Assessing the Impact of the Western Climate Initiative on Quebec industrial facilities

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Abstract

Since 2013, Quebec (Canada) has implemented a greenhouse gas emissions trading system (ETS) as part of the Western Climate Initiative. This carbon monetization has provoked strong reactions, particularly in the industrial sector, where companies feared a loss of competitiveness on world markets. The goal of this article is to assess the impact of these regulations on industrial plants in Quebec. Conditional Difference-in-Differences OLS regressions show that regulated plants in Quebec have reduced their GHG emissions about 10 percent faster than non-regulated plants in the rest of Canada. They have also reduced employment about 7 percent faster. However, the implementation of the Quebec carbon ETS had no significant impact on the efficiency of production with respect to GHG emissions. These results suggest that during the period 2013-2015, regulated facilities in Quebec did not adapt to the program through a change in their production processes or technology that would affect carbon intensity. This raises questions about how efficiently Quebec's ETS induces innovation in industrial facilities. Other studies on the early-stage effects of the British Columbia (Canada) carbon tax scheme reveal that facilities adapted to it by cutting employment, but that this effect has been mitigated thanks to the positive effect of a green fiscal reform that accompanied the carbon tax. This finding challenges the initial allocation scheme of carbon permits in the Western Carbon Initiative, underlying the importance of appropriately recycling carbon rent.

Introduction

On December 15, 2011, the Government of Canada announced its withdrawal from the Kyoto Protocol (Environment Canada, 2012a). At the time, the Canadian Minister of Environment Peter Kent justified the decision by citing the absence from the agreement of the two biggest emitters – China and the United States. He claimed that for Canada "[t]o meet [its] targets under Kyoto for 2012 would be the equivalent of […] removing every car, truck, ATV, tractor, ambulance, police car and vehicle of every kind from Canadian roads" (Environment Canada, 2012b). Canada's lack of leadership on climate issues was widely criticized in the media. Despite the federal government's withdrawal, the province of Quebec (Canada) decided to honor its commitments. On the same day as Canada's withdrawal from the protocol and with great ceremony, Quebec's Minister of the Environment announced that the province was adopting new regulations to set up a carbon emission trading system (ETS) based on the Western Climate Initiative (WCI)'s recommendations (MDDELCC, 2011). Implemented in 2013, the new cap and trade system is set to cover almost 85% of Quebec's emissions (MDDELCC, 2018). According to government authorities, this economic tool has several advantages. Notably, it offers emitters a variety of options for complying with the regulations and provides a reliable mechanism for achieving reduction targets (MDDELCC, 2018). Numerous social and environmental groups have praised the government for this initiative. Some businesses and industry representatives, however, were apprehensive about the regulations' impact on corporate competitiveness (Francoeur, 2011; Sansfaçon, 2011), arguing that his would result in a carbon leakage (with the relocation of production and emissions outside Québec) and in cut in local industrial productions.

According to the Government of Quebec, the first results of the province's carbon market are very encouraging (MDDELCC, 2017). From 2013 to 2018, Quebec's emissions trading scheme (QC ETS) generated more than 2.2 billion CAD. According to the government (MDDELCC, 2017), industrial emitters in Quebec reduced their emissions by almost 800 000 tons between 2012 and 2014. A decrease in emissions of 6.8% between 2012 and 2016 was also observed. The Government of Quebec considers these reductions a sign that the carbon market is working. However, the Sustainable Development Commissioner (2016) provides a more nuanced view of the QC ETS' performance, noting that emitters had access to an abundance of emission units during the first years of compliance (the supply was higher than the demand); if this worrisome situation persists, then in the long term, the carbon market might not produce the desired effect on GHG emissions. This implies that government authorities did not adequately plan for, or that they underestimated, the way businesses would react to the new regulations. In this context, conducting studies to evaluate the regulations' potential impact on emitters' economic performance is of utmost importance. The Government of Quebec wants to lower its GHG emissions, but it also wants to prevent carbon leakage and voluntary decreases in production (MDDELCC, 2018). The risk of a negative impact on competitiveness is an important concern for businesses and policymakers (e.g. Chan et al., 2013; Marin et al., 2017; Yang et al., 2016).

