percent decrease in manufacturing sales. Furthermore, I show this is likely a contracting force on the overall sector size. I use a difference-in-differences model to estimate the impact of the policy and a synthetic control method as a robustness check. I investigate the possible implications from similar policies in other provinces at this time. Expanding on previous research, I also test if the estimates are robust to the structural change of the BC policy in 2013. All of the tests show that the results are robust to these factors; however, the magnitudes of the estimates are slightly altered.

Contents

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Introduction

1.1 My Research

This paper investigates the effects of the BC carbon tax on the province's manufacturing sales. I focus on the manufacturing sales in order to further build upon previous research and better understand the policy implications within this sector. Previous research analyzed the effects of this policy on employment levels and found negative impact within the manufacturing sector. When analyzing employment levels, however, it is possible that the estimated effect of the policy is biased by firms shifting to newer (and less CO2 intensive) technologies that are also less labour intensive. Using manufacturing sales, I can corroborate the employment findings while removing the potential bias from labour productivity changes.

To estimate the effects of this policy I construct a difference-in-differences model that uses the remaining provinces of Canada as an untreated control group. This method compares the differences between this group and BC (the treated group) before and after the implementation of the policy. The change in the difference between these two groups is the estimated effect of the policy.

Using this method I find that the implementation of the policy has a statistically significant and negative effect on the sector's sales. This demonstrates that the policy was likely a contracting force on the sector. Building upon these findings, this paper tests the robustness of these estimates using multiple tests and checks. The tests indicate the estimates are likely robust to all of these factors.

1.2 Carbon Pricing

Global warming poses a threat due to increasing temperatures causing higher disaster variability and frequency. The generally accepted cause for this warming effect is the overabundance of greenhouse gasses (GHGs) in our atmosphere (NASA, 2020). Due to this threat, nations around the world are implementing policies in an attempt to decrease the release of GHGs. The most common method used by nations is a carbon tax due to its ease of implementation.

A carbon tax is a type of carbon pricing policy that aims to reduce CO2 emissions (one of the most common GHGs). A carbon tax is a fee imposed directly onto carbon emissions or carbon rich inputs, such as fuels or industrial oils. In a revenue neutral carbon tax, the funds that are collected are then redistributed back to individuals and firms. This redistribution is often structured in a way to mitigate the negative impacts from the tax. This attempts to minimize the social costs of the policy while reducing carbon emissions due to the now higher relative prices for the carbon rich products (Metcalf, 2009; Baranzini et al., 2017). For these reasons, economic theory formulates that the revenue neutral carbon tax (as well as Cap-and-Trade systems) is the most efficient way of reducing carbon emissions.

1.3 The British Columbian Policy

The BC carbon tax is one of the most renowned carbon pricing (CP) policies in the world due to its high price level (9th in the world) paired alongside it's high coverage rate (70% of regional emissions) (World Bank, 2020). The policy was first proposed on February 2008 and enacted on July 1st, 2008, by the BC legislature. Initially the tax was imposed at $10/tonne of CO2 emissions and set to rise by $5/tonne every year until 2012. The tax covers all fossil fuels and tires combusted for heat or energy, as well as industrial oils. Producers and importers of the fossil fuels are liable for payment of the tax and the tax is to be paid on a monthly basis (World Bank, 2020).

In 2012 the tax reached a price of $30/tonne. At this date, no future price increases were planned or scheduled for the immediate future (Ministry of Finance, 2013). In 2018, six years later, the policy was revised and the price began to increase once again. The tax was set to increase by $5/tonne every year until it reaches $50/tonne in 2021 (Ministry of Finance, 2017).

The BC carbon tax was a revenue neutral carbon tax. Due to this, the revenues from the tax were redistributed in order to lower income taxes, lower corporate taxes, and give out credits/benefits (Ministry of Finance, 2012). The structural form of the policy changed in 2014 and the redistribution scheme was altered (Ministry of Finance, 2014). At this time, corporate taxes were increased back to their 2008 levels and the surplus revenues from the tax were no longer used in a cost mitigation framework (Murray and Rivers, 2015). Surplus revenues were used instead to promote specific industries (primarily the BC film industry). Since the BC policy was no longer an example of a revenue neutral carbon tax, I test the robustness of my estimates to this structural change in the policy (in the results section of this paper).

1.4 Other Provinces' Carbon Policies

Around the same time as the BC carbon tax, two other provinces already had similar policies. In 2007, Alberta (AB) and Quebec (QC) implemented carbon pricing policies within their provinces. The Albertan policy was a large-emitter focused program that used previously acquired firm level data (starting in 2003) to impose firm specific reduction schedules over a 10 year period (Alberta Environment and Parks, 2008). The coverage and the effective price level of this policy were much lower than the BC carbon tax. Furthermore, this policy had a multitude of ways that companies could offset emissions in lieu of actual reductions (Alberta Environment and Parks, 2018). The AB policy was also criticized due it's incentivization of new companies to emit as much as possible, in their first year, so that later reductions would be easier (Hastings-Simon, 2018). In contrast to the AB policy, Quebec implemented a very low priced policy which was implemented across many different sectors and regions (Ministry of Sustainable Development, Environment and Parks, 2008). Due to these low prices, and levels of coverage, research on the BC carbon tax often dismisses the potential effects from these policies or finds they have no substantial impact on results (Azevedo et al., 2019; Yip, 2018). I test the robustness of these policies to the manufacturing sales in the results section of this paper.

1.5 Previous Policy Research

Current research on the topic finds that some existing carbon pricing (CP) policies successfully reduce carbon emissions in specific sectors/regions (Forbes and Zampelli, 2019; Lawley and Thivierge, 2018; Pretis, 2019; Martin et al., 2014; Murray and Rivers, 2015). Other research, however, attempts to measure the costs of these types of policies (Yamazaki, 2017; Yip, 2018). One such paper, by Azevedo et al. 2019, finds that the BC carbon tax reduces employment in the manufacturing sector while increasing employment in the "smaller firmed" proportion of the service sector. This positive impact in the service sector is theorized to stem from the revenue neutral aspect increasing consumer wealth and decreasing corporate taxes. The negative impact on the manufacturing sector is thought to be due to the increased costs levied upon carbon intensive firms due to the carbon tax.

These increased costs could cause some firms to scale back production or drop out of the market entirely. However, it is also possible that less employees were needed after these firms adopted newer (and less carbon intensive) equipment. For these reasons, this paper analyzes the effects of the policy on manufacturing sales in order to minimize estimation bias stemming from labour productivity changes. These findings, alongside previous research, help develop our understanding of the impacts on the manufacturing sector due to these policies.

Data and Summary Statistics

I use monthly data from the Statistics Canada website. The data for each of the variables is aggregated to the provincial level [excludes territories] and ranges from Jan 1, 1997 - Aug 1, 2019. This data range is chosen as some of the control variables are only available within this time frame; however, it thoroughly covers the dates of interest.

