The Green Paradox of Industrial Carbon Pricing*

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Abstract

How do the announcement and implementation of climate policy affect the environment and firm behavior? We study how firms respond to credible commitments to persistent energy prices increases by exploiting the staggered roll-out of carbon pricing across Canada and restricted-access microdata on the manufacturing sector. We find that the announcement of impending carbon pricing increases short-run energy use and emissions. Intertemporal substitution of production through inventories can explain these temporary emissions increases. This result is the first empirical evidence of an industrial "green paradox": firms increase emissions in response to increasing stringency of climate policy.

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1 Introduction

Atmospheric greenhouse gas concentrations are at historic highs and are causing unprecedented changes in the climate. The resulting damages from climate change are typically unpriced, and therefore ignored, by markets. This externality is “the biggest market failure the world has seen”, but implementing climate policy to internalize it is challenging because the private costs of reducing emissions are often large and salient while the climate benefits are shared (Stern 2008, p.1).

In theory, market-based climate policies allow governments to reduce emissions at the lowest cost (Baumol and Oates 1971; Montgomery 1972). The two main examples are carbon taxes, which are optimally equal to the full economic damages from one tonne of emissions (i.e., the social cost of carbon), and cap-and-trade programs, which set a ceiling on emissions at the pre-determined efficient level. Economists refer to these policies as “first best”.

In practice, such climate policy is rarely implemented. Virtually all market-based climate policies are “second best”: they are phased in after some delay, at levels that are less stringent than theory requires (Golosov et al. 2014). These second-best features characterize many of the major climate policies implemented globally, including Europe’s landmark Emissions Trading System (EU ETS), China’s national Emissions Trading Scheme, Sweden’s carbon tax, California’s cap-and-trade system, and Canada’s federal carbon price (World Bank 2025). Such concessions are often made to reduce opposition to carbon pricing: policies that are announced with a long lead time and increasing stringency allow firms to smooth expensive investments to reduce emissions.

This paper studies how changing firms’ beliefs about future climate policy affects their environmental and economic outcomes, and studies mechanisms for these effects. We show that delaying implementation of climate policy can have unintended consequences. In theory, more stringent future climate policy could increase or decrease current emissions in the industrial sector. Anticipation of higher future energy prices could encourage upfront energy-efficient investment, spurring emissions reductions before the policy is implemented. Anticipation of higher future energy prices could also encourage forward-looking industries to accelerate production and emissions in the short run, running counter to climate policy objectives. The possibility that anticipated climate policy can increase short-term emissions is called a “green paradox” (Sinn 2008). Empirical tests of this green paradox are limited, plausibly because settings with variation in both expected and actual climate policy are scarce (Norman and Schlenker 2024).

The first part of this paper conducts such a test by exploiting the staggered announcement and implementation of carbon pricing in Canada. Between 2011 and 2016, three Canadian provinces (Alberta, Ontario, and Quebec) implemented carbon pricing with a lag of at least one year between announcing the policy and implementing the price increases. The other provinces and territories did not introduce carbon pricing during this time; most did not do so until federal policy required it in 2019. This policy variation allows us to disentangle the effect of anticipation of future climate policy from the effect of the policy itself. We use a stacked differences-in-differences research design that estimates the average treatment effects of announcing and implementing carbon pricing on treated manufacturing plants in Alberta, Ontario, and Quebec relative to the pre-announcement period and relative to control manufacturing plants. We analyze effects on environmental and economic outcomes using restricted-access microdata from Statistics Canada. We assess the validity of the research design using event study graphs and sensitivity analyses using different data subsamples and estimation strategies. The evidence supports the identifying assumptions.

The second part of the paper studies mechanisms for firms' responses to expected and actual price increases. We estimate the effects of the announcement and implementation of carbon pricing on several economic outcomes that plants could adjust in response to higher energy prices, including revenue, inventories, and investment. We also estimate heterogeneous effects that allow responses to differ for plants that are more or less exposed to carbon pricing.

The analysis reveals an industrial green paradox: treated manufacturing plants *increase* energy use and emissions by 6.4%-10.2% after the announcement of future carbon pricing, rather than gradually reducing them. Energy use and emissions then fall when carbon pricing is implemented; increases in investment can explain this decline. We calculate an elasticity of energy use with respect to the carbon price of -0.49 after implementation.

While canonical literature focuses on a green paradox that arises through increases in extraction of upstream fossil fuels (Sinclair 1992; Sinn 2008), we find evidence of an alternative explanation that operates through inventory storage. The increase in energy use can be explained by a corresponding 7.0% increase in closing inventories: plants appear to ramp up production when carbon pricing is announced and store output after prices rise. We find no effects on revenue.

We calculate a modest upper bound on the social welfare cost of delaying implementation by one year, relative to a first-best counterfactual where announcement and implementation occur in the same year. Back-of-the-envelope calculations suggest that the private benefit to firms of deferring investment by one year is smaller than the maximum environmental cost. However, the private benefits plausibly reduce opposition to carbon pricing, and so one way to interpret our small welfare cost of delay is as the price of political feasibility.

This paper contributes to existing literature in three main ways. First, it provides the first empirical evidence of a green paradox in the manufacturing sector and mechanisms for this effect. A small number of empirical papers test whether future environmental policy increases pollution in sectors upstream of manufacturing. The evidence is mixed. One paper studies the coal purchasing behavior of power plants after the announcement of the U.S. Acid Rain Program, which regulates sulfur emissions from coal and other sources, and does not find pollution increases (Di Maria et al. 2014). Other work finds that oil and coal futures respond to changes in the probability of U.S. climate legislation, suggesting respectively that extraction and consumption would have increased had the Waxman-Markey carbon pricing bill passed the Senate in 2010 (Lemoine 2017; Norman and Schlenker 2024). Our analysis extends Colmer et al. (2025), who show that the implementation of the EU ETS reduced French manufacturing emissions. Ours is a story of carbon leakage over time; theirs focuses on leakage across countries. In settings such as the EU ETS, with a long consultation period and no clear price trajectory, theory predicts little anticipatory response (Norman and Schlenker 2024); they test for anticipation as a threat to identification and find none. By contrast, we study announcements of credible and imminent price increases; a rich theoretical literature shows that anticipatory increases in energy use and emissions may arise under these conditions (Smulders et al. 2012; van der Ploeg and Withagen 2015).

The second related literature is on climate policy design (Weitzman 1974; Goulder and Parry 2008; Metcalf and Weisbach 2009; Golosov et al. 2014; Schmalensee and Stavins 2017). An anticipated and increasingly stringent carbon price theoretically lowers firm adjustment costs (Vogt-Schilb et al. 2018). The British Columbia carbon tax legislation makes this explicit: "The carbon tax will be phased in to give individuals, businesses, and industry time to adapt, innovate, and reduce the impact of the tax" (BC 2008, p.1). But theory argues that such increasing stringency is a necessary but insufficient condition for short-run emissions increases (Sinn 2008; Kellogg 2024). We show that deferred price increases can have unexpected environmental costs that run counter to policy objectives, but this downside is not large and presumably serves valuable political objectives.

Finally, this paper contributes to literature on the responses of industrial energy use to environmental regulation (Jaffe et al. 1995; Porter and van der Linde 1995; Greenstone 2002; Linn 2008; Fowlie et al. 2012; Ryan 2012; Walker 2013; Shapiro and Walker 2018; Ganapati et al. 2020; Yamazaki 2022; Hawkins-Pierot and Wagner, Forthcoming). One strand of this literature studies industrial responses to carbon pricing (Ahmadi et al. 2022; Dechezlepretre et al. 2023; Colmer et al. 2025); most of these papers do not estimate industrial energy demand elasticities. One exception, Martin et al. (2014), provides an upper bound on this demand elasticity using the energy expenditure elasticity with respect to a UK energy tax. They highlight that the distinction between energy demand elasticities estimated using persistent price variation (e.g., from carbon pricing) and estimated using temporary price fluctuations is important because firms may invest more in abatement if they know policy will raise prices in the medium run, but the magnitudes are not yet well understood. Our results imply a short-run elasticity of energy use with respect to carbon price-induced persistent changes that is larger than short-run elasticity estimates based on temporary price changes.

The rest of this paper proceeds as follows. Section 2 describes industrial energy use and carbon pricing in Canada. Section 3 describes the data. Section 4 outlines our empirical strategy and Section 5 discusses results. Section 6 discusses welfare implications. Section 7 concludes.

2 Background on Canadian Carbon Pricing

2.1 Industrial Energy Use

The industrial sector in Canada produces approximately 35% of total greenhouse gas emissions and consumes approximately 40% of total energy. Manufacturing accounts for approximately 55% of this total; the other industrial sectors, including resource extraction, forestry, and construction, produce lower total emissions.[1] In 2019, natural gas and electricity each account for approximately one-third of manufacturing energy use, with the residual split roughly equally between coal, heavy fuel oil, and other fossil fuels (NRCAN 2020). Overall, the industrial sector consumes the most energy of all sectors in Canada, and is second in emissions only to transportation, which uses a dirtier energy mix. Climate policy in Canada focuses heavily on these two sectors (NRCAN 2022).

Overall, the Canadian manufacturing sector shares many similarities with the U.S. manufacturing sector, its larger and more thoroughly studied neighbor. The shares of energy types used , and the contribution of manufacturing to total energy use, are similar in magnitude (EIA 2022). Almost no electricity is generated on site in the manufacturing sector in either country. One difference, however, is that purchased electricity is much cleaner in Canada: Canada generates less than 20% of electricity using fossil fuels, compared to close to 60% in the U.S. (CER 2026a). Appendix Figure A.1 maps the share of electricity generated from non-fossil fuel (i.e., clean) sources by province in 2019.[2]

2.2 Industrial Carbon Pricing

Another key difference between the Canadian and American contexts is that Canada has a national industrial carbon price. The staggered adoption of carbon pricing across Canadian provinces provides variation in both the announcement and the implementation of climate policy. The latest adopters implemented carbon pricing in 2019, when the Canadian federal government passed the Greenhouse Gas Pollution Pricing Act. Its goal was to reduce Canadian greenhouse gas emissions by 30% below 2005 levels by 2030. To achieve this objective, the policy established a federal minimum carbon price on consumer fossil fuel purchases and industrial production emissions.

[1] Resource extraction has the highest greenhouse gas emissions per dollar of output, largely driven by oil sands extraction (NRCAN 2022).

[2] Canada has limited east-west electricity trade; the electricity price for industrial customers in Quebec is half the price of neighboring provinces, for example (Hydro-Quebec 2024).

Provinces could implement their own carbon pricing policies instead, provided their alternative was at least as stringent as the federal policy (ECCC 2020).[3] This federal policy was announced at the end of 2018 and phased in during 2019. We end our analysis in 2019 because all provinces are treated by the end of 2019 and some provinces with existing carbon pricing programs made changes to comply with federal requirements.

Prior to 2019, provincial governments could adopt carbon pricing at their discretion. Three provinces implemented either a carbon tax (Alberta) or a cap-and-trade program (Ontario and Quebec) with a lag of at least one year from the official announcement of the decision to implement each policy. Alberta's carbon tax was announced in November 2015 and took effect in January 2017 (Pachon and Weber 2016). Quebec announced its cap-and-trade program in December 2011 and compliance began in January 2013 (ICAP 2026b). Ontario announced its cap-and-trade program in April 2015 and the market opened in January 2017. The Ontario program was suddenly canceled in July 2018 due to a provincial government change and replaced by the federal policy in January 2019 (ICAP 2026a). Appendix A discusses additional policy details. Appendix Figure A.2 shows a timeline of carbon pricing policies and Appendix Figure A.3 shows their initial and subsequent levels.

Of the remaining provinces and territories, British Columbia announced and implemented a carbon tax in 2008, with a short delay of a few months. All other jurisdictions did not adopt carbon pricing until required to do so by federal policy.[4]

3 Data

This section describes data sets and steps taken to clean them. Appendix B provides more detail and discusses summary statistics.