The long-term goal of the QC ETS is to stimulate innovation and to make the transition to a less carbon-dependent economy easier. There are few studies on the effectiveness of markets that follow the WCI's norms (e.g. Martin & Saikawa, 2017; Sousa & Aguiar-Conraria, 2015), but these have not specifically examined the impact of the ETS on industrial emitters' economic and carbon performance. The majority of previous studies that tried to evaluate carbon markets' effectiveness have looked at the European Union Emission Trading Scheme (EU ETS). These studies showed the EU ETS' negative effect on emitters' GHG emissions (Martin et al., 2016). In the case of French and German industrial facilities, the reductions observed during the second phase of the EU ETS, between 2008 and 2010, amounted to 10-26% (Martin et al., 2016; Petrick & Wagner, 2014). At the same time, however, the reductions achieved during phase 1 – between 2005 and 2008 – were smaller, which raises questions about the impact that the design of the market had on its effectiveness. The results of studies examining carbon performance are relatively convergent. The results are more mixed when it comes to economic impact, particularly the market's effect on employment (Martin et al., 2016). This question of the carbon market's impact on employment is a good example of disparate results in the research. Contrary to what might have been expected when the carbon market was adopted, the majority of studies found no relationship between employment in regulated facilities and the implementation of the market (e.g. Anger & Oberndorfer, 2008; Commins, Lyons, Schiffbauer, & Tol, 2011; Marin et al., 2017). There is a noticeable exception: decreases in employment of up to 7% were observed for industrial facilities in France (Wagner et al., 2013). Studies have also investigated whether regulated plants in Europe have chosen between innovation (to reduce the carbon intensity of production) or cutting their operations, in order to meet with their emissions reduction targets. (Brohé & Burniaux, 2015; Löfgren, Wråke, Hagberg, & Roth, 2014; Sandoff & Schaad, 2009). For the two first phases of the EU ETS, results tend to show that facilities, rather than cutting their operations, have innovated on and improved their processes, passing the costs on to their customers (Martin et al., 2016; Petrick & Wagner, 2014; Wagner et al., 2013). What's more, Martin et al. (2014a; 2014b) have underscored that the risks of reducing production are relatively low, given the perceived impact that future carbon prices will have on business decisions about where to maintain facilities. While interesting, these results – because they are very context-dependent – are difficult to translate to North American carbon markets. This is all the more true because business behavior and climate-change strategies have historically differed from one continent to the other (e.g. Kolk & Levy, 2001; Levy, 2000; Talbot & Boiral, 2013).

This study's goal is to evaluate the impact of the QC ETS on industrial facilities' economic and carbon performance. To this end, we apply program evaluation methods on a panel of plant-level data on carbon emissions and employment from regulated facilities in Quebec and unregulated facilities both in Quebec and the rest of Canada. The results, robust as they were obtained using alternatively conditional Difference-in-Differences (DiD) OLS regressions and DiD matching estimator methods, challenge the economic effectiveness of the carbon market. Indeed, unlike their European counterparts, emitters in Quebec seem to have preferred to reduce their production rather than improve their technology and production procedures. This article has political implications for the future of the WCI, but also of Canadian climate change policies, since the Pan-Canadian Framework on Clean Growth and Climate Change calls for all Canadian provinces and territories to decide on their carbon-taxing strategies in 2018.

The rest of the article is organized as follows: first, it will address the main characteristics of the QC ETS; then, it will present the empirical methodology and the results; finally, it will discuss the results and their contribution in terms of policy implication and recommendations .

Quebec's system of capping and trading emission permits

The Government of Quebec has given itself ambitious GHG reduction targets. Notably, it is aiming for a reduction of 20% by 2020 and of 37.5% by 2030 (MDDELCC, 2014). To reach these goals, the government's preferred economic instrument is a system of capping and trading emission permits (C&T) within the framework of the Western Climate Initiative (WCI). This decision is explained in part by the flexibility that this mechanism provides to the regulated businesses. It should also allow Quebec to develop a more robust and less fossil-fuel-dependent economy (Gouvernement du Québec, 2012a). Inaugurated in 2013, the new market is one of the most ambitious ETS in the World, as it is covering almost 85% of emissions in Quebec. By way of comparison, the EU ETS covers only about 45% of European emissions (Sustainable Development Commissioner, 2016). According to government estimates, by 2020, the carbon market will have made possible 3 billion CAD worth of investments in the activities called for by the Climate Change Action Plan 2013-2020.