A limited time range is also used, during the robustness checks, which is truncated to Jan 1, 1997 - Jun 1, 2013. This is because, starting with the policy update on June 1, 2013 (Ministry of Finance, 2013) much of the revenues from the program were used with some "objectives of promoting certain sectors" (Murray and Rivers, 2015). Due to this, the policy was no longer a classic example of a revenue neutral carbon tax.

My final data set (with all of the combined variables) is panel data with 2720 total observations. Within this data, we have 10 provinces (N) and 272 time observations (T). All of the variables are seasonally unadjusted ("not seasonally adjusted" is also sometimes used by Statistics Canada). I use seasonally unadjusted data as any seasonal variation would be accounted for in my estimates due to my models time fixed effects. I also used the seasonally unadjusted data to avoid any potential estimation implications from Statistics Canada's adjusting methods.

My variables are:

1. SALES: *Provincial Manufacturing Sales* (Statistics Canada, 2020c). Converted into real 2002 dollars using a consumer price index of "all items" (Statistics Canada, 2020d). Units are in millions of dollars. Furthermore, this data is

aggregated at the sectoral level, and not broken down into specific industries, because Statistics Canada omits a large number of observations in the more detailed data set. These omissions are done to protect Canadian organizations but may lead to biases when estimating with this data. Restricted data, with no omissions, is a possibility and a future focus for my research.

2. POP: *Provincial Populations* (Statistics Canada, 2020a). Units are in millions of people. Furthermore, this variable was used in order to control for changes in sales due to population changes.

3. UNEMP: *Provincial Unemployment Rate* (Statistics Canada, 2020b). Units are the percent of the unemployed proportion of the labour force over the total labour force. Furthermore, this variable was one of the two variables used to control for changes in the data due to provincial business cycles.

4. INC: *Provincial Total Wage Income* (Statistics Canada, 2020f). Converted into real 2002 dollars using the same method as SALES. Units are in millions of dollars. Furthermore, this variable was one of the two variables used to control for changes in the data due to provincial business cycles.

5. GAS: *Provincial Average Consumer Gas Prices* (Statistics Canada, 2020e). Converted into real 2002 dollars using the same method as SALES. Units are in dollars. Furthermore, this variable was used as a proxy to control for changes in gasoline prices.

A table of summary statistics for all of these variables can be found on Table A.1 in the appendix.

Methodology

This section lays out the detailed background methodologies for the two key econometric factors of this paper. These factors are the estimation of the preferred model (Difference-in-differences model) for this paper and the the complementary synthetic control method. This section is thorough in its depiction in the interest of reproducibility and transparency. Readers may proceed to the results section if they don't need the background methodologies.

For the terminology of this section the treated group is BC, the untreated group is the remaining provinces of Canada, and the treatment is the BC Carbon tax imposed in July 2008.

3.1 The Difference-in-Differences Model

I use a Difference-in-Differences model to calculate the impact of the British Columbian Carbon tax on the province's manufacturing sales. This model effectively gives equal weighting to each of the provinces in the untreated group by taking the mean of the dependent values for these provinces. This averaged value is then compared to the values of BC in order to determine the differences between them. Any change to these differences occurring at the time of, or just after, the treatment is the estimated effect of the treatment (ie.the carbon tax's effect on manufacturing sales).

For Difference-in-Differences estimates to be accurate the two values must have parallel slopes in the periods leading up to the treatment. Figures B.1 and B.2 in the appendix display a plot of these two values from the data set. In these figures we see a multitude of seasonal variation. All of the seasonal variation is accounted for and removed from the estimates by using time fixed effects (shown in the next subsection). This method isolates any impact that is common to any month-by-year and removes it from the estimates. Ignoring the seasonal variation in figures B.1 and B.2, we can see that the overall trends are very similar; however, the untreated group is mildly steeper. This implies the difference between the two groups is converging with time. Due to this, the model's estimates for the effects of the treatment could be biased. This issue is addressed later in this section by using a synthetic control method.

3.1.1 The Model

$$\begin{aligned} Log(SALES_{it}) = \beta_0 BC_{1it} + \beta_1 BC_{2it} + \beta_2 POP_{it} + \beta_3 UNEMP_{it} + \beta_4 INC_{it} \\ + \beta_5 GAS_{it} + \beta_6 Log(SALES_{i(t-1)}) + \gamma_i + \rho_t + \upsilon_{it} \end{aligned} \tag{3.1}$$

The i represents the i-th province. The t represents the t-th time period. BC_1 is a dummy variable that represents if the BC Carbon Tax is implemented in the i-th province at the t-th time period. BC_2 is a dummy variable that represents if the expansion of the BC Carbon Tax has happened in the i-th province at the t-th time period. $SALES_{i(t-1)}$ is a lag dependent variable that represents the manufacturing sales in the i-th province at the (t-1) time period. This allows the SALES value of today to depend on the SALES value of the period before. The γ is the entity fixed effect variable that represents the i-th province. This accounts for variation due to different provinces. The ρ is the time fixed effects that represents the t-th time period. This accounts for variation due to different months and due to different years. The β's are the effect, on the dependent variable (SALES), from a one unit increase of the paired variable. Due to the log term on the dependent variable, these beta values are now representing the percentage change in SALES from a one unit increase of the respective variable. β_0 is the effect of the carbon tax on BC's manufacturing sales. Furthermore, since there is a lag dependent variable in the model, a simple estimate for the long-run effects of this tax are estimated to be $\frac{\widehat{\beta}_0}{1-\widehat{\beta}_6}$ (Henry, 1994). The the results of this model can be seen on table A.3 and will be further discussed in the results section.

3.1.2 Potential Biases

For omitted variable bias, if any shock is unaccounted for and occurs uniformly to both the treated and untreated groups, then the effects of the shock are equal. This means that the values for the two groups would change in the same way and the difference between them would be unchanged. Because of this, any uniform shock to both groups does not affect the estimates of the treatment effect. This feature removes a great deal of the omitted variable bias in this system. The remaining sources of omitted variable bias in this model come from shocks that only happen to one of the groups, or happen to one of the group disproportionately.

Another source of potential bias in this model is from outlying shocks. To address this we must plot the residuals and see if there are any large outliers indicating potential shocks to one province and not the others (see Figures B.3-B.6). From figure B.5, we see that NFL, PEI, ON, and SK show signs of large shocks not likely present within the BC data. In this model, where the untreated provinces are given equal weights, this is likely to lead to biased estimates. This bias is mitigated later in this section by using the synthetic control method.

3.1.3 Standard Errors and Residuals

In this model the standard errors are clustered at the provincial level. This is to account for similarities in observations within a group (ie. province) so that our regressions do not predict smaller standard errors.

In time series observations, such as this panel data set, the current values in the data often greatly depend on the values in the previous periods. If this relationship is not modeled then this results in serial correlation between the current error terms and the previous error terms. Furthermore, this correlation can bias our estimated coefficients and standard errors. I model this by including lagged values of the dependent variable which isolates the intertemporal relationship and removes it from the policy estimates.

When including a lag there can be a bias in the estimates (Nickell, 1981). However, that bias becomes smaller as the time dimension of the panel increases. The time dimension of my panel is 272 observations long and, for this reason, it is likely sufficiently large enough that the bias is negligible.