3.1 Establishment Data

Our primary data sources are Statistics Canada's restricted-access Annual Survey of Manufacturing and Logging Industries (ASML) and National Accounts Longitudinal Microdata File (NALMF).

The ASML is an annual plant-level survey conducted by Statistics Canada from 1998 through the present (Statistics Canada 2025a). Until 2012, it includes the universe of manufacturing plants in Canada; after 2012, the format changed to survey a nationally representative sample of

[3] The consumer fuel charge was repealed in 2025. The industrial carbon price was not affected (Department of Finance Canada 2025).

[4] These provinces and territories are Manitoba, New Brunswick, Newfoundland and Labrador, Northwest Territories, Nova Scotia, Nunavut, Prince Edward Island, Saskatchewan, and Yukon.

approximately 20,000 plants per year. The survey includes sampling weights for comparability across time. The data comprise financial information, including revenue and energy expenditures by energy type (e.g., electricity, natural gas). The ASML is our main source of economic and environmental variables.

We supplement the ASML with the NALMF, a longitudinal firm-level database produced by Statistics Canada for the years 2000 onward (Statistics Canada 2025b). The NALMF is a census of firms with at least one paid employee. The data are based on corporate tax returns and payroll records; they include some of the ASML variables, but exclude information on energy use. We use these data to recover capital investment not reported in the ASML. We link these data sets using firm identifiers and apportion firm-level capital to their component plants using a plant's share of revenue in its firm's total revenue. Appendix B.2 provides details.

We deflate all monetary values to 2024 Canadian dollars using the GDP deflator for Canada (FRED 2026). Where relevant, we convert Canadian dollars to U.S. dollars for comparison to the literature using the average exchange rate in 2024 (Bank of Canada 2026).

3.2 Energy Data

We collect additional data on fuel prices, fuel carbon content, electricity generation sources, and provincial carbon prices.

We draw on annual provincial prices for gasoline, diesel, natural gas, heavy fuel oil, light fuel oil, and electricity from the Canada Energy Regulator (CER 2026b). Province-specific prices are unavailable for coal and propane, and so we use their national prices from industry reports (Teck Resources Limited 2025) and from the Canadian Gas Association (CGA 2026), respectively. We calculate fuel quantities by dividing ASML fuel-specific expenditures by prices.

We merge conversion factors from energy quantities to tonnes of carbon dioxide (CO_2) for each fuel from the U.S. Energy Information Administration (EIA 2026). We multiply quantities of energy in gigajoules (GJ) by these fuel-specific conversion factors to obtain CO_2 emissions.

For electricity, obtaining CO_2 emissions requires an additional step. The embedded emissions are produced at the generation stage, and provinces use different fuels to generate electricity (Appendix Figure A.1). We obtain the amount of each fuel used to generate electricity in each province from the Canada Energy Regulator (CER 2026a), which we multiply by the same conversion factors and divide by total electricity production to obtain emissions per GJ of electricity.

Finally, we include data on provincial carbon prices from the International Carbon Action Partnership (ICAP 2026c). The provincial fuel price data above are exclusive of carbon prices.

3.3 Treatment Status

We impose several restrictions on these data to define our treatment and control groups. Plants in Alberta, Ontario, and Quebec are our treatment group: they are treated sequentially by the announcement and implementation of carbon pricing. We exclude observations in Ontario in 2015 because its cap-and-trade program was announced halfway through that year, about 20 months before implementation; sensitivity analyses add these partially treated observations back. There are no partially treated observations in Alberta and Quebec because they announced their policies at the end of the calendar year about 13 months prior to implementation. We define the full calendar year before implementation as the announcement year for all three provinces.

The control group consists of plants in the other provinces and territories. Of these, we exclude Nova Scotia and New Brunswick because they announced carbon pricing policies that they did not implement before the federal backstop program took effect in 2019. We include British Columbia in the control group because most other control provinces are small and may not be comparable to the larger, more manufacturing-intensive treated provinces. Our main analysis therefore spans the years 2008 to 2019, during which British Columbia had continuous carbon pricing coverage and we observe four pre-announcement years and four post-announcement years for each treated province. Figure 1 plots the average carbon price paid by plants in treated provinces relative to control plants and shows little evidence of changes in British Columbia's carbon price during this time. Sensitivity analyses include Nova Scotia and New Brunswick, exclude British Columbia, and drop 2019 data.

4 Econometric Model

We use a stacked differences-in-differences regression to estimate how plants respond to the announcement and implementation of carbon pricing. The analysis sample consists of three cohorts c of treated plants in each of Alberta, Ontario, and Quebec and their respective control plants, which we append into a single sample spanning four years before and after announcement for each cohort. Control plants may be repeated in each cohort, and regressions weight repeat control observations by the number of treated plants in each cohort relative to the total number of treated plants (Wing et al. 2024).[5] We estimate the equation:

$$y_{itc} = \beta_1 \, \text{Treat}_i \times \text{Announce}_{tc} + \beta_2 \, \text{Treat}_i \times \text{Implement}_{tc} + \rho_{pc} + \gamma_{jtc} + \delta_{fc} + \varepsilon_{itc} \tag{1}$$

In this equation, y_{itc} is an outcome (e.g., CO_2 emissions) for plant i in year t and treatment

[5] For example, a plant in Saskatchewan that is a control in all three cohorts receives three separate observations in the stacked data set, weighted respectively by the fraction of total treated plants in Alberta, Ontario, and Quebec.

cohort c; Treat_i is an indicator variable equal to 1 for treated plants in provinces that announce and implement carbon pricing; Announce_{tc} and Implement_{tc} are indicator variables that are equal to 1 in all years after the announcement and the implementation of carbon pricing in cohort c, respectively; ρ_{pc}, γ_{jtc}, and δ_{fc} are province-by-cohort, industry-by-year-by-cohort, and firm-by-cohort fixed effects; and ϵ_{itc} is the error term. Standard errors are two-way clustered by firm and treatment cohort throughout.

Our parameters of interest are the β coefficients on the carbon pricing policy phases. These parameters measure the effects of the announcement and implementation phases on treated plants relative to control plants and relative to the preceding time period. Specifically, the parameter β_1 measures the effect of announcing carbon pricing on treated plants relative to control plants and relative to the pre-announcement period. The parameter β_2 measures the effect of implementing carbon pricing on treated plants relative to control plants and relative to the announcement period: β_2 measures whether the implementation effect is different from the announcement effect. The implementation effect relative to the pre-announcement period is $\beta_1 + \beta_2$. If plants front-load emissions in response to climate policy announcement, $\beta_1 > 0$; this is evidence of a green paradox. If subsequent implementation reduces emissions as it is designed to, $\beta_2 < 0$. If emissions fall below their pre-announcement levels, $\beta_1 + \beta_2 < 0$.

The identifying variation comes from changes in within-firm exposure to information about impending carbon prices and to the actual price changes, relative to firms in provinces that do not announce or implement carbon pricing during our sample period. We include several sets of fixed effects. Province-by-cohort fixed effects ρ_{pc} control for time-invariant provincial characteristics, such as primary electricity generation sources. Industry-by-year-by-treatment cohort fixed effects γ_{jtc} control for changes in regulatory or business environments of three-digit North American Industrial Classification System (NAICS) industries over time. These fixed effects also control for common macroeconomic conditions, such as the 2008 recession. The interaction of year-by-cohort fixed effects accounts for the same calendar year falling at different points in event time for different cohorts (i.e., the year 2008 is three years before Quebec announced carbon pricing, but seven years before Ontario did). Firm-by-cohort fixed effects δ_{fc} control for time-invariant firm characteristics, such as organizational structure. Importantly, the interaction of all fixed effects with indicators for treatment cohort c means that the identifying variation is within-cohort.

The identifying assumptions for our two effects of interest in equation (1) are that announcing and implementing carbon pricing are the only factors that differentially affect plants, conditional on model covariates:

$$E[\text{Treat}_i \times \text{Announce}_{tc} \times \epsilon_{itc} | \rho_{pc}, \gamma_{jtc}, \delta_{fc}] = 0$$

$$E[\text{Treat}_i \times \text{Implement}_{tc} \times \epsilon_{itc} | \rho_{pc}, \gamma_{jtc}, \delta_{fc}] = 0$$

These assumptions hold if no contemporaneous factor generates differential trends in plant outcomes when the carbon pricing policies are announced and implemented. For example, controlling for industry-by-year-by-cohort fixed effects γ_{jtc} addresses any potential concerns about simultaneous changes in the regulatory environment of particular industries. We implement an indirect test of the identifying assumption by examining whether treated and control plant outcomes have similar trends in the pre-announcement years. We estimate the coefficients ψ_t from the event study version of equation (1):

$$y_{itc} = \Sigma_{t=-3}^{4} \psi_t 1[\text{YrsRelAnn}_{ct} = t] \times \text{Treat}_i + \psi_0 \text{Treat}_i + \rho_{pc} + \gamma_{jtc} + \delta_{fc} + \eta_{itc} \quad (2)$$

Here, t indexes the number of years before and after the announcement year and is equal to 0 in the year before carbon pricing is announced. We normalize ψ_0, the year before carbon pricing is announced, to be equal to 0. We plot the parameters ψ_t, which measure annual differences between treatment and control plants in years before and after carbon pricing is announced relative to the year before announcement.

We also estimate equation (1) allowing the treatment effects to differ according to a plant characteristic X_i:

$$\begin{aligned} y_{itc} = {} & \theta_1 \text{Treat}_i \times \text{Announce}_{tc} \times \text{X}_i + \theta_2 \text{Treat}_i \times \text{Implement}_{tc} \times \text{X}_i \\ & + \theta_3 \text{Treat}_i \times \text{Announce}_{tc} + \theta_4 \text{Treat}_i \times \text{Implement}_{tc} + \rho_{pc} + \gamma_{jtc} + \delta_{fc} + \nu_{itc} \quad (3) \end{aligned}$$

In this analysis, X_i is coal intensity (i.e., coal inputs per \$1000 revenue) in the pre-treatment period. Coal differs from other energy inputs because it is highly polluting and can be stored. We expect that more coal-intensive plants are more exposed to carbon pricing and more able to preemptively purchase and inventory inputs.[6]

5 Results

5.1 Environmental Outcomes

Figure 1 shows the event study of carbon prices in treated provinces relative to control provinces. The x-axis is years since the announcement of carbon pricing: $t = 0$ is the year before announce-

[6] Our data contain only 3-digit NAICS industry codes, which limits industry-specific heterogeneity analysis.

ment, $t = 1$ is the announcement year (i.e., plants have known for the whole year that carbon pricing is coming), and $t = 2$ is the implementation year, when prices actually increase. This figure shows that the average carbon price for treated plants increased significantly after the implementation of carbon pricing relative to control plants and relative to before the implementation of carbon pricing. This is the first stage of our analysis. Importantly, there are no economically meaningful differences between treatment and control provinces in the years before the implementation of carbon pricing in the treatment provinces, including during the announcement year. There is a small statistically significant difference (less than 10% of the post-implementation effect, Appendix Table A.2) four years before the announcement of carbon pricing, when British Columbia's carbon tax increased.

Figure 2 shows the event study results for total CO_2 emissions, total energy use, fossil fuel energy inputs, and electricity inputs. Fossil fuel energy inputs aggregate natural gas, coal, diesel, gasoline, heavy fuel oil, light fuel oil, and liquefied petroleum gas used as direct production inputs; total energy use is the sum of fossil fuel and electricity inputs. Total CO_2 emissions aggregate direct emissions from the consumption of fossil fuels and upstream emissions produced to generate electricity. We report results in levels because many of these outcomes take the value zero (e.g., plants that consume only electricity in provinces that produce electricity using only hydropower have zero fossil fuel inputs and emissions). Appendix Table A.4 estimates similar patterns using the log of one plus the value of these outcomes.