<u>The QC ETS: Origin and organization</u>

In 2008, the Government of Quebec announced its intention to set up a carbon market. It took five years of highly political negotiation and equivocation before it was possible to adopt the new regulations, notably in order to create a framework for emitters' GHG emissions declarations and to harmonize the markets in Quebec and California. The QC ETS includes three compliance periods. The first period (January 2013 – December 2014) impacted 78 industrial facilities whose annual GHG emissions are equal to or greater than 25 kiloton-equivalents of CO2. The number of facilities subject to the regulation increased considerably during the second period (January 2015 – December 2017) to include fossil-fuel distributors (MDDELCC, 2014). The annual cap on emissions for 2013 and 2014 was set at 23.30 million units. This cap increased in 2015 to 65.30 million units to take into account the newly-regulated establishments and decreased afterwards to settle at 61.08 million units at the end of the second period. The third period (January 2018 – December 2020) will end with a decrease in the cap by nearly 15% compared to 2015, settling at 55.74 million units (Gouvernement du Québec, 2012b). To comply with the new ceiling, emitters must either decrease or compensate their GHG emissions. To compensate their emissions, they can (1) purchase emissions units (auctioned off or by mutual agreement with the minister), (2) take advantage of credits earned in exchange for early reductions achieved between 2008 and 2011 or (3) use compensatory credits for GHG emission reduction projects in industries that are not subject to compliance (MDDELCC, 2014; Sustainable Development Commissioner, 2016).

The design of Quebec's carbon market was influenced by the malfunctions observed in the EU ETS. To avoid the problems of tax evasion, price slumps and market manipulation, oversight mechanisms were integrated into the market. First, the Government of Quebec decided to impose a minimum price for emissions units sold at auction. In December 2013, the price floor was 10.75 CAD. The regulations call for an annual indexed increase of 5%. This oversight mechanism decreases the volatility of carbon prices that had notably been observed in the European market (Grubb & Neuhoff, 2006; Pearse & Böhm, 2014; Wood & Jotzo, 2011). It also sends a clear signal about the desired development of carbon prices in Quebec (Sustainable Development Commissioner, 2016). To minimize potential market manipulations as well, Quebec's regulations set a maximum on the quantity of emissions units that can be purchased or held. For example, an emitter cannot acquire more than 25% of available units during an auction. Moreover, bidders must comply with certain norms that require them to communicate information about their participation in the auction and their strategies for acquiring emissions permits, the goal being to prevent collusion and insider trading (Sustainable Development Commissioner, 2016).

Research Design

Empirical methodology

Following the empirical methodology of Fowlie et al. (2012), variations in carbon regulations across Canadian provinces were exploited to assess the effect of the QC ETS on regulated facilities. For this, econometrically adjusted ex-post observed outcome variables (i.e., GHG emissions, employment, carbon intensity) of facilities with similar characteristics (size, industrial subsectors) were analyzed across provinces in Canada. Based on the program evaluation literature that has introduced the potential outcome framework, industrial facilities as either participating in the Québec ETS or not were considered. Let the "treatment" indicator $T_i = 1$ if the facility *i* is enrolled in the QC ETS (i.e., *i* is "treated"). Let $T_i = 0$ if the facility *i* is not regulated on its carbon emissions. The potential outcomes $Y_{it}(1)$ and $Y_{it}(0)$ are the average annual outcomes (emissions, employment, or carbon intensity), conditional on participation and non-participation respectively, at facility *i* in the post-treatment period *(t=1)* or the pre-treatment period *(t=0)*. Our purpose is to estimate the sample average treatment effect on the treated (ATT):

$$\alpha_{ATT} = E\left[Y_{i1}(1) - Y_{i1}(0) \mid T_i = 1\right] \quad (1)$$

Where α_{ATT} measures the average effect of the QC ETS on facility-level outcome variables observed at both treated and non-treated facilities, over several years prior to, and after the launch of the program. Facility-level outcome variables collected from participants in the QC ETS in the post-treatment period, enable the following estimate $E\left[Y_{i1}(1) \mid T_i = 1\right]$. However, because $E\left[Y_{i1}(0) \mid T_i = 1\right]$ cannot be observed due to missing data, counterfactual outcomes were constructed using data on outcome variables collected on a "comparison group" of non-participating facilities, in both periods *t=0* and *t=1*.