To test the form of the serial correlation in the data, and determine how many lags I need, I increase the number of lags while monitoring the plots of the regression residuals. The first lag greatly reduces the residuals from the model and makes them more normally distributed (See figure B.4 and B.5). The second lag, however, does not seem to change the residuals in any meaningful way (See figures B.5 and B.6). For these reasons, I am confident that at least one lag needs to be included into the model to prevent biased estimates.

To further analyse the form of the serial correlation in the data I use a modified Breusch-Godfrey test that is geared toward panel data (Croissant and Millo, 2008). This test uses an auxiliary regression to test if any of the previous error terms are correlated to the current error term. The test indicates that there is always evidence of serial correlation even as I include up to 24 lag dependent variables (ie. two years worth) (See Table B.2). This suggests that I still need to include one lag term; however, serial correlation persists within my data. To address this I use heteroskedastic-and-autocorrelation robust standard errors.

I use the Newey-West method for these robust standard errors (Newey and West, 1987). A function to achieve this is present in the panel regression software I am using and further details of the methods see Millo (2017). I use the Newey-West robust standard errors in all of the regressions in this paper; however, I ran a robustness check (table A.6) testing two alternative robust standard errors. This test shows no significant differences between any of the methods so I will use the more common Newey-West method for everything in this paper.

3.2 Synthetic Control

The synthetic control method is a complimentary procedure to be used alongside difference-in-differences analyses. When comparing the two methods, the synthetic control method is able to reduce the potential for specific biases, gives us more information beyond just point estimates, and allows us to optimize the weights within our data. This method, however, still has the potential for bias and the best estimate for the impact of our treatment is likely to be a combination of the synthetic control and the difference-in-differences results.

3.2.1 Synthetic Control Methodolgy

I use a synthetic control method (Abadie et al., 2011) to address the issue of non-parallel trends as well as the dissimilar provinces in the original model. This method synthesizes an untreated control group by determining the optimal weighting of all of the variables and untreated provinces. To determine this, the method chooses the weights that minimize the difference between the synthesized control and the actual values of the treated group (BC). It minimizes this difference for all of the periods before treatment. This results in an estimate for the counterfactual of the treated group. We can compare differences between this estimated value and the real values to determine the effect of the treatment. To estimate the effects of the treatment, I average the difference between the synthetic control and the treated group over the post treatment period. This gives us the estimated average effect of the policy over the remaining 11 years in the data.

Figures B.7 and B.8 display the synthetic control alongside the treated group. In these figures, we can see that the synthetic control has parallel trends in the periods leading up to the treatment. This means this method adjusted the untreated group and has removed the bias that was present in the initial regressions. One source of bias that could still be present within this method, however, is if a shock impacts one of the provinces, and not the others, during the post treatment period. A similar issue arises if a shock disproportionately affects the treated or untreated groups. If this happens, it will alter the differences between the synthetic control and the actual values resulting in biased estimates for the effects of the treatment. The most likely event of this style to note in the data could be the 2009 recession. This event would likely affect all of the provinces, but would bias the estimates if the impact to BC was disproportionate when compared to the other provinces.

Another benefit of the synthetic control method is displayed on Table A.6. This table shows the optimized weights for the provinces and variables in the second synthetic control. On this table we can see that NFL, PEI, ON, and SK are weighted extremely low in this system. This means that I have greatly reduced the bias in the estimates by reducing the impact from the dissimilar provinces that experiences large, outlying shocks in the data. With the synthetic control method, the results are primarily weighted upon AB, QC, and MB (75.9%).

Main Results

4.1 Difference-in-Differences Results

This model estimates that the implementation of the BC Carbon Tax results in a statistically significant 3.7% percent decrease to manufacturing output sales [see Table A.3]. Furthermore, due to the lag dependent variable in our regression, a simple estimate of the long-run (LR) effects of this tax can be calculated using $\frac{\widehat{\beta}_0}{1-\widehat{\beta}_6}$ (Henry, 1994). The $\widehat{\beta}_0$ is the estimated coefficient of the policy implementation and $\widehat{\beta}_6$ is the estimated coefficient of the lag term. My model estimates $\widehat{\beta}_0 = 0.037$ and $\widehat{\beta}_6 = 0.853$, therefore, this method estimates the long-run (LR) effect of this policy is approximately -0.252 or a 25.2% decrease to BC manufacturing sales. This method, however, is only using the point estimates from the model to attempt to measure the long-run impacts. A more developed estimation of the long-run effect can be ascertained using the synthetic control method.

4.2 Synthetic Control Results

The Synthetic Control method estimates that there is an average 10.37 percent decrease in manufacturing sales over the periods 2008-08-01 to 2019-08-01. Figure B.9 shows that the difference between the two groups converges after 7 years. This shows that the long run estimate is likely not as large as the 25.2% decrease indicated from using the point estimates. A 10.37% decrease to manufacturing sales is more likely the long-run effect due to the unexplained convergence in figure B.9. Future research into the convergence in this data is needed to develop a more thorough understanding of the long-run effects.

Robustness Tests

5.1 Alternative Model Specifications

To test the robustness of these findings I run two other specifications of this model. The first is keeping the same model but with dummy variables for each of the different price levels of the BC Carbon Tax now included (See Table A.4). This method gives results comparable the preferred model discussed earlier; however, now we can also see the estimated effect of each specific policy price increase. The most notable price increase occurred in 2012. For this year, this model estimates a statistically significant 2.5% increase to manufacturing sales. This implies that manufacturing sales could have gone up due to a lack of scheduled price increases in 2012 and due to firm's expectations of future costs. It is also possible that this aspect is the reason for the convergence in figure B.9 as that convergence occurs during the periods without any price increases. Future research into firm behaviour around these policies is required in order to better understand this possibility.

The second alternative model removes all of the policy dummy variables and replaces them with the price level of the tax in the t-th time period (See Table A.5). This method gives us estimates of the (semi-) elasticity of manufacturing sales with respect to the tax. This model shows a statistically significant and negative relationship. This corroborates the findings of the preferred model and my resulting expectations.

5.2 Limited Time Ranges

As noted earlier, the structural form of the policy changed in 2014. Due to this, I rerun all of the regressions with time ranges truncated to Jan. 1, 1997 to Dec. 1, 2013. The estimates are not substantially changed in any of the estimations (See Tables A.2-A.4). This indicates that estimations are likely robust to the structural change in 2014.

5.3 Other Province's Policies

At the time of the implementation of the BC Carbon Tax, there were two provinces with similar policies. To test the robustness of the findings to these policies, I include dummies for the other policies in the model. These consist of policy implementation and any structural changes to the policies. In this model there is: the implementation of the Albertan SGER program on July 1, 2007; the price increase to the SGER program on January 1, 2017; the transition to the Albertan CCIR program; the implementation of the Quebec Carbon Tax in June 1, 2007; and the implementation of the Quebec Cap-And-Trade program in January 1, 2013. No estimates are substantially changed due to this modelling. This indicates the results are likely robust to these factors.