Figure 2 provides evidence of a green paradox in industrial carbon pricing: emissions increase when carbon pricing is announced. Panels A and B show statistically significant increases in CO_2 emissions and total energy use during the one-year announcement window. Panels C and D show that these increases are driven by increasing fossil fuel inputs (Panel C) rather than electricity inputs (Panel D), which are flat. Fossil fuel inputs become more expensive when carbon pricing is implemented because their use produces CO_2 emissions. The impact on electricity may be smaller because Canada generates less than 20% of electricity using fossil fuels (CER 2026a). There is no evidence of pre-trends for any outcome before carbon pricing is announced, supporting the identifying assumption.

Figure 2 also shows that carbon pricing reduces emissions when implemented. When emissions become more costly, emissions and total energy use fall relative to the announcement period (Panels A and B). By the end of the third year of implementation, the point estimates indicate that emissions and total energy use are below their pre-announcement levels, suggesting that carbon pricing reduced emissions overall, though the confidence intervals include zero. Panel C indicates that fossil fuel inputs track the decline in emissions. Panel D shows that there are also reductions in electricity use in the post-implementation period, as plants plausibly make long-term adaptations to higher costs.

Table 1, Panel A shows the estimates of the differences-in-differences equation (1). Consistent with the event study graphs, emissions, total energy use, and fossil fuel energy use increase after announcement: the estimates of the announcement effect on treated plants imply increases of 6.4%-10.2% of the pre-treatment mean. After implementation, these environmental outcomes fall relative to the announcement window, and the point estimates are similar to or larger than the jump at announcement. This provides some evidence that carbon pricing reduced emissions and energy use below pre-announcement levels. Motivated by this evidence, Appendix C.3 discusses results from a trend-break specification that allows a discrete increase in outcomes followed by a gradual decline, instead of pooling post-implementation years. These results support a steady decline in emissions and total energy use.

We calculate a price elasticity of demand for energy of -0.49 with respect to the carbon price. This calculation uses the decline in total energy use after carbon pricing is implemented relative to the pre-announcement period (i.e., $\beta_1 + \beta_2$ in Table 1). It therefore captures the change in pre- and post-policy energy use, rather than the transitory increase and subsequent decrease around the announcement window; Appendix D provides details. A recent meta-analysis reports estimates of the price elasticity of industrial energy demand with a short-run mean of -0.19 and a long-run mean of -0.51 (Labandeira et al. 2017). The carbon price signals that energy prices will be higher for many years, and so it is perhaps unsurprising that our point estimate is closer to long-run elasticities.

Table 1, Panel B shows larger increases in emissions, total energy use, and fossil fuel energy use for more coal-intensive plants, and a larger decline after the implementation of carbon pricing. The increases and subsequent declines for the mean plant, which has a pre-treatment coal intensity of 0.11 GJ per $1000 revenue, are roughly twice as large as for a plant that uses no coal.[7] Coal-intensive plants are more highly exposed to carbon pricing because coal is a polluting input, but they can also more easily shift energy purchases forward in time because coal inputs can be stored. The electricity results are not significantly different.

These results are generally robust to a range of different samples, weights, and estimation strategies. The qualitative pattern of increases in total and fossil fuel energy use and emissions persists, with magnitudes centered around the main estimates. The effects on electricity continue to be smaller. Appendix Table A.4 presents sensitivity analyses using different samples and weights and Appendix C.1 discusses them. Appendix Figure A.4 shows event study graphs from estimating equation (2) using Sun and Abraham (2021), which obtain the same pattern. Appendix Table A.3 presents the corresponding differences-in-differences regression estimates and Appendix C.2 discusses them.

[7]This result obtains by multiplying the coal treatment effects by 0.11 and comparing to the baseline effects.

5.2 Economic Mechanisms

This section analyzes mechanisms through which an industrial green paradox can arise. We consider the effects of announcing and implementing carbon pricing on revenue, inventories, investment, and energy expenditures.

Figure 3 shows the event study graphs for the log of these outcomes. Similar to Figure 2, the graphs plot the time series of the difference between treatment and control plants relative to the difference in the year before the announcement of carbon pricing, which we normalize to zero.

This figure suggests that plants temporarily increase production during the announcement window and store output produced during this cheaper period. Panel A shows that there are no significant effects on revenue: the difference between treatment and control plants in all years after announcement is statistically indistinguishable from the difference in the year before announcement. However, Panel B shows a statistically significant increase in inventories after announcement, and inventories remain persistently higher after the implementation of carbon pricing. During the period when plants are consuming more energy inputs but not selling more units, they appear to be storing intermediate goods and output in closing inventories. We presume these inventories will be gradually run down beyond our three-year post-implementation window. There is no evidence of pre-trends, which supports the interpretation that the announcement of impending cost increases encouraged plants to increase production to take advantage of temporarily lower costs.

Panel C of Figure 3 shows that announcing carbon pricing incentivizes investment. Models of firm behavior typically assume that investment adjustment costs have a convex component, so that a given amount of investment spread over two years costs less than the same amount in one year (Lucas 1967; Cooper and Haltiwanger 2006). Policymakers justify a lag between announcing and implementing climate policy on the basis that such investment smoothing reduces costs (BC 2008). The pattern of investment that we find is consistent with this model: the value of machinery and equipment begins to increase during the announcement window and continues following implementation. Panel D shows that plants pay less for energy inputs during the post-implementation period, plausibly as a result of investment in more efficient capital.

Table 2, Panel A summarizes these results using the differences-in-differences equation (1). Consistent with Figure 3, we estimate increases in inventories, machinery and equipment, and energy expenditures during the announcement window. Inventories and energy expenditures increase by approximately 7.0% and 7.8%, respectively, which is consistent with the increase in emissions and energy use of approximately this magnitude. Energy expenditures fall significantly after implementation; inventories remain high, to be gradually consumed or sold. The book value of machinery and equipment assets increases by 2.9% during the announcement window, and then further increases by 2.3% above pre-announcement levels following implementation; the second treatment effect is less precisely estimated. The full investment effect of 5.2% is statistically indistinguishable from the 8.6% increase in investment following the EU ETS implementation (Colmer et al. 2025). We continue to find no significant revenue effects.

Appendix C.3 discusses trend-break specifications. The event study graphs show that machinery and equipment and inventories remain elevated after implementation; hence a trend-break specification may be less appropriate. Consistent with this, we find a significant downward trend only for energy expenditures.

We find larger effects for coal-intensive plants (Table 2, Panel B). Inventories and energy expenditures rise by more during the announcement window than for plants that do not use coal, consistent with plants purchasing and storing coal when it is cheaper; this is more challenging for most other energy inputs. Coal-intensive plants appear to draw down inventories more after implementation, but the estimate is imprecise. Lemoine (2017) proposes the storability of coal as a key explanation for why the inventory of upstream coal suppliers became more valuable, as measured by coal futures, when the Waxman-Markey bill collapsed in the U.S. Senate; our results also support a story where announcement of climate policy encourages preemptive purchase of coal. Investment is not significantly different during the announcement window, though coal-intensive plants appear to divest more machinery and equipment after implementation.

Appendix Tables A.3 and A.5 show that these results are largely robust to different samples, weights, and estimation using Sun and Abraham (2021). Appendix C discusses the sensitivity analyses.

6 Social Welfare Effects

Do the costs of higher emissions exceed the benefits of deferring investment? We approximate the net social welfare effects ΔW from the one-year lag between announcement and implementation as:

$$\Delta W = \Delta Investment \times (1 - \beta) - \Delta Emissions \times SCC$$

The benefits are the present discounted value of deferring some investment until after implementation, $\Delta Investment$; this is the 2.3% increase in investment post-implementation times the \$9,082,900 pre-treatment machinery and equipment value in Table 2. The costs are the additional emissions in the announcement window, $\Delta Emissions$, equal to the 217 tonnes in Table 1, times the social cost of carbon (SCC). Deferred carbon price payments do not enter because they are a transfer between firms and the government, although they are privately valuable to firms. With a discount factor of $\beta = 0.98$ and an SCC of \$253 CAD (\$185 USD) (Rennert et al. 2022), we find a social welfare cost of \$50,723 CAD (\$37,027 USD) per treated plant, or approximately 0.1% of annual revenue.

We interpret this modest quantity as an upper bound on the welfare cost for several reasons. First, it is based on the maximum environmental cost, which assumes all emissions during the announcement window are additional, rather than retimed. The fact that inventories do not fall immediately after implementation suggests that this may be the case for some amount of emissions. Higher investment also suggests that the emissions declines are not only the result of intertemporal shifting. However, some emissions may be pulled forward into the announcement window and would be discounted at rate $(1-\beta)$; if more than 6% of emissions would have occurred later, delay becomes welfare-improving. Second, some emissions may be additional, but necessary to transition to new capital and obtain long-term declines. Third, the benefits to firms in the form of reduced adjustment costs, such as less production downtime due to more gradual investment, are not observed.

7 Conclusion

This paper studies industrial responses to announcing and implementing carbon pricing. We find evidence of an industrial green paradox: manufacturing plants temporarily increase energy use and emissions in anticipation of carbon pricing. Inventorying production can explain this response. However, we find that carbon pricing incentivizes emissions reductions and investment when implemented, as intended.

Our heterogeneity analysis suggests that plants differ in their capacity to respond to both the announcement and implementation of carbon pricing. With more detailed industry data, future work could identify which sectors drive the anticipatory increase in emissions and how policy might mitigate it. In particular, the role of second-best features beyond delayed implementation, such as revenue recycling, in offsetting anticipatory effects is an open question.

Our stylized welfare analysis suggests that the social costs of delay may exceed the benefits. However, the benefits of deferring investment and carbon tax payments accrue privately to firms, and so the lag may make carbon pricing politically feasible. In this case, the relevant counterfactual isn't a policy announced and implemented in the same year; it may be no policy at all. This paper's green paradox is a cost of second-best policy design, but this cost is not large and it may be worth paying for political feasibility.

References

Ahmadi, Younes, Akio Yamazaki, and Philippe Kabore, "How Do Carbon Taxes Affect Emissions? Plant-Level Evidence from Manufacturing," *Environmental and Resource Economics*, 2022, *82*, 285–325.

Bank of Canada, "Annual Average Exchange Rates (USD/CAD)," 2026.

Baumol, William J. and Wallace E. Oates, "The Use of Standards and Prices for Protection of the Environment," *The Swedish Journal of Economics*, 1971, *73* (1), 42–54.

BC, "Backgrounder: B.C.'s Revenue-neutral Carbon Tax," Technical Report, British Columbia Public Affairs Bureau 2008.

CARB, "Cap-and-Trade Program: Program Linkage," 2026.

CER, "Canada Energy Regulator Electricity Generation," 2026.

_ , "Canada Energy Regulator End-Use Industrial Prices," 2026.

CGA, "Canadian Gas Association Energy Commodity Prices," 2026.

Climate Change Advisory Panel, "Climate Leadership: Report to Minister," Technical Report, Government of Alberta, Edmonton 2015. Chaired by Andrew Leach. November 20. Available at https://open.alberta.ca/publications/climate-leadership-2015.

Colmer, Jonathan, Ralf Martin, Mirabelle Muûls, and Ulrich J Wagner, "Does Pricing Carbon Mitigate Climate Change? Firm-Level Evidence from the European Union Emissions Trading System," *Review of Economic Studies*, 2025, *92* (3), 1625–1660.

Cooper, Russell W. and John C. Haltiwanger, "On the Nature of Capital Adjustment Costs," *Review of Economic Studies*, 2006, *73*, 611–633.

Dechezlepretre, Antoine, Daniel Nachtigall, and Frank Venmans, "The joint impact of the European Union emissions trading system on carbon emissions and economic performance," *Journal of Environmental Economics and Management*, 2023, *118*, 102758.