Conditional difference-in-difference OLS regression

To estimate the effect of the QC ETS on facility-level outcome variables, a conditional Difference-in-Differences (DiD) ordinary least square (OLS) regression model of the following form was used:

$$\Delta Y_i = \beta X_i + \alpha T_i + \varepsilon_i \qquad (2)$$

Where $\Delta Y_i = Y_{it_1} - Y_{it_0}$ is the difference in the outcome variable between the post-treatment and pre-treatment periods. X_i is a vector of facility-level observable characteristics that are likely to vary across facilities (i.e., comparison and treatment groups), impact the evolution of facility-level outcome variables, and are assumed to be orthogonal with the treatment status. These characteristics are facility-level historical emissions (prior to the launch of the QC ETS) and NAICS industrial classification indicators (dummy variable). The coefficient α estimates the average effect of the QC ETS on changes in Y_i over time, and conditional on characteristics in X_i. ε_i is an error term, independent of the treatment indicator T_i and covariates in X_i, by assumption.

Difference-in-difference matching estimator

This simple comparison of QC ETS facilities with non-ETS facilities, when controlling for observables may result in bias if some of the changes in the outcome variables are attributed to the ETS, whereas in reality they are induced by some other systematic differences between ETS and non-ETS facilities. Such differences may rest in the distribution of the vector of control variables X_i. To mitigate this bias, semi-parametric matching estimators (Heckman, Ichimura, and Todd, 1997) of the following form were used:

$$\alpha_{DID} = \frac{1}{N_1} \sum_{j \in \Pi_1} \left\{ \left(Y_{jt_1}(1) - Y_{jt_0}(0) - \sum_{k \in \Pi_0} w_{jk} \left(Y_{kt_1}(0) - Y_{kt_0}(0) \right) \right) \right\} \qquad (3)$$

With Π_1 the set of facilities *j* in the treatment group and N_1 their total number. Π_0 is the set of facilities *k* in the comparison group. w_{jk} is a weight placed on facility *k* when building the counterfactual estimate for the treated facility *j*. The weight on control plants is based on a Nearest Neighbor (NN) matching process, and it is stronger the more similar a control facility is to the treated facility. The similarity is based on the covariates in X_i (i.e., historical emissions and NAICS industrial classification indicators). For sensitivity analysis, matching alternatively on the closest and the three closest neighbours was carried out. Since a poor match quality could bias the results, and following Abadie and Imbens (2006), the matching estimation is augmented with a regression-based adjustment (i.e., quadratic form, as the outcome variable is in log). In all our matching, an exact match on industry-specific historic emissions quartile indicators wasspecified. This is in order to account for potential unobserved determinants of facility-level emissions, such as production technology or demand for the product. Standard errors are estimated using the Abadie and Imbens' (2006) methodology.

Data

As the treatment group, industrial facilities in Québec covered by the ETS were considered. These are facilities with GHG emissions exceeding 30,000 t CO_2e in 2012 or 2013. They pertain to twelve industrial sectors, as listed in Table 1.

Table 1: NAICS sectors covered by the Québec ETS

Subsectors	NAICS code
Oil & gas extraction	211
Mining	212
Power generation	221
Food & beverage	311 & 312
Pulp, paper & wood	321 & 322
Refineries, oil & coal products	324
Chemicals & plastics	325 & 326
Glass, cement, lime & ceramics	327
Iron & steel	3311 & 3312
Non-ferrous metals & forging	3313, 3314 & 3315
Automobile	336
Miscellaneous	339

As the comparison group, industrial facilities from the same sectors and with the same characteristics (level of emissions in 2012 or 2013) from other provinces of Canada were considered, but excluding British Columbia (BC). This is because the government of BC decided in 2007, and implemented in 2008, a carbon tax scheme (complemented with a revenue-neutral green fiscal reform), with a carbon price set initially at CAN$ 10/tCO_2, and increasing gradually to reach CAN$ 30/tCO_2 in 2012, the year of the program full implementation. There were no such carbon pricing policies in other Canadian provinces at that time.[1]

Facility-level data on annual GHG emissions and employment over the period 2010-2015 were retrieved through Environment and Climate Change Canada (ECCC), which are publicly available. GHG emissions data was accessed through the Greenhouse Gas Reporting Program (GHGRP). Facility-level characteristics data (i.e., size, subsector) was accessed through the National Pollutant Release Inventory (NPRI). These data were linked using the ECCC's unique facility-level identifier "NPRI_ID".