Conclusion

Using a difference-in-differences model alongside a synthetic control method, I have provided evidence that the BC Carbon Tax has had a negative impact on the province's manufacturing sector. The results suggest that there was a statistically significant 3.7% decrease to manufacturing sales at the time of implementation. Furthermore, the evidence suggests that the policy reduced manufacturing sales by 10.37% on average over the 11 years following the policy implementation. The long-run effects of the policy are harder to ascertain, however, as table A.4 suggests manufacturing sales increased when there was a period of halted price increases. Furthermore, in figure B.9 we can see that the manufacturing sales for BC and our synthetic control variable converge during the period of halted price increases. This suggests that the greatest reduction to manufacturing sales may be during the initial implementation and that long-run effects (or future price increases) may not be as large.

This evidence, alongside the evidence that the policy also reduced the employment level in the sector (Azevedo et al., 2019), demonstrates that the policy design lead to negative impacts on the individuals in the manufacturing sector and positive impacts on the service sector. Though these findings are not general to all economies, this growing body of research indicates policy designers will likely need to give extra attention towards the potential impacts to this sector and it's labour force in future implementations.

Further work that can be done on this topic would be to validate these results by exploring the firm behaviour behind the policy price changes or investigating the convergence demonstrated in figure B.9. Furthermore, to establish more general and conclusive findings, further research is required on other possible areas of impact as well as research into the impacts of similar policies in other economies. This field of research will become more accessible as more economies implement similar policies in the future.

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Tables

Table A.1: Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Log(SALES)	2,720	7.515	1.579	3.754	6.558	8.738	10.594
POP	2,720	2.680	3.189	0.105	0.610	3.535	12.162
UNEMP	2,720	0.082	0.034	0.029	0.057	0.097	0.220
INC	2,720	7,609.792	10,213.020	97.085	1,153.496	11,483.200	54,861.350
GAS	2,720	158.270	55.546	60.524	105.364	207.006	294.309

Note: Data taken from Statistics Canada Website. Data time range is Jan. 1, 1997 - Aug. 1, 2019. All data is seasonally unadjusted. Data has 10 provinces (N) and 272 time observations (T). SALES, INC, and GAS were converted into real 2002 dollars. Further details found in section two of this paper (Data and Summary Statistics)

Table A.2: Breusch-Godfrey/Wooldridge test for serial correlation in panel models

Results:	$\chi^2 = 700.92$	DoF = 248	P-value 2.2e-16

Note: Results for panel regression specific Breusch-Godfrey test. Method used is the PBGtest methods discussed in (Croissant and Millo, 2008). Number of lags testing is 24. Test ran on model (2) from table A.3

Table A.3: BC Policy Implementation & Expansion

	Dependent variable:				
	Log(SALES)				
	(1)	(2)	(3)	(4)	(5)
BC Implementation (2008)	−0.028**	−0.035***	−0.037***	−0.039***	−0.042***
	(0.012)	(0.012)	(0.013)	(0.012)	(0.014)
BC Expansion (2010)	0.003	0.004	−0.010	0.004	−0.010
	(0.010)	(0.010)	(0.012)	(0.010)	(0.012)
Lag	0.885***	0.856***	0.797***	0.837***	0.780***
	(0.012)	(0.014)	(0.019)	(0.016)	(0.021)
Controls Included	[✗]	[✓]	[✓]	[✓]	[✓]
AB & QC Controlled	[✗]	[✗]	[✗]	[✓]	[✓]
Limited Range	[✗]	[✗]	[✓]	[✗]	[✓]
Observations	2,710	2,710	1,960	2,710	1,960
R^2	0.797	0.801	0.796	0.803	0.798
Adjusted R^2	0.773	0.777	0.771	0.779	0.774
F Statistic	3,174.550***	1,390.287***	974.611***	821.807***	691.332***

Note: Data time range is Jan. 1, 1997 - Aug. 1, 2019. Data has 10 provinces (N), 272 time observations (T), and 2720 total observations. Control variables are INC, POP, UNEMP, and GAS. Variables SALES, INC, and GAS were converted into real 2002 dollars (Further information in Section 2). AB QC have 5 dummy variables (explained in section 5.3). Limited time range is Jan. 1, 1997 - Jun. 1, 2013 (explained in section 2). Entity and time fixed effects used in all models. Estimates are point estimates for policy implementation and expansion. Newey-West heteroskedastic-and-autocorrelation robust standard errors used in all models.

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table A.4: BC Policy Levels & Expansion

	Dependent variable:				
	Log(SALES)				
	(1)	(2)	(3)	(4)	(5)
BC Implementation (2008)	−0.028*	−0.039**	−0.041***	−0.043***	−0.047***
	(0.016)	(0.015)	(0.016)	(0.016)	(0.017)
$15 Price Level (2009)	0.002	0.010	0.011	0.012	0.014
	(0.020)	(0.018)	(0.018)	(0.018)	(0.017)
BC Expansion (2010)	−0.002	−0.005	−0.002	−0.005	−0.002
	(0.025)	(0.024)	(0.026)	(0.024)	(0.026)
$20 Price Level (2010)	−0.006	−0.005	−0.004	−0.004	−0.004
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
$25 Price Level (2011)	−0.010	−0.013	−0.022	−0.016	−0.023
	(0.013)	(0.014)	(0.016)	(0.014)	(0.016)
$30 Price Level (2012)	0.025**	0.024**	−0.0004	0.025**	−0.002
	(0.011)	(0.012)	(0.016)	(0.012)	(0.017)
$35 Price Level (2018)	0.005	0.006		0.013	
	(0.009)	(0.011)		(0.012)	
$40 Price Level (2019)	−0.021	−0.020		−0.018	
	(0.018)	(0.018)		(0.018)	
Lag	0.885***	0.856***	0.797***	0.836***	0.779***
	(0.012)	(0.014)	(0.019)	(0.016)	(0.021)
Controls Included	[✕]	[✓]	[✓]	[✓]	[✓]
AB & QC Controls	[✕]	[✕]	[✕]	[✓]	[✓]
Limited Range	[✕]	[✕]	[✓]	[✕]	[✓]
Observations	2,710	2,710	1,960	2,710	1,960
R^2	0.797	0.801	0.796	0.803	0.799
Adjusted R^2	0.773	0.777	0.771	0.779	0.773
F Statistic	1,056.223***	747.165***	619.161***	546.873***	493.025***

Note: Data time range is Jan. 1, 1997 - Aug. 1, 2019. Data has 10 provinces (N), 272 time observations (T), and 2720 total observations. Control variables are INC, POP, UNEMP, and GAS. Variables SALES, INC, and GAS were converted into real 2002 dollars (Further information in Section 2). AB QC have 5 dummy variables (explained in section 5.3). Limited time range is Jan. 1, 1997 - Jun. 1, 2013 (explained in section 2). Entity and time fixed effects used in all models. Estimates are point estimates for policy implementation and expansion. Newey-West heteroskedastic-and-autocorrelation robust standard errors used in all models.