Department of Finance Canada, "Removing the Consumer Carbon Price, Effective April 1, 2025," 2025.

Di Maria, Corrado, Ian Lange, and Edwin van der Werf, "Should we be worried about the green paradox? Announcement effects of the Acid Rain Program," *European Economic Review*, 2014, *69*, 143–162.

ECCC, "Greenhouse Gas Pollution Pricing Act: Annual report for 2019," Technical Report, Environment and Climate Change Canada 2020.

EIA, "Manufacturing Energy Consumption Survey 2022," Technical Report, U.S. Energy Information Administration 2022.

_ , "U.S. Energy Information Administration Carbon Dioxide Emissions Coefficients," 2026.

Financial Accountability Office of Ontario, "Cap and Trade: A Financial Review of the Decision to Cancel the Cap and Trade Program," Technical Report, Financial Accountability Office of Ontario 2018.

Fowlie, Meredith, Stephen P. Holland, and Erin T. Mansur, "What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program," *American Economic Review*, 2012, *102* (2), 965–993.

FRED, "Gross Domestic Product Deflator for Canada [NGDPDSAIXCAQ]," 2026. International Monetary Fund, retrieved from FRED, Federal Reserve Bank of St. Louis.

Ganapati, Sharat, Joseph Shapiro, and Reed Walker, "Energy Cost Pass-Through in U.S. Manufacturing: Estimates and Implications for Carbon Taxes," *American Economic Journal: Applied Economics*, 2020, *12* (2), 303–342.

Golosov, Mikhail, John Hassler, Per Krusell, and Aleh Tsyvinski, "Optimal Taxes on Fossil Fuel in General Equilibrium," *Econometrica*, 2014, *82* (1), 41–88.

Goulder, Lawrence H. and Ian W. H. Parry, "Instrument Choice in Environmental Policy," *Review of Environmental Economics and Policy*, 2008, *2* (2), 152–174.

Government of Alberta, "Climate Leadership Regulation," Alberta Regulation 175/2016, Alberta Queen's Printer 2016.

_ , "Carbon Levy Exemptions," Fact Sheet, Alberta Tax and Revenue Administration 2017.

_ , "Overview of Carbon Levy on Fuel," Carbon Levy Administration Information Circular CL-1, Alberta Tax and Revenue Administration 2017.

_ , "An Act to Repeal the Carbon Tax," SA 2019, c 1, Alberta Queen's Printer 2019. Royal Assent 4 June 2019.

Government of Ontario, "The Cap and Trade Program," O. Reg. 144/16, Climate Change Mitigation and Low-carbon Economy Act, 2016, Queen's Printer for Ontario 2016. Consolidation as of February 27, 2017.

Government of Québec, "Regulation Respecting a Cap-and-Trade System for Greenhouse Gas Emission Allowances – Overview," Technical Report, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs December 2012.

_ , "Regulation Respecting a Cap-and-Trade System for Greenhouse Gas Emission Allowances," CQLR chapter Q-2, r. 46.1, Éditeur officiel du Québec 2013. Version as of November 28, 2013.

Greenstone, Michael, "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures," *Journal of Political Economy*, 2002, *110* (6), 1175–1219.

Hawkins-Pierot, Jonathan T. and Katherine R. H. Wagner, "The Use and Misuse of Average and Marginal Energy Prices: Implications for Climate Policy," 2024. Working Paper.

_ **and** _ , "Technology Lock-In and Costs of Delayed Climate Policy," *Journal of Political Economy Microeconomics*, Forthcoming.

Hydro-Quebec, "Comparison of Electricity Prices in Major North American Cities," Technical Report, Hydro-Quebec 2024.

ICAP, "Canada – Ontario Cap-and-Trade Program," 2026.

_ , "Canada – Québec Cap-and-Trade System," 2026.

_ , "International Carbon Action Partnership Allowance Price Explorer," 2026.

Jaffe, Adam B., Steven R. Peterson, Paul R. Portney, and Robert N. Stavins, "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?," *Journal of Economic Literature*, 1995, *33* (1), 132–163.

Jr., Robert E. Lucas, "Adjustment Costs and the Theory of Supply," *Journal of Political Economy*, 1967, *75* (4, Part 1), 321–334.

Kellogg, Ryan, "The End of Oil," 2024. NBER Working Paper no. 33207.

Labandeira, Xavier, José M. Labeaga, and Xiral López-Otero, "A meta-analysis on the price elasticity of energy demand," *Energy Policy*, 2017, *102*, 549–568.

Lemoine, Derek, "Green Expectations: Current Effects of Anticipated Carbon Pricing," *The Review of Economics and Statistics*, 2017, *99* (3), 499–513.

Linn, Joshua, "Energy Prices and the Adoption of Energy-Saving Technology," *Economic Journal*, 2008, *118*, 1986–2011.

Martin, Ralf, Laure B. de Preux, and Ulrich Wagner, "The impact of a carbon tax on manufacturing: Evidence from microdata," *Journal of Public Economics*, 2014, *117*, 1–14.

Metcalf, Gilbert E. and David Weisbach, "The Design of a Carbon Tax," *Harvard Environmental Law Review*, 2009, *33* (2), 499–556.

Montgomery, W. David, "Markets in licenses and efficient pollution control programs," *Journal of Economic Theory*, 1972, *5* (3), 395–418.

Norman, Maya A. and Wolfram Schlenker, "Empirical Tests of the Green Paradox for Climate Legislation," 2024. NBER Working Paper no. 32405.

NRCAN, "Industrial Consumption of Energy (ICE) Survey, 2020," Technical Report, Natural Resources Canada 2020.

_ , "Energy Use in the Industrial Sector," Technical Report, Natural Resources Canada 2022.

Pachon, Angela and Dillon Weber, "Taxing the Tar Sands," Digest, Kleinman Center for Energy Policy, University of Pennsylvania, Philadelphia, PA August 2016.

Porter, Michael E. and Claas van der Linde, "Toward a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives*, 1995, *9* (4), 97–118.

Rennert, Kevin, Frank Errickson, Brian C. Prest, Lisa Rennels, Richard G. Newell, William Pizer, Cora Kingdon, Jordan Wingenroth, Roger Cooke, Bryan Parthum, David Smith, Kevin Cromar, Delavane Diaz, Frances C. Moore, Ulrich K. Müller, Richard J. Plevin, Adrian E. Raftery, Hana Ševčíková, Hannah Sheets, James H. Stock, Tammy Tan, Mark Watson, Tony E. Wong, and David Anthoff, "Comprehensive evidence implies a higher social cost of CO_2," *Nature*, 2022, *610* (7933), 687–692.

Ryan, Stephen P., "The Costs of Environmental Regulation in a Concentrated Industry," *Econometrica*, 2012, *80* (3), 1019–1061.

Schmalensee, Richard and Robert N. Stavins, "Lessons Learned from Three Decades of Experience with Cap and Trade," *Review of Environmental Economics and Policy*, 2017, *11* (1), 59–79.

Shapiro, Joseph S. and Reed Walker, "Why is Pollution from U.S. Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade," *American Economic Review*, 2018, *108* (12), 3814–3854.

Sinclair, Peter J. N., "High Does Nothing and Rising Is Worse: Carbon Taxes Should Keep Declining to Cut Harmful Emissions," *The Manchester School of Economic & Social Studies*, 1992, *60* (1), 41–52.

Sinn, Hans-Werner, "Public policies against global warming: A supply side approach," *International Tax and Public Finance*, 2008, *15* (4), 360–394.

Smulders, Sjak, Yacov Tsur, and Amos Zemel, "Announcing climate policy: Can a green paradox arise without scarcity?," *Journal of Environmental Economics and Management*, 2012, *64* (3), 364–376.

Statistics Canada, "Annual Survey of Manufacturing and Logging Industries (ASML), confidential master microdata file," 2025.

_ , "National Accounts Longitudinal Microdata File (NALMF), confidential master microdata file," 2025.

Stern, Nicholas, "The Economics of Climate Change," *American Economic Review: Papers and Proceedings*, 2008, *98* (2), 1–37.

Sun, Liyang and Sarah Abraham, "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, 2021, *225* (2), 175–199.

Teck Resources Limited, "2025 Annual Report," Technical Report, Teck Resources Limited 2025. Released 12 March 2026.

van der Ploeg, Frederik and Cees Withagen, "Global Warming and the Green Paradox: A Review of Adverse Effects of Climate Policies," *Review of Environmental Economics and Policy*, 2015, *9* (2), 285–303.

Vogt-Schilb, Adrien, Guy Meunier, and Stéphane Hallegatte, "When starting with the most expensive option makes sense: Optimal timing, cost and sectoral allocation of abatement investment," *Journal of Environmental Economics and Management*, 2018, *88*, 210–233.

Walker, W. Reed, "The Transitional Costs of Sectoral Reallocation: Evidence from the Clean Air Act and the Workforce," *The Quarterly Journal of Economics*, 2013, *128* (4), 1787–1835.

Weitzman, Martin L., "Prices vs. Quantities," *The Review of Economic Studies*, 1974, *41* (4), 477–491.

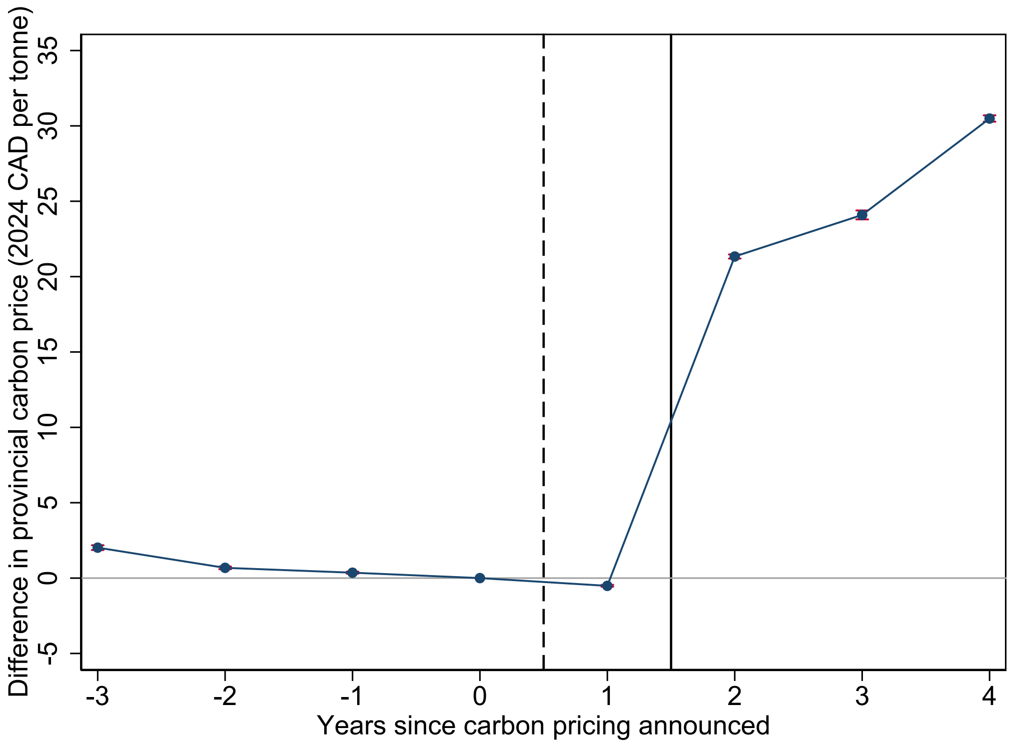
Wing, Coady, Seth M. Freedman, and Alex M. Hollingsworth, "Stacked Differences-in-Differences," 2024. NBER Working Paper no. 32054.

World Bank, "State and Trends of Carbon Pricing 2025," Technical Report, World Bank, Washington, DC 2025.

Yamazaki, Akio, "Environmental taxes and productivity: Lessons from Canadian manufacturing," *Journal of Public Economics*, 2022, *205*, 104560.