<u>Variables and their Specifications</u>

[1] In 2007, Alberta implemented a carbon pricing scheme (SGER) for large industrial emitters (over 100,000t CO_2/year) with an effective average carbon price comprised between 1.8 and 5 CAN$/t$CO_2$e, considered as too low to induce firms to cut their emissions (Leach 2012). Québec has also implemented a carbon tax on energy producers since October 2007 (CBC, 2007). But its low level, 3.5 CAN$/t$CO_2$, made it ineffective (Yamazaki, 2017), thus negating its effect.

Changes in GHG emissions are defined as $ln(GHG_1 + 1) – ln(GHG_0 + 1)$, with GHG_0 and GHG_1 the average annual emissions during periods 0 and 1 respectively. For that purpose, GHG emissions are averaged in three years periods (2010-2012 or 2013-2015) or two years period (2010-2011).

Changes in facility-level employment follow the same construction with $ln(EMP_1 + 1) – ln(EMP_0 + 1)$.

Due to data limitations, investigation of the effect of the QC ETS on carbon intensity, defined as GHG emissions divided by output was not possible. As an alternative, and following Wagner et al. (2014), a measure of carbon intensity in terms of employment, i.e. GHG emissions / employment was used. Changes in carbon intensity defined as $ln(GHG_1/EMP_1 +1) – ln(GHG_0/EMP_0 +1)$ were also considered

OLS estimates control for historical GHG emissions in 2010 (in log) and industrial classification indicator variables, which yields 51 facilities in the treatment group and 248 in the comparison group. Summary statistics are reported in Table 2.

Table 2: Summary statistics

Variables	Mean	sd	Min	Max	N
Full sample					
GHG emissions in 2010, 1000tCO2e	724	1625	51	15788	299
Employment in 2010	385	756	0	6500	296
Δ(GHG emissions), 1000tCO2e	12	266	-1177	2519	299
Δ(employment)	7.60	167	-900	879	294
Δ(GHG/employment)	0.54	12	-82	121	292
ETS participants in Québec					
GHG emissions in 2010, 1000tCO2e	367	360	51	1258	51
Employment in 2010	475	407	1	1690	49
Δ(GHG emissions), 1000tCO2e	-23	106	-377	389	51
Δ(employment)	-36	121	-508	354	48
Δ(GHG/employment)	-0.21	0.74	-3.48	0.75	47
Non-regulated facilities, rest of Canada excluding BC					
GHG emissions in 2010, 1000tCO2e	798	1769	51	15788	248
Employment in 2010	367	807	0	6500	247
Δ(GHG emissions), 1000tCO2e	19	287	-1177	2519	248
Δ(employment)	16	174	-900	879	246
Δ(GHG/employment)	0.68	13	-82	121	245

Notes: Variations in GHG emissions, employment and carbon intensity (GHG/employment) are between the periods 2010-2012 and 2013-2015. For that purpose, variables are averaged in three years periods (2010-2012 and 2013-2015).

Seven observations were dropped due to missing employment data in order to harmonize the number of observations across the tests (47 regulated facilities in Québec and 245 in the control group). These seven observations correspond to four facilities in Québec and 3 in the treatment group. Among these four facilities from Québec, one is a heat & power generation station (Boralex, Kingsey Falls) emitting ~132Kt in 2010 and that shut down in 2013. Another one is a lime manufacturer (Graymont Inc., Joliette) emitting ~78Kt in 2010 and only 65t in 2015 (certainly shut down). The third one is a polystyrene foam manufacturer (OC Celfortec LPValleyfield) emitting ~230Kt in average in 2010-2012, and that cut its emissions by 37% in the period 2013-2015. The last one had constant emissions over the period of ~50Kt. The three facilities from the treatment group were emitting between 65Kt and 80Kt on average over the period 2010-2012, and their emissions rose by 7% (an assembly plant in the automobile sector), 40% (a gas plant) and 62% (a power plant), respectively, in the period 2013-2015. Given the small size of the sample, dropping these seven facilities may impact the results, which is why a series of tests assessing the effect of the regulation on changes in GHG emissions on a sample (unrestricted) including these facilities were run.

Results

To generate conditional DiD estimates, a simple linear regression framework was used. Changes in facility-level emissions (in log) were regressed on historical emissions (level in 2010, in log), industry fixed effects and the treatment indicator. Standard errors are clustered by province.

Changes in emissions between the periods 2010-2012 and 2013-2015, and also between 2010-2011 and 2013-2015 were considered to account for a potential anticipation effect (i.e., facilities reducing their emissions as early as 2012). The results are presented in column (1) of Table 3.