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table A.5: BC Policy Prices

	Dependent variable:				
	Log(SALES)				
	(1)	(2)	(3)	(4)	(5)
Policy Prices	-0.001^{***}	-0.001^{***}	-0.002^{***}	-0.001^{***}	-0.002^{***}
	(0.0002)	(0.0003)	(0.0004)	(0.0003)	(0.0005)
Lag	0.887^{***}	0.858^{***}	0.797^{***}	0.839^{***}	0.780^{***}
	(0.011)	(0.014)	(0.019)	(0.015)	(0.021)
Controls Included	[✕]	[✓]	[✓]	[✓]	[✓]
AB & QC Controls	[✕]	[✕]	[✕]	[✓]	[✓]
Limited Range	[✕]	[✕]	[✓]	[✕]	[✓]
Observations	2,710	2,710	1,960	2,710	1,960
R^2	0.797	0.800	0.796	0.803	0.798
Adjusted R^2	0.773	0.777	0.772	0.779	0.774
F Statistic	$4{,}760.220^{***}$	$1{,}620.881^{***}$	$1{,}137.746^{***}$	895.608^{***}	768.572^{***}

Note: Data time range is Jan. 1, 1997 - Aug. 1, 2019. Data has 10 provinces (N), 272 time observations (T), and 2720 total observations. Control variables are INC, POP, UNEMP, and GAS. Variables SALES, INC, and GAS were converted into real 2002 dollars (Further information in Section 2). AB QC have 5 dummy variables (explained in section 5.3). Limited time range is Jan. 1, 1997 - Jun. 1, 2013 (explained in section 2). Entity and time fixed effects used in all models. Estimates are point estimates for policy implementation and expansion. Newey-West heteroskedastic-and-autocorrelation robust standard errors used in all models.

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table A.6: Alternate Standard Error Estimates

	Dependent variable:					
	Log(SALES)					
	(1)	(2)	(3)	(4)	(5)	(6)
BC Implementation (2008)	−0.035***	−0.035***	−0.035***	−0.039**	−0.039***	−0.039***
	(0.012)	(0.010)	(0.010)	(0.015)	(0.012)	(0.014)
$15 Price Level (2009)				0.010	0.010	0.010
				(0.018)	(0.010)	(0.016)
BC Expansion (2010)	0.004	0.004	0.004	−0.005	−0.005	−0.005
	(0.010)	(0.004)	(0.008)	(0.024)	(0.009)	(0.020)
$20 Price Level (2010)				−0.005	−0.005	−0.005
				(0.023)	(0.010)	(0.016)
$25 Price Level (2011)				−0.013	−0.013	−0.013
				(0.014)	(0.015)	(0.009)
$30 Price Level (2012)				0.024**	0.024**	0.024***
				(0.012)	(0.010)	(0.009)
$35 Price Level (2018)				0.006	0.006	0.006
				(0.011)	(0.009)	(0.008)
$40 Price Level (2019)				−0.020	−0.020**	−0.020
				(0.018)	(0.009)	(0.013)
Lag	0.856***	0.856***	0.856***	0.856***	0.856***	0.856***
	(0.014)	(0.035)	(0.015)	(0.014)	(0.035)	(0.015)
SE Estimation	[HAC]	[CLST]	[SCC]	[HAC]	[CLST]	[SCC]
Controls Included	[✓]	[✓]	[✓]	[✓]	[✓]	[✓]
AB & QC Controls	[✕]	[✕]	[✕]	[✕]	[✕]	[✕]
Limited Range	[✕]	[✕]	[✕]	[✕]	[✕]	[✕]
Observations	2,710	2,710	2,710	2,710	2,710	2,710
R^2	0.801	0.801	0.801	0.801	0.801	0.801
Adjusted R^2	0.777	0.777	0.777	0.777	0.777	0.777
F Statistic	1,390.287***	1,390.287***	1,390.287***	747.165***	747.165***	747.165***

Note: First three models are Table A.3 model (2) with varying standard error methods. The last three models and Table A.4 model (2) with varying standard error methods. HAC is the Newey-West method for robust standard errors. CLST is the White-Arellano one way clustering method. SCC is the Driscoll and Kraay method for estimation. Further information on any of these methods can be found (Millo, 2017).

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table A.7: Table A.4 but with Year-over-Year Growth Rates

	Dependent variable:				
	Log(SALES)				
	(1)	(2)	(3)	(4)	(5)
BC Implementation (2008)	110.534*	145.105*	106.863	35.868	13.508
	(65.313)	(75.351)	(92.360)	(76.631)	(92.907)
$15 Price Level (2009)	−85.924	−57.698	−44.351	−44.803	−21.892
	(126.160)	(130.142)	(143.438)	(126.359)	(139.889)
BC Expansion (2010)	−9.352	−57.004	−52.795	−81.918	−64.034
	(136.855)	(141.572)	(141.891)	(147.276)	(143.008)
$20 Price Level (2010)	29.191	−5.599	39.668	−23.899	32.697
	(140.881)	(140.859)	(129.036)	(155.247)	(138.787)
$25 Price Level (2011)	27.985	35.843	40.938	26.070	43.340
	(90.639)	(92.827)	(85.538)	(97.840)	(88.261)
$30 Price Level (2012)	−21.285	−36.996	61.670	6.881	72.470
	(66.632)	(73.505)	(79.922)	(76.476)	(77.191)
$35 Price Level (2018)	−118.674*	−121.919*		−132.881*	
	(70.580)	(72.675)		(71.874)	
$40 Price Level (2019)	−22.616	−19.557		−27.815	
	(119.466)	(123.775)		(125.286)	
Lag	0.699***	0.693***	0.698***	0.648***	0.673***
	(0.036)	(0.036)	(0.039)	(0.042)	(0.042)
Controls Included	[✗]	[✓]	[✓]	[✓]	[✓]
AB & QC Controls	[✗]	[✗]	[✗]	[✓]	[✓]
Limited Range	[✗]	[✗]	[✓]	[✗]	[✓]
Observations	2,590	2,590	1,840	2,590	1,840
R^2	0.492	0.494	0.516	0.508	0.523
Adjusted R^2	0.432	0.432	0.456	0.447	0.463
F Statistic	249.073***	173.225***	158.555***	131.922***	127.894***

Note: These models have the variables converted into year-over-year growth rates. This method addresses issues with non-stationary data. The previous models explained in this paper show that there is not likely issues from the non-stationary data and, therefore, this table is not necessary. These models were not referenced within this paper. They were ran to satisfy a professor's curiosity and left in the appendix for reference if anyone else is interested.