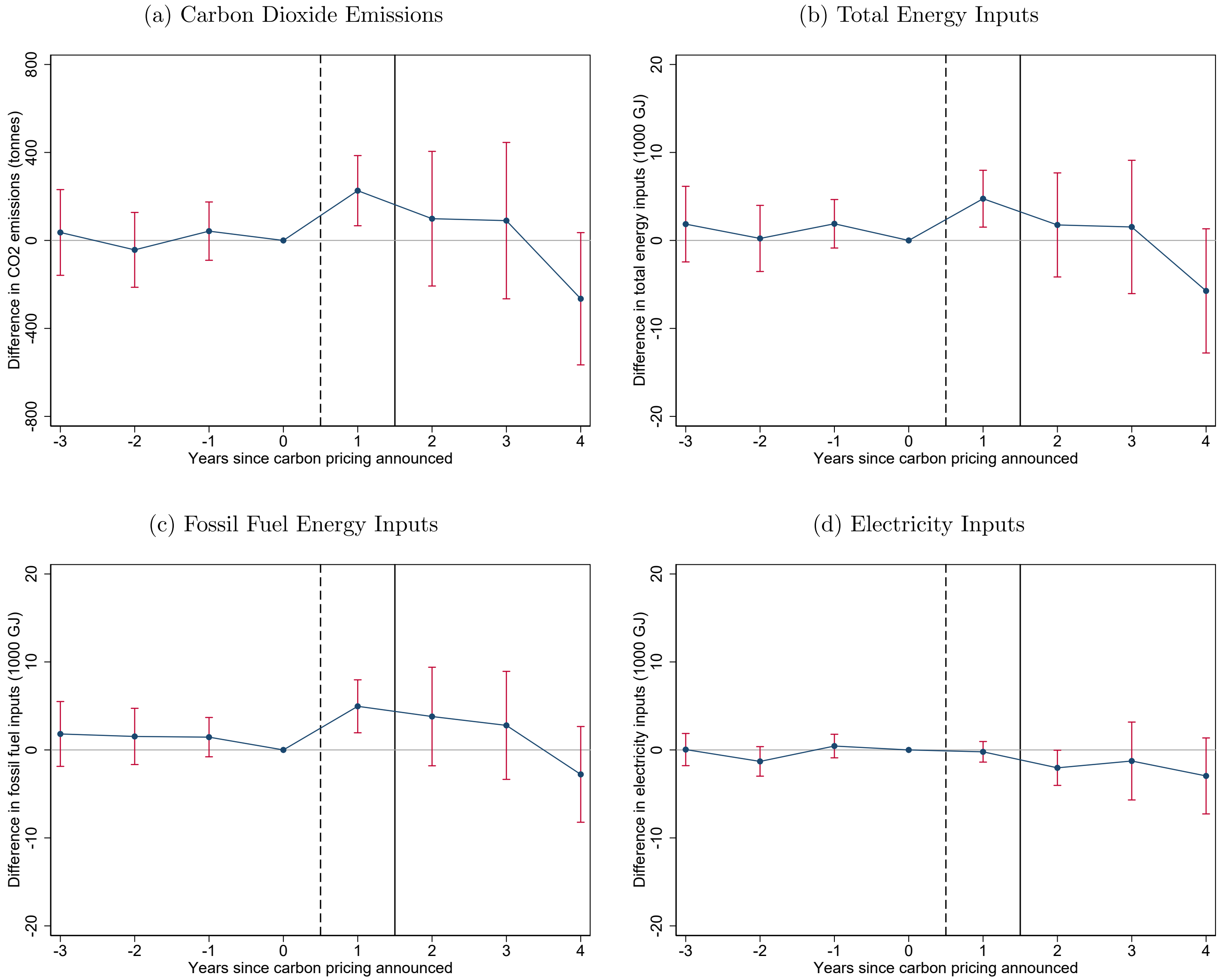
Figures and Tables

Figure 1: Difference in Carbon Dioxide Price for Treated Plants Relative to Control Plants



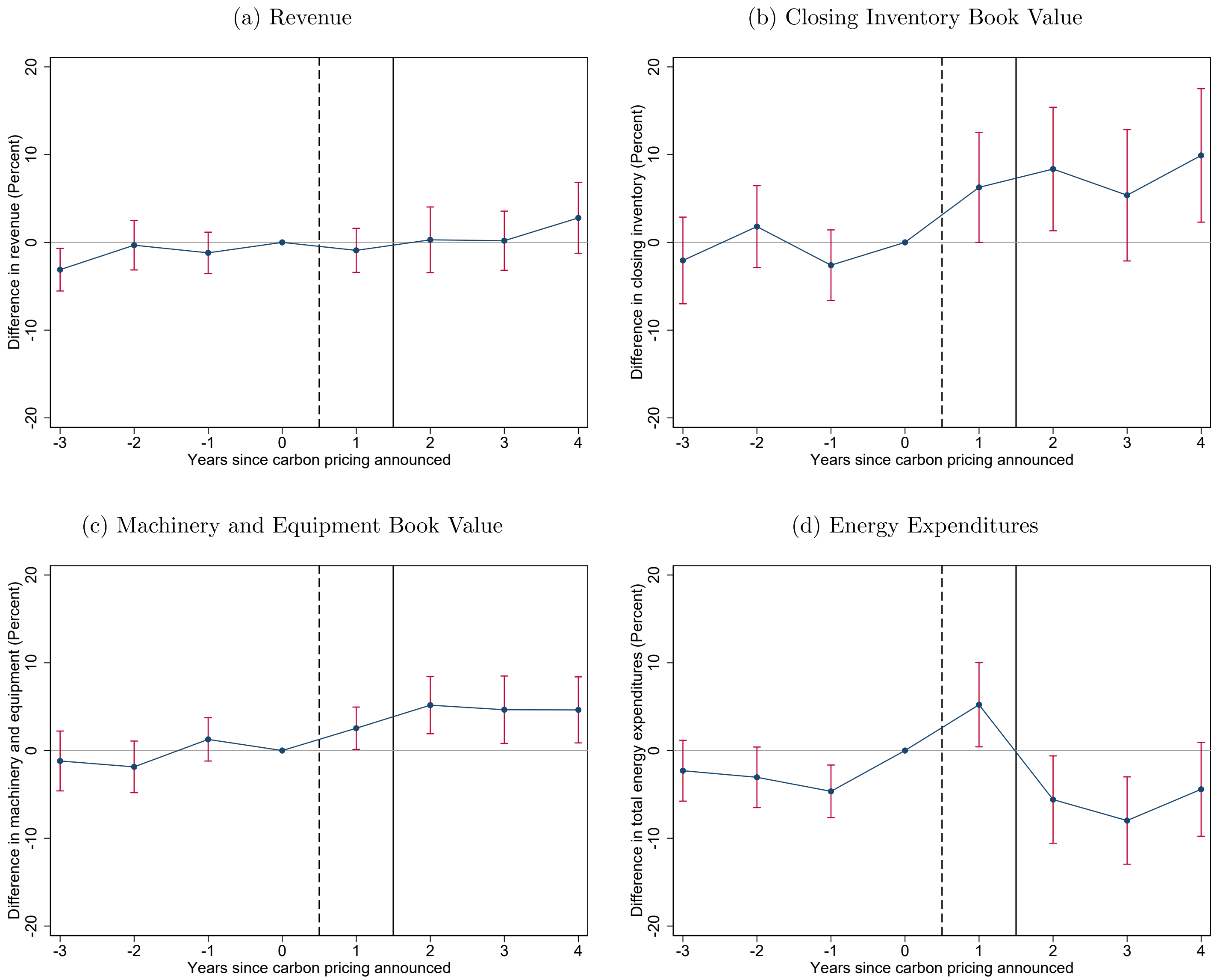
Notes: This graph shows the effects of announcing and implementing carbon pricing on the actual price of emitting CO_2 for treated manufacturing plants relative to control manufacturing plants in Canada. The dashed vertical line indicates the timing of the announcement of carbon pricing and the solid vertical line indicates the timing of the implementation of carbon pricing for treated plants. Solid navy dots show the difference in outcomes for treated and control plants relative to the difference in the year before carbon pricing is announced (year 0). The capped maroon lines indicate 95% confidence intervals. The outcome variable is the provincial annual carbon price. Estimates use equation (2) inverse-weighted by the number of observations in each province-year.

Figure 2: The Effects of Announcing and Implementing Carbon Pricing on Emissions and Energy Use



Notes: These graphs show the effects of announcing and implementing carbon pricing on environmental outcomes for treated manufacturing plants relative to control manufacturing plants. The dashed vertical line indicates the timing of the announcement of carbon pricing and the solid vertical line indicates the timing of the implementation of carbon pricing for treated plants. Solid navy dots show the difference in outcomes for treated and control plants relative to the difference in the year before carbon pricing is announced (year 0). The capped maroon lines indicate 95% confidence intervals. Estimates use equation (2).

Figure 3: The Effects of Announcing and Implementing Carbon Pricing on Economic Outcomes



Notes: These graphs show the effects of announcing and implementing carbon pricing on the log of economic outcomes for treated manufacturing plants relative to control manufacturing plants. Inventories and investment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. The dashed vertical line indicates the timing of the announcement of carbon pricing and the solid vertical line indicates the timing of the implementation of carbon pricing for treated plants. Solid navy dots show the difference in outcomes for treated and control plants relative to the difference in the year before carbon pricing is announced (year 0). The capped maroon lines indicate 95% confidence intervals. Estimates use equation (2).

Table 1: The Effects of Carbon Pricing Announcement and Implementation on Environmental Outcomes

	CO_2 Emissions (1)	Total Energy (2)	Fossil Fuels (3)	Electricity (4)
Panel A: Differences-in-Differences				
Announcement × Treated	217.21**	3.74*	3.75**	-0.01
	(96.34)	(1.96)	(1.85)	(0.65)
Implementation × Treated	-249.53**	-5.55**	-3.67*	-1.88
	(109.49)	(2.36)	(1.92)	(1.27)
Panel B: Coal Intensity Heterogeneity				
Announcement × Treated	170.98*	2.95	3.05*	-0.10
	(96.65)	(1.96)	(1.86)	(0.65)
Announcement × Treated × Coal Intensity	2376.51*	39.92**	35.67**	4.25
	(1409.71)	(16.28)	(15.91)	(4.70)
Implementation × Treated	-207.74*	-4.99**	-3.15*	-1.84
	(106.88)	(2.37)	(1.90)	(1.32)
Implementation × Treated × Coal Intensity	-2111.71**	-30.94*	-28.16**	-2.79
	(979.27)	(16.71)	(14.30)	(4.95)
Pre-Treatment Dep. Var. Mean	2,147.88	58.85	36.82	22.04
Pre-Treatment Coal Intensity Mean	0.11	0.11	0.11	0.11
Firm × Cohort FE	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes
Observations	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on environmental outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are CO_2 emissions in tonnes (Column 1), total energy inputs in 1000 GJs (Column 2), fossil fuel energy inputs in 1000 GJs (Column 3), and electricity inputs in 1000 GJs (Column 4). Coal intensity is in GJ per $1000 revenue. Estimates use equation (1) in Panel A and equation (3) in Panel B. The pre-treatment dependent variable mean and the coal intensity mean are the pre-treatment means for treated plants in the four years prior to the announcement of carbon pricing. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table 2: The Effects of Carbon Pricing Announcement and Implementation on Economic Outcomes

	log(Revenue) (1)	log(Inventory Value) (2)	log(Machinery and Equipment Value) (3)	log(Energy Expenditures) (4)
Panel A: Differences-in-Differences				
Announcement × Treated	0.002	0.070**	0.029**	0.078***
	(0.012)	(0.029)	(0.012)	(0.023)
Implementation × Treated	0.020	0.018	0.023*	-0.110***
	(0.016)	(0.032)	(0.014)	(0.025)
Panel B: Coal Intensity Heterogeneity				
Announcement × Treated	0.001	0.067**	0.029**	0.077***
	(0.012)	(0.029)	(0.012)	(0.023)
Announcement × Treated × Coal Intensity	0.042**	0.129***	0.017	0.058**
	(0.018)	(0.041)	(0.012)	(0.024)
Implementation × Treated	0.021	0.018	0.025*	-0.108***
	(0.016)	(0.032)	(0.014)	(0.025)
Implementation × Treated × Coal Intensity	-0.043**	-0.052	-0.052***	-0.070***
	(0.019)	(0.035)	(0.013)	(0.026)
Pre-Treatment Dep. Var. Mean (1000s)	42,838.85	4,508.24	9,082.90	867.77
Pre-Treatment Coal Intensity Mean	0.11	0.11	0.11	0.11
Firm × Cohort FE	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes
Observations	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on the log of economic outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are total revenue (Column 1), closing inventory book value (Column 2), machinery and equipment book value (Column 3), and total energy expenditures (Column 4). Inventories and machinery and equipment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. Coal intensity is in GJ per $1000 revenue. Estimates use equation (1) in Panel A and equation (3) in Panel B. The pre-treatment dependent variable mean and the coal intensity mean are the pre-treatment means for treated plants in the four years prior to the announcement of carbon pricing. All monetary values are in 1000s of 2024 Canadian dollars. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Appendix

A Provincial Carbon Pricing Programs

This section provides additional details on the Alberta carbon tax, the Quebec cap-and-trade program, and the Ontario cap-and-trade program.