Looking first at the restricted sample, the DiD OLS estimated parameter for the treatment indicator is negative and statistically significant (α=-0.098; p-value <0.01),, meaning that regulated facilities in Québec have reduced their GHG emissions by approximately ten percent faster than non-regulated facilities in the rest of Canada. In the pre-treatment period (2010-2011), the estimate is negative and statistically significant (α=-0.099; p-value <0.01), suggesting a slight anticipation effect. The same regressions were run on the "unrestricted" sample, yielding estimates that were also negative (α=-0.485, and α=-0.492) and significant (p-value <0.01), but were greater in magnitude.

Columns (2) and (3) of Table 3 present the results for DiD nearest neighbour matching estimator matching with the closest neighbour (NNM1), and the three closest neighbours (NNM3). The estimates are significant, close in magnitude and with the same sign compared to those obtained with DiD OLS, thus supporting our previous results.

Change in employment (in log) as the dependent variable were also considered. The DiD OLS estimates (column 1) of the Québec ETS' effect on employment variations were negative and statistically significant for pretreatment period 2010-2012 (α=-0.071; p-value <0.01) and for pretreatment period 2010-2011 (α=-0.065; p-value <0.01). This means that regulated facilities in Québec have reduced employment by approximately seven percent faster compared to unregulated facilities in the rest of Canada. This result is confirmed by the NNM estimates (columns 2 and 3) that are also negative and significant (p-value<0.01), ranging between α=-0.183 and α=-0.148, depending on the specification and the pretreatment period considered.

Finally, the effect of the ETS on the changes in carbon intensity (GHG/employment, in log) were considered. The DiD OLS estimates of the treatment's effect were negative but only moderately significant considering the pretreatment period 2010-2012 (($\beta\alpha$=-0.027; p-value <0.10) and not for the pretreatment period 2010-2011 (α=-0.031, p-value = 0.104). Turning to the DID NNM, estimates were never significant, meaning that the implementation of the QC ETS had no significant impact on the efficiency of production with respect to GHG emissions. During the period 2013-2015, regulated facilities did not adapt to the program through a change in their production process or technology that would affect carbon intensity.

Altogether, these results suggest that facilities in Québec have responded to the implementation of the ETS mainly by adjusting their production scale, not their intensity. This contrasts with the results from previous studies on the early effects (up to 2010) of the European ETS on French and German facilities and firms (Petrick & Wagner, 2014; Wagner et al., 2014). According to these studies, European industry adapted to changes in regulations through changes in the GHG intensity of production, not production scale.

Table 3: Impacts on GHG emissions, employment and carbon intensity of regulated facilities in Québec

	DiD using OLS (1)	**nnm1** (2)	**nm3** (3)	Regulated facilities	Control group
Dependent variable is Δln(GHG emissions)					
Unrestricted sample					
2010-**2012**/2013-2015	-0.485***	-0.419*	-0.391*	51	248
	(0.102)	(0.233)	(0.229)		
2010-**2011**/2013-2015	-0.492***	-0.439*	-0.400*	51	248
	(0.010)	(0.235)	(0.230)		
Restricted sample					
2010-**2012**/2013-2015	-0.098***	-0.152**	-0.131**	47	245
	(0.012)	(0.065)	(0.066)		
2010-**2011**/2013-2015	-0.099***	-0.160**	-0.134*	47	245
	(0.013)	(0.070)	(0.070)		
Dependent variable is Δln(employment)					
2010-**2012**/2013-2015	-0.071***	-0.174***	-0.148***	47	245
	(0.012)	(0.055)	(0.052)		
2010-**2011**/2013-2015	-0.065***	-0.183***	-0.155***	47	245
	(0.017)	(0.059)	(0.058)		
Dependent variable is Δln(GHG/employment)					
2010-**2012**/2013-2015	-0.027*	0.021	0.017	47	245
	(0.014)	(0.068)	(0.064)		
2010-**2011**/2013-2015	-0.031	0.027	0.032	47	245
	(0.017)	(0.073)	(0.070)		

Notes: GHG emissions are averaged in three years periods (2010-2012 or 2013-2015) or two years period (2010-2011). Emissions differences between two periods 0 and 1 are defined as ln(GHG1 + 1) – ln(GHG0 + 1). The OLS estimates control for historic GHG emissions in 2010 (in log) and NAICS code indicator variables, with standard errors clustered by province.
nnm is nearest neighbor matching estimator. We match on the closest (nnm1) or the three closest neighbors (nm3) and with quadratic bias adjustment. The nnm model matches on historic emissions and NAICS code indicators and exactly on industry-specific historic emissions quartile indicators. Standard errors are Abadie–Imbens robust.
*** is significant at 1% level, ** at 5%, * at 10%. Standard errors are reported in parentheses.