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

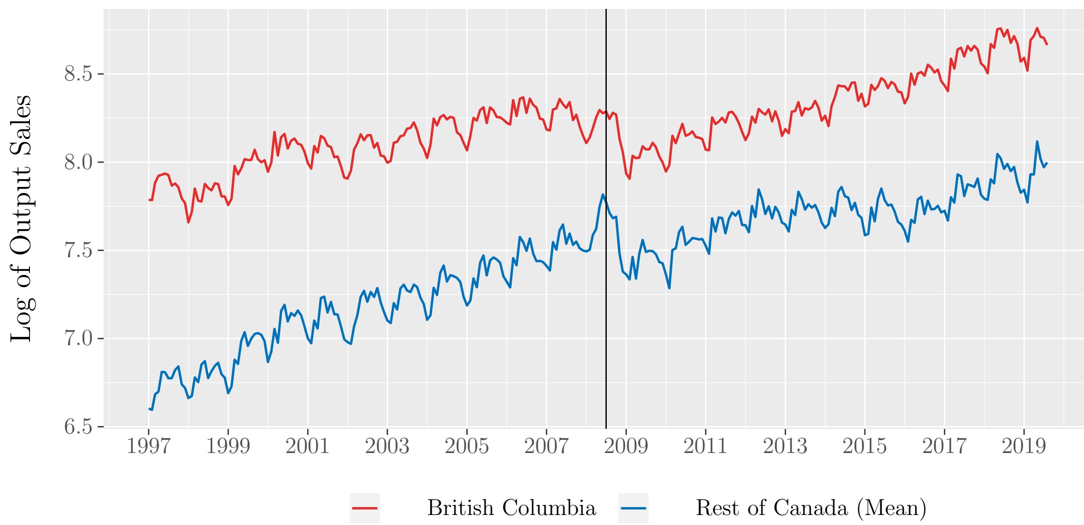
Table A.8: Synthetic Control Results

Province	P.Weight	Variable	V.Weight
Alberta	0.157	GNDR	0.020
Manitoba	0.235	POP	0.704
New Brunswick	0.033	UNEMP	0.004
Newfoundland	0.025	GAS	0.000
Nova Scotia	0.034	INC	0.273
Ontario	0.039		
Prince Edward Island	0.029		
Quebec	0.367		
Saskatchewan	0.081		

Note: Weights for the provinces and the control variables from the data set

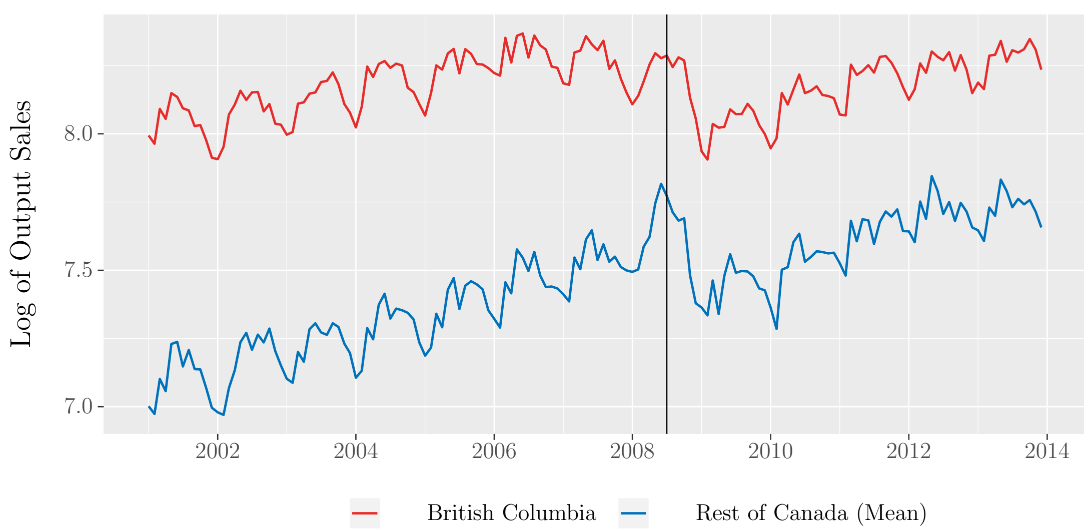
Figures

Firgure B.1: Log Manufacturing Sales BC vs. ROC



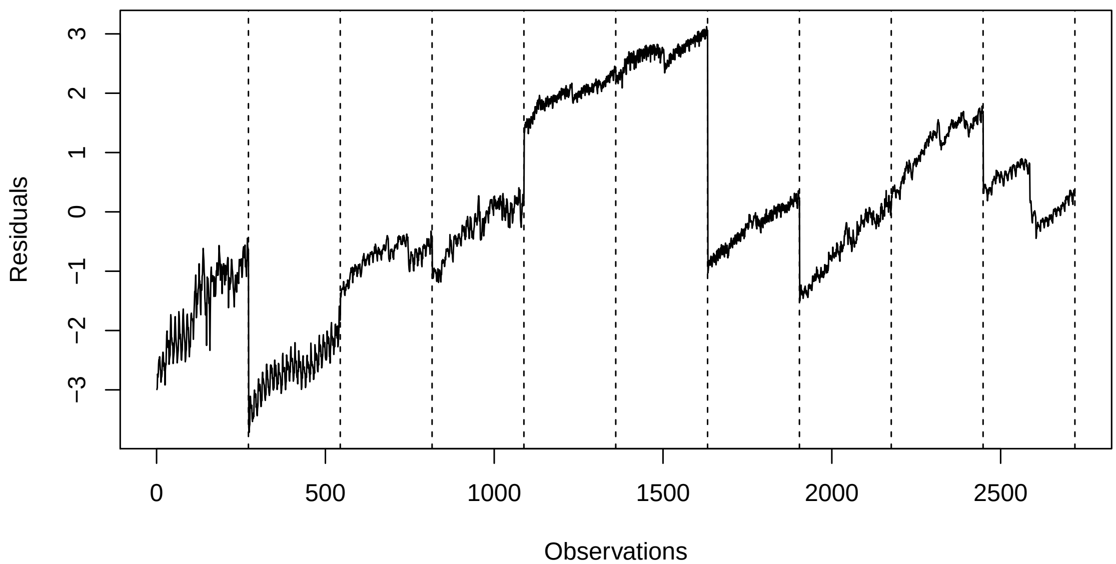
Note: ROC means "rest of Canada". ROC is the average of the Log(SALES) for all provinces excluding BC.

Firgure B.2: Log Manufacturing Sales BC vs. ROC [Closer]