The province of Alberta announced a broad-based carbon tax on November 22, 2015. The corresponding legislation was passed on May 24, 2016 and the carbon tax came into effect on January 1, 2017. The carbon tax was payable upon the purchase or importation of greenhouse gas-producing fuel; if the fuel was produced in Alberta, the producer, rather than the consumer, was responsible for paying the tax (Government of Alberta 2016; Government of Alberta 2017b). Exemptions were few and based on fuel use, rather than specific industries. The main exemptions were aviation fuel on flights outside the province, biofuels (e.g., ethanol), fuels used in the production of oil and gas, and fuels already covered by the Specified Gas Emitters Regulation (discussed below) (Government of Alberta 2017a). This tax was repealed in June 2019 and replaced with the federal backstop carbon tax on January 1, 2020 (Government of Alberta 2019). Appendix Figure A.3 shows the time path of carbon prices in Alberta.

This carbon tax is the second climate policy passed in Alberta. In 2007, the province implemented the Specified Gas Emitters Regulation, a standard that applied to facilities emitting more than 100,000 tonnes of CO_2 per year. These facilities were required to comply with limits on their production emissions intensity or pay a fee of \$15 CAD/tonne in excess of the limit. The high emissions threshold for inclusion–four times the threshold for inclusion in the Quebec and Ontario cap-and-trade programs, below–meant that this standard applied mostly to oil sands extraction and electricity generation. Oil and gas extraction alone account for almost 50% of Alberta's emissions and the Alberta electricity sector accounts for 65% of coal power generation in the country (Climate Change Advisory Panel 2015); Appendix Figure A.1 shows that most electricity in Alberta is generated using fossil fuels. Critiques note that the generous emissions intensity limit combined with low fees for non-compliance limited the effectiveness of the standard, prompting the implementation of the broad-based 2017 carbon tax (Pachon and Weber 2016). Since our analysis focuses on the manufacturing sector, we limit our analysis to the 2017 policy.

Quebec publicly announced legislation enacting a cap-and-trade program for greenhouse gases on December 16, 2011. This legislation had passed two days earlier. The year 2012 was an administrative transition year during which covered plants were required to register for accounts to track their emissions and permits; Quebec already had mandatory greenhouse gas reporting requirements in place since 2007. Beginning January 1, 2013, covered entities had to remit permits equal to their greenhouse gas emissions produced since that date; permits were remitted at the end of pre-determined compliance periods lasting a few years. The first compliance period required industrial plants with annual emissions exceeding 25,000 tonnes to participate in the program; other plants with emissions exceeding 10,000 tonnes could voluntarily opt in if they wanted to participate in the sale of permits. Initial participation in the program was based on emissions reported during the years 2009-2011 through Quebec's greenhouse gas reporting system, i.e., before Quebec enacted the cap-and-trade program at the end of 2011 (Government of Québec 2013). Between 2013 and 2015, the cap-and-trade program applied only to industrial and electricity generation facilities, though unlike in Alberta most electricity generation in Quebec is clean (Appendix Figure A.1); in 2015, the program was extended to include the transportation sector, covering 85% of Quebec greenhouse gas emissions at that time. Failure to comply results in financial and possibly legal penalties (Government of Québec 2012).

To assuage competitiveness concerns, the government provided free permits to some industrial emitters, including trade-exposed manufacturing sectors such as aluminum, cement, chemicals, and a few others. For these industries, governments used an output-based allocation calculated using plant-specific (or, in some cases, sector-specific) historical emissions intensity of production and current output, adjusted depending on the perceived competitiveness effects on a particular plant. Emissions intensity is based on 2007-2011 emissions intensity and output is based on actual production in the years 2013 onward, after the program was implemented.[8] Between 2013 and 2020, free permits comprised about 36% of total permits. Subsequent permits must be purchased through auctions; Appendix Figure A.3 shows the annual average auction price per tonne CO_2-equivalent. Free permit allocation blunts the average price signal while leaving the marginal price signal intact (Government of Québec 2013; ICAP 2026b).

In January 2014, the Quebec market linked with the California cap-and-trade market. Subsequent to this date, covered plants in both California and Quebec participated in joint auctions for permits totaling a joint cap across the two jurisdictions. The permit price was largely driven by the larger Californian economy, with Appendix Figure A.3 showing an increasing price trend (CARB 2026).

Ontario's cap-and-trade program was officially announced on April 13, 2015, with legislation finalized on February 24, 2016 and compliance required beginning January 1, 2017. The Ontario cap-and-trade program linked with the Quebec-California system on January 1, 2018. The Ontario program was very similar to Quebec's cap-and-trade program discussed above: it also required compliance from plants with emissions exceeding 25,000 tonnes of greenhouse gas, plants with emissions exceeding 10,000 tonnes could voluntarily participate, few electricity-generation emissions were covered due to the cleanliness of Ontario's electricity grid, and output-based allocation of free permits (using either current output or historical emissions) was provided to some industries. Unlike Quebec, the transportation sector was included in the Ontario cap-and-trade program immediately (Government of Ontario 2016; ICAP 2026a).

A key difference between the Quebec and Ontario cap-and-trade programs is that the Ontario program was relatively short-lived. A change in provincial leadership prompted the cancellation of the program in July 2018. Ontario had a brief window with no carbon pricing in effect, though many plants had already purchased permits for the 2018 compliance year. The federal backstop policy took effect in Ontario on January 1, 2019 (Financial Accountability Office of Ontario 2018).

B Data Details

B.1 Cleaning Statistics Canada Data

This section provides additional details on the steps to clean the data sets described in Section 3.

The ASML information has two vintages: 2004-2012 and 2013-2022. At the end of 2012, the ASML changed from a plant-level census to a nationally representative survey. Before 2012, the census comprised information from financial statements for all plants, with some variables, including energy expenditures, collected via survey for a nationally representative subset of approximately 20,000 plants per year. After 2012, the ASML began reporting only the survey variables for the nationally representative subsample. The survey vintage is re-weighted (i.e., pre-multiplied by the sampling weights) to report nationally representative aggregates in the raw data; we recover plant-level information by dividing the raw data by the sampling weight, which we use as weights in some regressions instead. Observations in the census vintage have weight 1. The main variables of interest (total revenue, closing inventories, total expenses, energy expenditures by input type, province, and industry) have continuity across the two time periods. Practically, as we discuss below, we restrict analysis to plants with non-missing energy expenditure information, and so our analysis sample has a continuous survey format across the two time periods. Our

[8]Higher output during the 2012 announcement window does not translate into higher free permit allocations when the program is implemented, though higher output in subsequent years would. Whether this was well understood by plants could be tested directly by identifying industries with output-based allocations using 4-digit NAICS codes if available.

sensitivity analyses show that re-weighting using the ASML survey weights has very little effect on the magnitudes of the main estimates (Appendix Tables A.4 and A.5).

We append both vintages and clean the data using the following steps. First, we restrict observations in the ASML to the manufacturing sector. Second, we drop plants without an identifier since these cannot be followed over time or matched to the NALMF. Third, we drop plants that are not surveyed in the pre-treatment period of any cohort. Fourth, we drop observations with missing revenue. Fifth, we replace closing inventory values that are missing or negative with the next period's beginning inventory value. Sixth, we calculate total energy expenditures by summing expenditures on electricity, gasoline, light fuel oil, heavy fuel oil, diesel, liquefied petroleum gas, natural gas, and coal; total energy expenditures on fossil fuels omit electricity from this sum. In this calculation, we treat any expenditures that are negative as missing; if a plant is missing expenditures on all fuels, it is dropped. Seventh, we merge external prices at the province-year level for each fuel and recover quantities of each fuel by dividing fuel expenditures by the respective price; total energy quantities and total fossil fuel quantities replace expenditures by quantities in the summation above. Eighth, we calculate CO_2 emissions by multiplying the quantities of individual fuels by the fuel-specific conversion factors; for electricity, we merge in the amount of fuels used to generate electricity to calculate emissions embedded in electricity purchases. Total emissions therefore includes both direct CO_2 emissions from fossil fuel consumption and embedded upstream emissions from electricity consumption. Finally, we deflate all monetary values to 2024 Canadian dollars using the GDP deflator for Canada (FRED 2026).

Calculating energy and emissions quantities creates several obvious outliers. We drop observations that have energy intensity (total energy quantity per dollar of revenue) or energy efficiency (revenue per energy quantity) greater than 100 times the 99th percentile of their 3-digit NAICS industry.

We calculate coal production intensity as coal inputs in GJ per $1000 of revenue. About 5% of plants are missing coal input data but have information on other energy inputs. We assume these plants are part of the 75% of our sample that does not use coal and set these coal intensity values equal to 0. We winsorize coal intensity at the 99th percentile of the distribution of positive values.

We impose several additional restrictions on the analysis sample that are motivated by the policy structure. As outlined in Section 3, our main analysis excludes observations in Ontario in 2015 because its cap-and-trade program was announced partway through that year, creating a set of plants with a partial treatment status. Plants in Alberta and Quebec have a clear announcement window that lines up with the annual survey because their carbon pricing policies are announced at the end of the calendar year 12-13 months before the January 1 implementation date of their respective policies. Excluding partially treated Ontario plants has the additional advantage of creating a consistent one-year announcement window across the three treatment provinces, facilitating the stacking of the three treatment cohorts. In the main analysis, the control group excludes plants in Nova Scotia and New Brunswick, which announced carbon pricing policies that they did not implement before 2019, and includes British Columbia, which did not announce or implement carbon pricing during our sample period (see Figure 1) but did so before the start of our sample. We assess the sensitivity of our results to excluding British Columbia, including Nova Scotia and New Brunswick, and including Ontario 2015 observations, among other analyses.

B.2 Constructing Plant-level Investment

Plant-level information on investment in machinery and equipment (or other assets) is not collected by Statistics Canada, and is therefore not available at the plant-level in the ASML. The book value of machinery and equipment assets is collected at the firm-level and reported in the NALMF. To recover plant-level assets, we link the ASML to the NALMF using firm identifiers when available (84% of our analysis sample). Of plants that can be matched, about two-thirds are single-establishment firms, and so firm-level and plant-level assets are equivalent. For the remaining multi-establishment matched firms, we apportion assets based on the share of plant revenue in the total revenue of the firm. For the remaining plants with missing machinery and equipment values, we impute assets using a regression of machinery and equipment value on total revenue and province $\times$ year $\times$ industry fixed effects. The results are robust to estimation on samples that include and exclude the matched plants (Appendix Tables A.4 and A.5).