Tests on different groups and samples.

As a robustness check, regressions with different treatment and/or comparison groups, and different samples were run.

First, as an alternative treatment group, a set of British Columbia (BC) industrial facilities having the same characteristics as those facilities analyzed above were considered (same NAICS sectors; GHG emissions higher than 30,000 tCO_2 in 2012 or 2013). There were 38 facilities in the treatment group. The comparison group remains the same. The results must be considered with caution since, during the pre-treatment period (2010-2011), the BC treatment group was already regulated with a carbon tax and not the comparison group. 2012 is nonetheless a cutoff year as it is the first year of full implementation of the carbon tax reaching 30 CAN$, which is why 2012 was used as the treatment year.

Table 4 presents the results of DiD OLS regressions for the three outcome variables and two alternative post-treatment periods. Estimates of the treatment effect on the change in GHG emissions (log) are negative and significant for the 2012-2015 post-treatment period (α=-0.082, p-value<0.01) and the 2013-2015 post-treatment period (α=-0.092, p-value<0.01). This suggests that the full implementation of the BC government's revenue-neutral carbon tax in 2012 induced these facilities to cut their GHG emissions 8-9% faster as compared to similar industrial facilities from the rest of Canada (excluding QC).

The effect on change in carbon intensity is also negative and significant for the 2012-2015 post-treatment period (α=-0.250, p-value <0.05) and the 2013-2015 post-treatment period (α=-0.100, p-value<0.01), whereas the effect of the treatment is not significant on changes in employment in either period (2012-2015: α=0.152, p-value=0.112; and 2013-2015: α=-0.008, p-value=0.600). These results suggest that during that period (2012-2015), these industrial facilities in BC, adapted to the carbon tax scheme by reducing their emissions, through changes in production technologies and processes, thus lowering carbon intensity, rather than adjusting production scale.

Table 4: DiD using OLS with different treatment and comparison groups

	Dependent variable			Regulated	Control
	Δln(GHG emissions)	Δln(employment)	Δln(GHG/employment)	facilities	group
Treatment group is BC and control group is the rest of Canada, excluding QC					
2010-2011/2012-2015	-0.082***	0.152	-0.250**	38	245
	(0.019)	(0.087)	(0.096)		
2010-2011/2013-2015	-0.092***	-0.008	-0.100***	38	245
	(0.020)	(0.015)	(0.024)		
Treatment group is QC and control group is the rest of Canada, including BC					
2010-2012/2013-2015	-0.095***	-0.063***	-0.032**	47	283
	(0.007)	(0.012)	(0.014)		
2010-2011/2013-2015	-0.096***	-0.057***	-0.035**	47	283
	(0.008)	(0.015)	(0.014)		

Notes: GHG emissions are averaged in two (2010-2011), three (2010-2012 or 2013-2015) or four years period (2012-2015). Emissions differences between two periods 0 and 1 are defined as ln(GHG1 + 1) – ln(GHG0 + 1). The OLS estimates control for historic GHG emissions in 2010 (in log) and NAICS code indicator variables, with standard errors clustered by province.
*** is significant at 1% level, ** at 5%, * at 10%. Standard errors are reported in parentheses.

Second, QC regulated facilities were kept as the treatment group, and BC facilities included in the comparison group, with the rest of Canadian provinces (283 facilities in the comparison group). Estimates of the treatment effect on changes in GHG emissions remain negative and significant, but smaller in magnitude compared to the main tests' results. This is the same for the effect on changes in employment. Results are reported in the lower part of Table 4.

Thirdly, the same treatment group of QC regulated facilities were analyzed, but against an alternative dataset for the comparison group. Data on small facilities in Québec (GHG emissions lower than 25,000 tCO_2e in 2012 or 2013) and from the same NAICS industrial sectors were collected. Data on GHG emissions and employment are originating from the Government of Quebec Due to missing data, the period covered is 2012-2015, with 2012 considered as the pre-treatment period and 2013-2015 as the post-treatment period. As the pre-treatment period (2012) is just prior to the launch of the program, a potential anticipation effect can introduce bias, and results must be considered cautiously. To mitigate that issue, at least partially, 2014 and 2015 were considered separately as post-treatment periods.