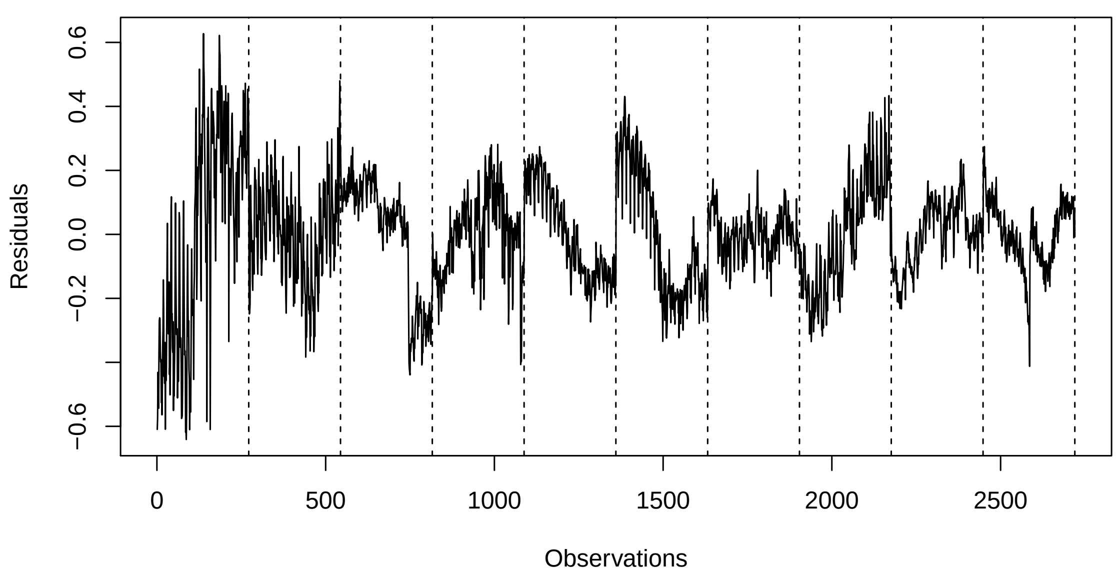
Note: ROC means "rest of Canada". ROC is the average of the Log(SALES) for all provinces excluding BC.

Figure B.3: Residual Plot [Policy Implemenetation]



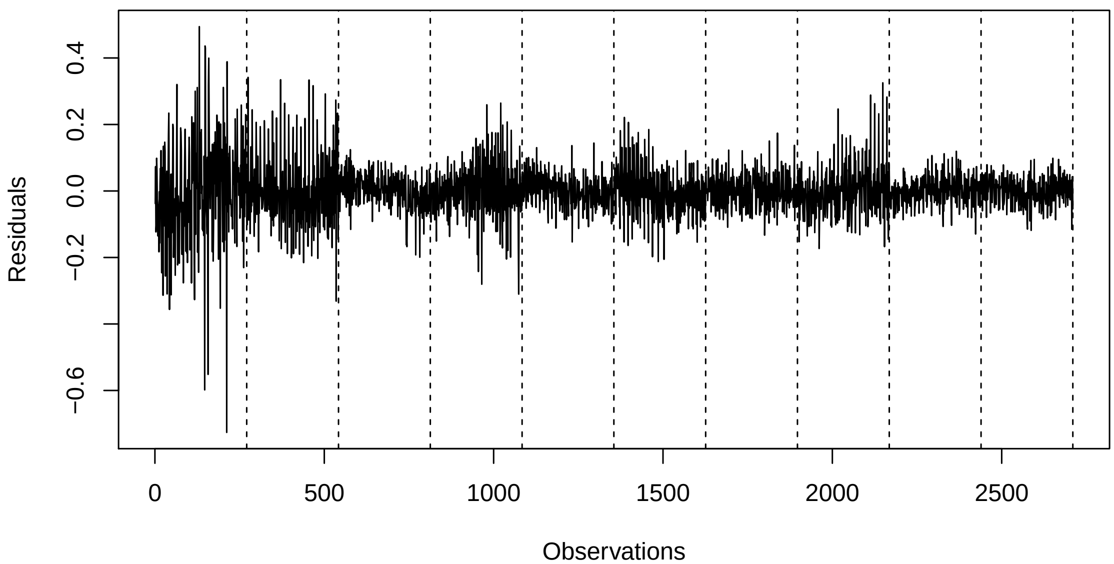
Note: Residuals sorted by province and then time. Dashed lines indicate residuals of a specific province. Provinces from left to right: NF, PEI, NS, NB, QB, ON, MB, SK, AB, BC. Residuals from regression of Table A.3 Model (2) but without entity or time fixed effects.

Figure B.4: Residual Plot [Fixed Effects]



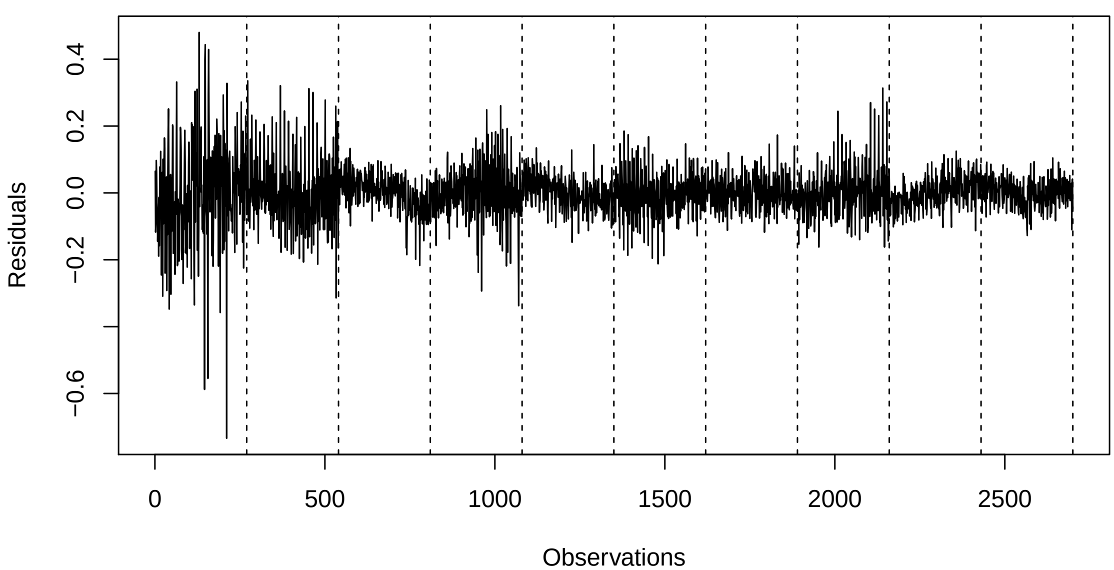
Note: Residuals sorted by province and then time. Dashed lines indicate residuals of a specific province. Provinces from left to right: NF, PEI, NS, NB, QB, ON, MB, SK, AB, BC. Residuals from regression of Table A.3 Model (2).