B.3 Descriptive Statistics

Appendix Table A.1 reports descriptive statistics on our analysis sample in the pre-treatment period. This table shows that our treated plants are almost twice as large on average as our control plants; excluding British Columbia from our control group makes the difference in plant size larger. Differences in the other economic variables (closing inventory book value, closing machinery and equipment book value, and energy expenditures) are roughly proportional to the differences in revenue. Of course, for our differences-in-differences analysis, what matters for identification is that the two groups would have followed similar trends in the absence of treatment, not that the levels of their outcomes are the same.

This table also underscores that electricity use is relatively clean in Canada. In both the treatment and control groups, electricity accounts for about one-third of energy use but only about 10% of CO_2 emissions. These CO_2 emissions are produced upstream during the generation of electricity; emissions from consumption of fossil fuels are produced on site. We note that the relatively low average CO_2 emissions level has a large standard deviation.

C Sensitivity Analyses

C.1 Stacked Differences-in-Differences

This section discusses sensitivity analyses of the main environmental and economic estimates in Tables 1 and 2, respectively. We discuss estimates using different data subsamples and weights; Appendix C.2 reports estimation results using Sun and Abraham (2021).

Appendix Table A.4 reports sensitivity analyses for the environmental outcomes: CO_2 emissions in Panel A, total energy inputs in Panel B, fossil fuel energy inputs in Panel C, and electricity inputs in Panel D. Column 1 reproduces the estimates from Table 1 in the main text for comparison.

Columns 2-7 report results using different samples. Column 2 adds the Ontario 2015 partially treated observations to the analysis sample, assigning them to the pre-treatment period. Column 3 drops all 2015 observations in the Ontario cohort. Column 4 excludes plants in British Columbia from the control group; these plants have continuous carbon pricing coverage during our sample period. Column 5 adds plants in New Brunswick and Nova Scotia to the control group; these provinces announced carbon pricing policies but did not implement them until required to do so by the federal backstop in 2019. Column 6 ends our analysis sample in 2018, rather than 2019; control plants start to be treated by the federal policy beginning in 2019. Column 7 restricts the sample to plants that can be matched to firms in the NALMF and for which we do not have to impute machinery and equipment.

We obtain estimates of the announcement and implementation effects across all four environmental outcomes that are generally very similar in sign, magnitude, and precision across all of these different samples. The estimates are more precise with larger samples (e.g., including plants in New Brunswick and Nova Scotia in the control group in Column 5) and less precise for smaller samples (e.g., including only plants that can be matched to the NALMF in Column 7). The smallest sample is the sample that excludes plants in British Columbia from the control group; this restriction reduces the size of our analysis sample by approximately one-third and limits the size of the control group. We continue to find estimates of the same size and magnitude but these are less precisely estimated on the smaller sample.

Columns 8-10 of Appendix Table A.4 report sensitivity analyses using different weights. The main results in Column 1 use the weights in the stacked differences-in-differences estimator in the main text (Wing et al. 2024). Column 8 presents unweighted results. Column 9 replaces the stack weights in the main text with the ASML sampling weights only. Column 10 weights by both ASML sampling weights and the stack weights. All of these alternative weights create a similar or larger increase in emissions, total energy use, and fossil fuel energy use during the announcement period and a similar or larger post-implementation decline. The post-implementation decline in electricity use also becomes marginally statistically significant at 10%. We highlight that using the stack weights only in the main estimation or the ASML survey weights and the stack weights as in Column 10 yield virtually identical estimates.

Column 11 reports results using the log of one plus the value of our outcomes, instead of the levels in the main text. We interpret these results cautiously due to the presence of zeroes in the environmental outcomes data. These results suggest increases of 2.4%-4.7% in CO_2 emissions, total energy inputs, and fossil fuel energy inputs, or roughly half the magnitudes of the main estimates, though the confidence intervals include the implied percentages. All of these effects are highly statistically significant. There is also a significant increase in electricity in the announcement window. We continue to find declines in emissions and total energy use in the post-implementation period; fossil fuels and electricity separately are both less precisely estimated.

Appendix Table A.5 reports sensitivity analyses for the economic outcomes: revenues in Panel A, closing value of inventories in Panel B, closing value of machinery and equipment in Panel C, and total expenditures on energy inputs in Panel D. The table follows the same format as Appendix Table A.4 discussed above: Column 1 reproduces the estimates from Table 2 in the main text for comparison, columns 2-7 report estimates on the same sets of samples, columns 8-10 use the same sets of weights, and column 11 reports results with the outcomes in levels instead of logs.

The results using different samples continue to tell the same story as the results in the main text (columns 2-7). For most estimates, the magnitudes are tightly centered around the main effects in column 1. An exception is the model in column 4, which again finds announcement effects that are smaller and less precisely estimated, plausibly due to the much smaller and less comparable control group that results from excluding BC. This model and the model that includes New Brunswick and Nova Scotia in the control group find small positive revenue effects on the treatment group in the post-implementation period.

The results using different sampling weights are also very similar to the main estimates (columns 8-10). We continue to find precisely estimated null effects on revenue. The effect of announcement on inventories, at 5.6%-6.9%, is very close to our main estimate of 7.0%, with a limited effect of implementation. Machinery and equipment results are also similar, with more investment in the implementation phase when using ASML survey weights only (column 9), with a positive but insignificant announcement effect. The energy expenditure results are highly statistically significant, similar in sign and magnitude in the announcement phase, and somewhat smaller in the implementation phase.

Column 11 reports results with outcomes in levels instead of logs. The results are generally qualitatively similar, but differ somewhat in precision. There is now a small statistically significant difference in revenue between treatment and control plants in the post-implementation period, equal to 3.4% of the pre-treatment mean of treated plants. The inventory and machinery and equipment results are positive in both the announcement and implementation phases, but are larger and more highly statistically significant in the implementation period than the announcement period. The energy expenditure results become marginally negative in both time periods and are less precisely estimated.

C.2 Estimation using Sun and Abraham (2021)

We re-estimate our results from the main text, obtained with the stacked differences-in-differences estimator (Wing et al. 2024), using the differences-in-differences estimator of Sun and Abraham (2021). We focus on the stacked differences-in-differences estimator in the main text for two main reasons. First, it has the advantage that it can separately estimate the effects of two sequential treatments (i.e., announcement followed by implementation). Second, it allows us to estimate trend-break specifications, which may more accurately capture plant adjustment dynamics than pooling all post years. However, we find estimates of the event study graphs and the combined announcement and implementation effects that are virtually identical in sign, magnitude, and precision to our main results when we use this alternative estimator.

Appendix Figures A.4 and A.5 show the event study graphs estimated using equation (2) using Sun and Abraham (2021) for the environmental outcomes and the economic outcomes, respectively. The Sun and Abraham (2021) estimator does not stack cohort samples, so this estimation omits interactions with cohort fixed effects. Both sets of graphs show very similar patterns to the event study graphs of the same outcomes in the main text (Figures 2 and 3, respectively). Emissions, total energy use, and fossil fuel energy use continue to spike in the announcement year and then decline. Emissions continue to fall below the pre-announcement level by the third post-implementation year, though the confidence interval includes 0. There is now a marginally statistically significant decline in use of electricity inputs during the announcement window, and this is more significant in the post-period.

The economic outcomes in Figure A.5 also continue to track the corresponding graphs estimated using the stacked differences-in-differences regressions (Figure 3). We continue to find no significant effects on revenue. Inventories increase by roughly 7% upon announcement and show limited decline upon implementation. Investment in machinery and equipment continues to increase in the announcement window and remains 3-4% higher than in the pre-implementation window throughout the post-implementation period. Energy expenditures continue to increase by approximately 8% in the announcement year and decline afterward, with the decline less stark than in the stacked differences-in-differences regressions.

Appendix Table A.3 shows the corresponding estimates of equation (1) using Sun and Abraham (2021). The Sun and Abraham (2021) estimator takes in one dummy variable for each year (or a bin of years) relative to the treatment year; this makes it ideal to replicate the event study graphs in the main text, but unlike in equation (1), we cannot directly estimate the implementation phase relative to the announcement phase. Instead, we estimate the effect of the implementation and announcement phase relative to the pre-announcement period using a variant of equation (1):

$$y_{it} = \lambda_1 \, \text{Treat}_i \times \text{Announce}_{pt} + \lambda_2 \, \text{Treat}_i \times \text{Implement}_{pt} + \rho_p + \gamma_{jt} + \delta_f + \varepsilon_{it} \tag{4}$$

In this equation, Announce_{pt} is an indicator variable that takes the value 1 in the announcement year only in treated provinces and Implement_{pt} is an indicator variable equal to 1 in all years after the implementation of carbon pricing in treated provinces. All other variables are the same as in equation (1), but omit the interactions with cohorts. In particular, Treat_i continues to be an indicator variable equal to 1 for treated plants in provinces that announce and implement carbon pricing (i.e., Alberta, Ontario, Quebec); ρ_p, γ_{jt}, and δ_f are province, industry-by-year, and firm fixed effects, respectively. The parameter λ_1 measures the announcement effect relative to the pre-announcement period like β_1 in the main text, the parameter λ_2 measures the implementation effect relative to the pre-announcement period (equal to $\beta_1 + \beta_2$ in the main text), and $\lambda_1 + \lambda_2$ measures the implementation effect relative to the announcement period (equal to β_2 in the main text). We calculate the implementation effect relative to the announcement effects as $\lambda_1 + \lambda_2$ and report these in Appendix Table A.3 to compare with the main results. Standard errors are clustered by firm.

Consistent with the event study graphs, the results in Appendix Table A.3 tell the same story as the estimates in the main text. Panel A shows the environmental outcome results. The emissions effects are within 5% of the main estimates, the total energy and fossil fuel energy estimates show a larger increase upon announcement, and the electricity estimates show a larger, and more statistically significant, decline upon announcement. The post-implementation results for the environmental outcomes have the same sign, are mostly slightly smaller, and mostly slightly less precisely estimated than the results in the main text. Panel B shows the economic outcome results. The announcement effects are all very similar in sign, magnitude, and precision to the main estimates, and statistically indistinguishable from them. The implementation effects are as well, except for investment, which is more highly concentrated in the announcement window. We find no statistically significant revenue effect using either estimation strategy.

A few other elements of this table are worth highlighting. First, there are fewer observations in these models because there are no repeat observations; the stacked approach in the main text repeats control observations for each (weighted) cohort. Second, this estimator does not accommodate a trend-break specification, and so unlike the other tables, we do not present trend-break results here.

C.3 Trend-Break Analysis

The event study graphs in Figure 2 show that the responses to carbon pricing are dynamic: there is a discrete increase in energy use and emissions followed by a gradual year-over-year decline. This pattern suggests that a trend-break specification may be more informative than regressions which pool all post-period years. We therefore estimate versions of equation (1) that allow for a trend-break rather than a level shift across time periods. The regression equation is:

$$y_{itc} = \alpha_0 \,\text{Treat}_i \times \text{YrsRelAnn}_{tc} + \alpha_1 \,\text{Treat}_i \times \text{Post}_{tc} + \alpha_2 \,\text{Treat}_i \times \text{YrsSinceAnn}_{tc} + \rho_{pc} + \gamma_{jtc} + \delta_{fc} + \mu_{itc} \quad (5)$$

Here, YrsRelAnn_{tc} is a continuous variable that measures how many years (positive or negative) a year is relative to the announcement year, Post_{tc} is an indicator variable equal to 1 beginning in the announcement year, and YrsSinceAnn_{tc} is a continuous variable measuring the number of years since the announcement of carbon pricing ($= \text{Post}_{tc} \times \text{YrsRelAnn}_{tc}$). All other variables are the same as in equation (1). If environmental or economic outcomes jump discretely in the announcement year, so that the post-announcement trend has a different intercept than the pre-announcement trend, α_1 will be different from zero; $\alpha_1 > 0$ is an increase after the announcement of the policy. If the subsequent implementation of carbon pricing causes treated plant outcomes to trend in a different direction relative to the pre-announcement period and relative to control plants, then α_2 will be different from zero. The slope parameter α_0 measures whether the treated and control plants follow parallel trends in the years before announcement, and testing $\alpha_0 \neq 0$ provides an indirect test of the identifying assumption.