Results of DiD OLS regressions are presented in Table 5. The coefficients for all post-treatment periods were negative, but only significant for 2015.

Table 5: DiD using OLS with small facilities in Québec as comparison group.

	DiD using OLS	Regulated facilities	Control group
Dependent variable is Δln(GHG emissions)			
2012/2013-2015	-0.510	58	60
	(0.501)		
2012/2014	-0.625	58	60
	(0.569)		
2012/2015	-2.577**	58	60
	(1.298)		

Notes: GHG emissions are averaged in three years period for 2013-2015. Emissions differences between two years or period 0 and 1 are defined as ln(GHG1 + 1) – ln(GHG0 + 1). The OLS estimates control for historic GHG emissions in 2012 (in log) and NAICS code indicator variables.
*** is significant at 1% level, ** at 5%, * at 10%. Robust standard errors are reported in parentheses.

Conclusion and Discussion of results

A condition for the robustness of the results is that the potential outcome at one facility must be independent of the treatment status of other facilities. This is known as the Stable unit treatment value assumption (Fowlie et al., 2012). It is of importance as it might be the case that within a firm, emissions are reallocated from ETS-facilities to non-ETS facilities. Such a spillover may have occurred within firms, from regulated facilities in Québec, towards smaller non-regulated facilities in Québec and/or non-regulated facilities located in other Canadian provinces, or across the US border. The empirical literature on the effect of ETS usually tries to circumvent this issue, for example by conducting the analysis at the more aggregated firm level, thereby, internalizing between facilities spillover effects. Rather than circumventing the issue, assessing the magnitude of such a potential spillover effect would be an avenue for future search. Evidencing a significant between facilities or between firms spillover effect would support the call for the coordination/harmonization of carbon pricing policies across territories.

It is interesting to compare our results with those from Yamazaki (2017). The study covers more sectors, including service industries (Finance, Insurance, environmental services, health…) and the early stage of implementation of the BC revenue-neutral carbon tax (pre-treatment period is 2002-

2007; the post-treatment period is 2008-2013). It shows, at the aggregated level, that the BC revenue-neutral carbon tax had a positive effect on employment, explained in particular by the green fiscal reform (i.e. double dividend). But looking at Yamazaki's (2017) disaggregated results and considering the same subset of sectors as those covered in our study (Table 1), it appears that the BC carbon tax scheme had a negative effect on employment in these sectors. This is comparable to what we observe during the early stage after the implementation of the QC ETS.

Our study doesn't investigate the overall net employment effect of the QC ETS on the economy of Québec. We may nonetheless consider, based on the earlier literature on the topic, that for a 'double dividend' to appear in terms of employment, as in the case of BC, a necessary condition would be to implement a green fiscal reform (Goulder, 1995). This is possible with an emissions trading system, but as long as all permits are sold, and the revenue recycled through the reduction of pre-existing fiscal distortions, such as personal and/or corporate income taxes (Cramton and Kerr, 2002).[2] In the case of the QC ETS, only part of the permits has been sold until 2017, and the revenue allocated to the international green climate fund (add reference???).

Our results obtained for BC considered as a treatment group must be taken cautiously, as mentioned previously. The sharp contrast between these results (no significant impact on employment change) and those obtained in Yamazaki (2017) (negative and significant effect on employment) for the same industrial sectors is remarkable. An explanation certainly lays in the timing of the studies. Yamazaki (2017) consider the treatment effect in the early stage of implementation of the BC tax scheme (2008-2013), whereas we consider a later/subsequent stage (2012-2015). One may expect that rational firms willing to abate emissions, choose first the options with the lowest marginal abatement cost. If cutting emissions through the reduction in the scale of production was less costly than improving production technologies and processes, this could explain the contrast between our results and those of Yamazaki (2017). This is the sense of the results obtained by Wagner et al. (2014) in the frame of the EU ETS, showing that the treatment effect varies between the phases I and II of the EU ETS.

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[2] Note that tradable permits have been usually granted for free during the early stages of the experiences with ETS (e.g. the US SO2 in 1993; the EU carbon ETS in 2005) in order to ensure the political acceptability of the all environmental policy (Stavins, 1998) and/or as a response to industrial lobbying (Hanoteau, 2014).

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