Figure B.5: Residual Plot [One Lag]



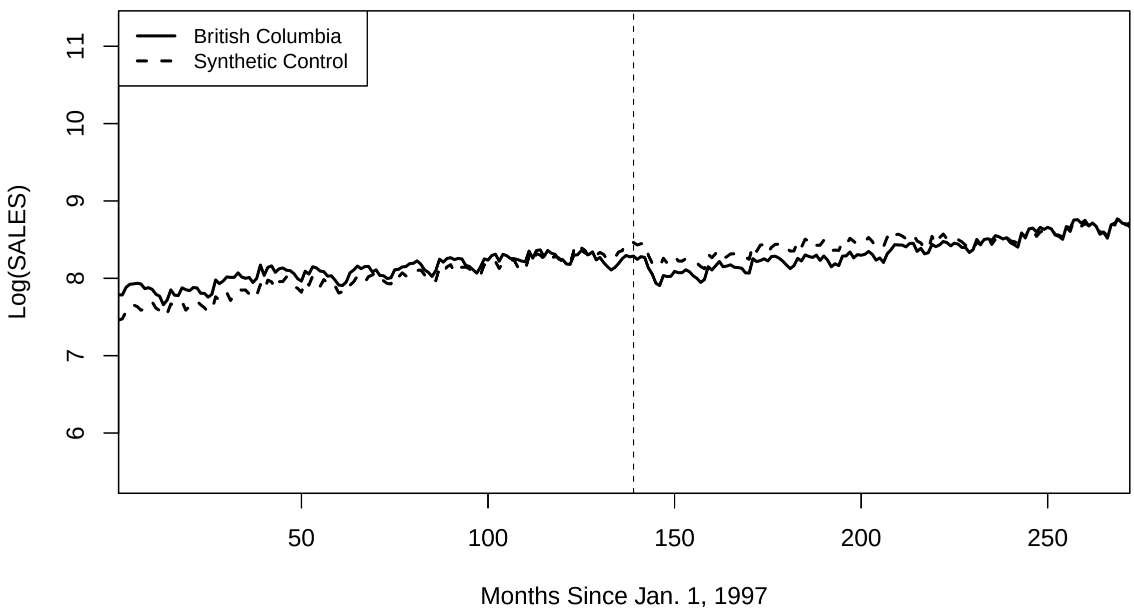
Note: Residuals sorted by province and then time. Dashed lines indicate residuals of a specific province. Provinces from left to right: NF, PEI, NS, NB, QB, ON, MB, SK, AB, BC. Residuals from regression of Table A.3 Model (2) with one lag included.

Figure B.6: Residual Plot [Two Lags]



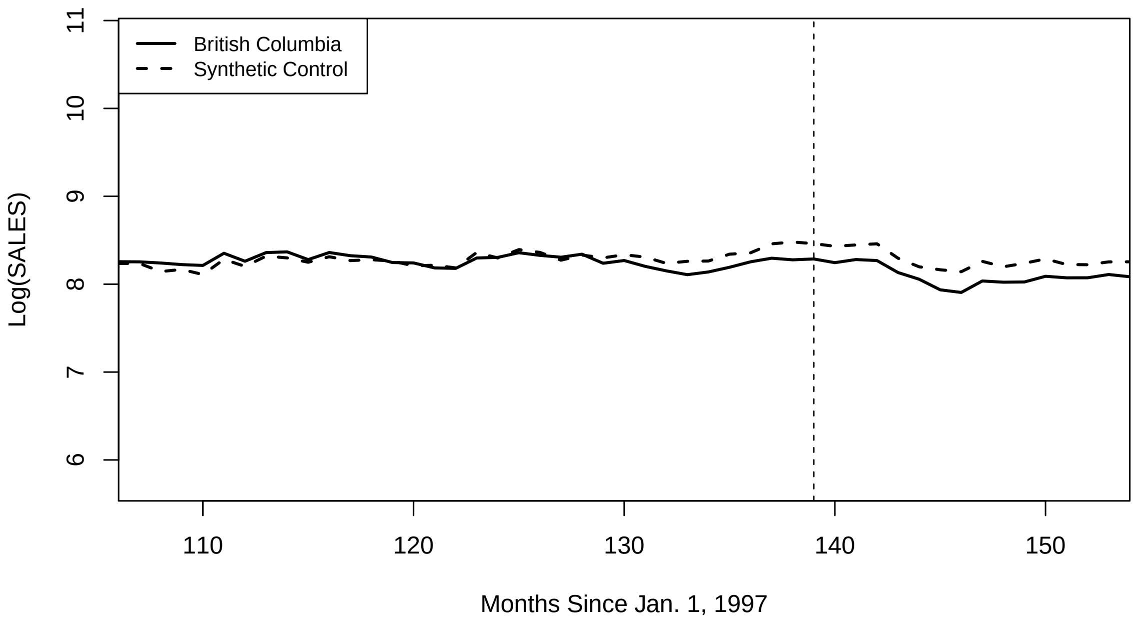
Note: Residuals sorted by province and then time. Dashed lines indicate residuals of a specific province. Provinces from left to right: NF, PEI, NS, NB, QB, ON, MB, SK, AB, BC. Residuals from regression of Table A.3 Model (2) with two lag included.

Figure B.7: Synthetic Control



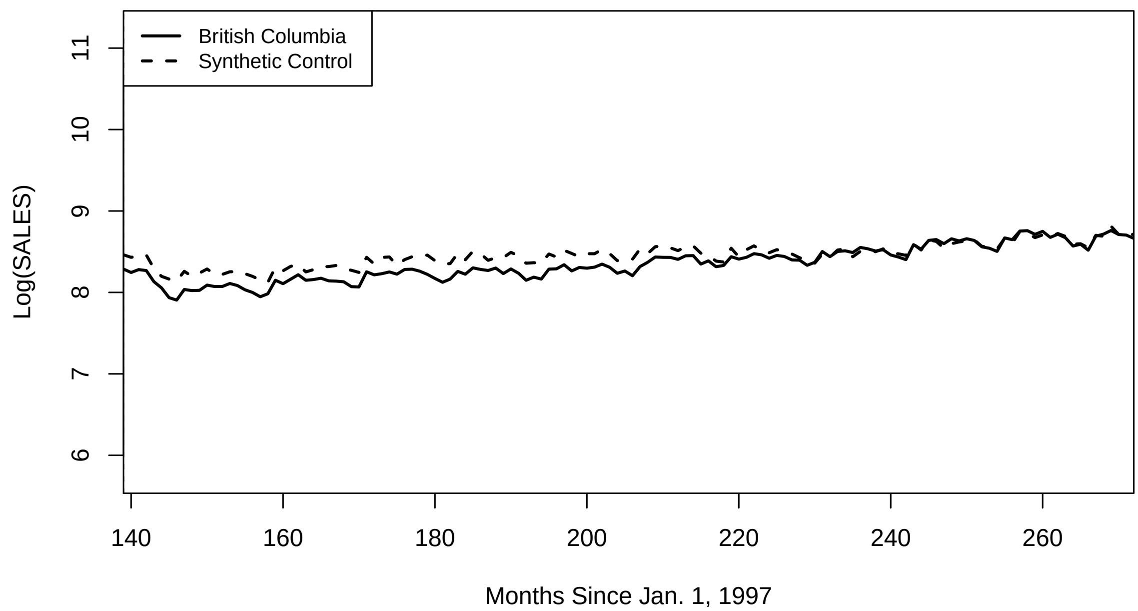
Note: Time range is Jan. 1, 1997 - Aug. 1, 2019 (272 months). Dotted line indicates the policy implementation at Jun. 1, 2008 (month 139).

Figure B.8: Synthetic Control [Closer]



Note: Time range is Jan. 1, 2003 - Jan. 1, 2009. The dotted line indicates the policy implementation at Jun. 1, 2008 (month 139).

Figure B.9: Synthetic Control [Post Treatment]



Note: Time range is Jun. 1, 2008 - Aug. 1, 2019. Convergence happens 7.5 years after policy implementation (around 210 months).