Appendix Tables A.6 and A.7 present results. We evaluate the same set of subsamples and estimation strategies as in Appendix C.1. In both tables, column 1 reports the results corresponding to our main results, i.e., estimating equation (1) in the main text using the trend-break version of the regression in equation (5) instead, and columns 2-7 and columns 8-10 report results using the different samples and weights from Appendix C.1, respectively. Column 11 of Appendix Table A.6 reports log results for the environmental outcomes and column 11 of Appendix Table A.7 reports levels outcomes for the economic outcomes.

Appendix Table A.6 presents results for environmental outcomes: CO_2 emissions in Panel A, total energy inputs in Panel B, fossil fuel energy inputs in Panel C, and electricity inputs in Panel D. For the emissions, total energy, and fossil fuel outcomes, we find statistically significant jumps during the announcement window across all models estimated in levels, including the results on the smallest sample that excludes British Columbia from the control group. Force-fitting a linear trend to the post-implementation data increases the magnitude of the jump in the announcement window relative to the level-shift estimates in the main text. This trend is negative in almost all models and statistically significant at conventional levels in most, again the exceptions generally being the results estimated on smaller samples. The log results in column 11 follow the same qualitative pattern with more mixed levels of precision across the announcement and implementation windows.

In Panel D, the electricity estimates of both the announcement and implementation effects are small and statistically indistinguishable in almost all models. An exception is the log-one-plus results, which show a modest increase in electricity use during the announcement window and statistically significant decline after.

Appendix Table A.7 shows the corresponding results on the same models for the economic outcomes. The event study graphs in Figure 3 suggest that a trend-break analysis is less appropriate for revenue, which has no trend before or after carbon pricing is announced, and inventories and machinery and equipment assets, which change discretely in the announcement window with no trend afterward. Energy expenditures look more similar to the environmental outcomes.

Consistent with the event study graphs, we find that few of the trend-break estimates are significant for the revenue, inventories, and machinery and equipment outcomes across all of the different models (Panels A, B, and C respectively). The energy expenditure outcomes in Panel D increase during the announcement window and then decline year-over-year in the post-implementation period, consistent with the pattern of the environmental outcomes; the levels outcomes in column 11 are imprecisely estimated.

These tables also provide some support for the identifying assumption for the differences-in-differences results in the main text: the estimate on the pre-announcement trend measures whether the treatment and control groups were on similar trends in the years before announcement. In Appendix Table A.6, there are no significant pre-trends for CO_2 emissions, total energy inputs, and fossil fuel inputs, and the magnitudes of the parameter estimates are close to zero. The electricity results in levels show a small trend only in four of 11 models, equal to 2.5% or less of the pre-treatment mean and significant only at 10%. The 0.9% trend in logs is significant but is not likely to be economically meaningful. There is also limited evidence of pre-trends for the economic outcomes in Appendix Table A.7. This evidence is limited to a small revenue trend in six out of 11 models, equal to 1% of revenue or less and in most cases significant at 10% only, and a pre-trend of 1% for one of the 11 machinery and equipment models that is significant at 10% only.

D Elasticity Calculations

We calculate the price elasticity of demand for energy implied by our treatment effects in Table 1 using the following equation:

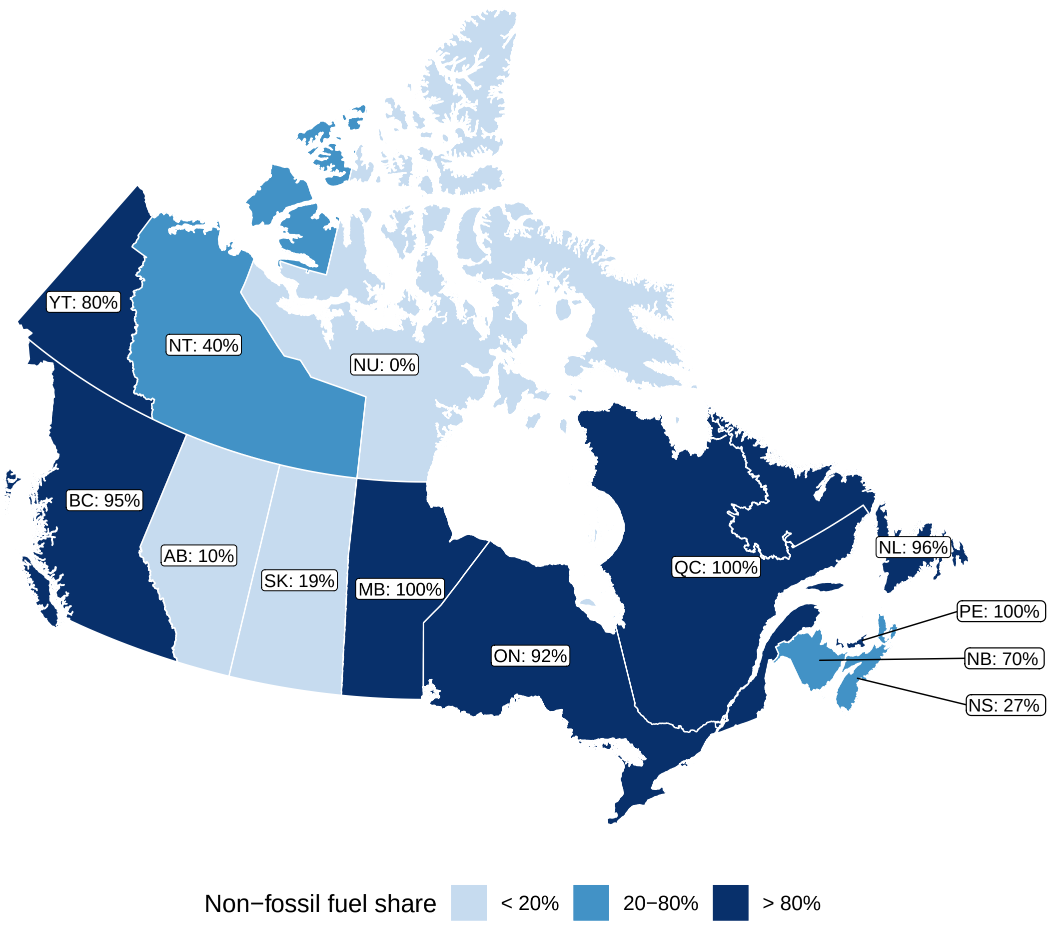
$$\epsilon = \frac{\Delta q}{\Delta \text{carbon tax}} \times \frac{p}{q}$$

In this equation, q is pre-treatment total energy use in GJ from Table 1; p is baseline price per GJ, calculated as pre-treatment total energy expenditures divided by pre-treatment total energy use from Table 1; Δq is the change in total energy use post-implementation relative to the pre-announcement period, calculated as the sum of the announcement effect relative to the pre-announcement period and the post-implementation effect relative to announcement period (i.e., $\beta_1 + \beta_2$) from Table 1; and Δcarbon tax is the increase in the per-GJ price of energy from the carbon tax, which we calculate as the average price per tonne CO_2 (from Appendix Table A.2, Column 2) times the pre-period tonnes per GJ conversion (i.e., pre-treatment CO_2 emissions divided by pre-treatment energy use), with the interpretation that the carbon tax is a marginal change in the price of energy even though it is a discrete policy change (Hawkins-Pierot and Wagner 2024). Substituting in the corresponding values from the tables yields the elasticity estimate of -0.49.

We calculate the change in total energy use as the linear combination of the coefficients $\beta_1 + \beta_2$ from Table 1 and compute its standard error using the estimated variance-covariance matrix (via lincom). The sum is relatively imprecisely estimated, with a point estimate of -1.8 thousand GJ and a standard error of 3.04. The elasticity point estimate is informative, but the 95% confidence interval includes 0.

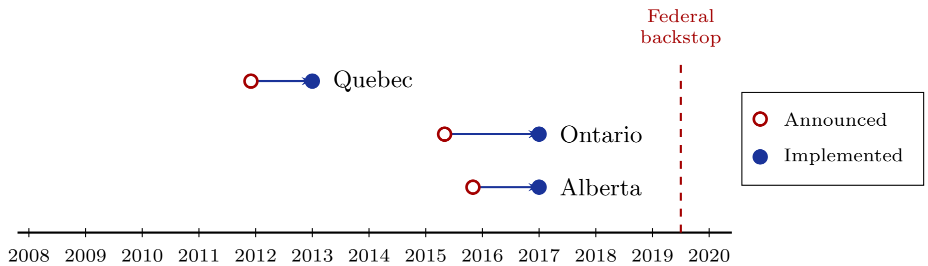
E Figures and Tables

Figure A.1: Share of Electricity Generated using Non-Fossil Fuel Sources, by Province and Territory



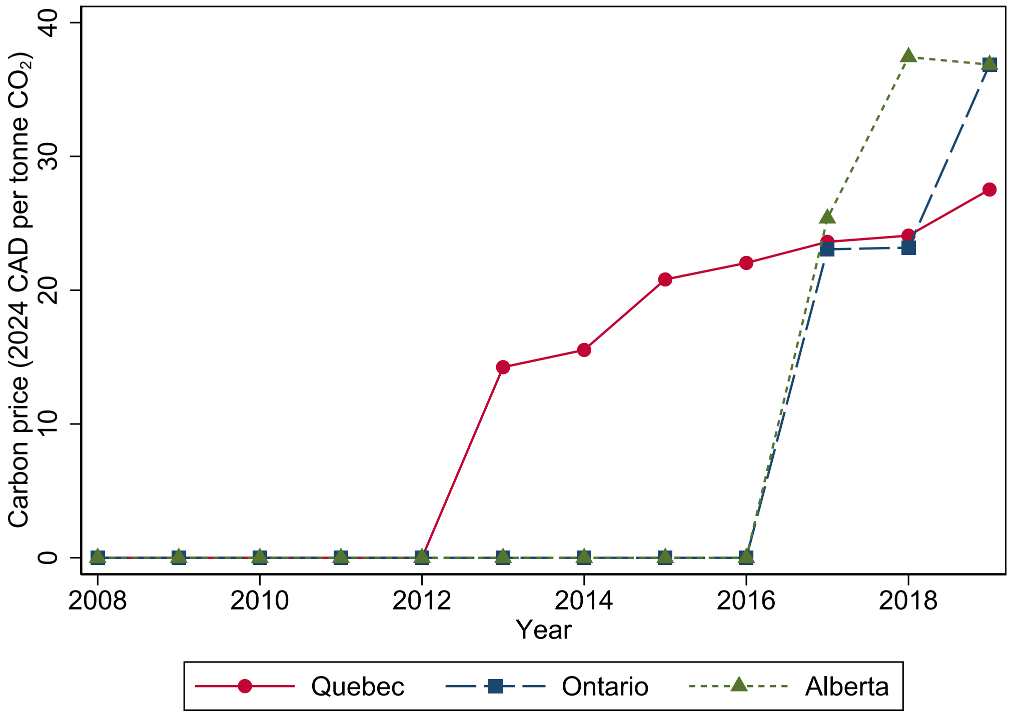
Notes: This map shows the share of electricity generated using non-fossil fuel (i.e., clean) energy sources in Canadian provinces and territories in 2019. Non-fossil fuel sources include hydro, nuclear, geothermal, solar, and wind generation. The remaining share of electricity generation uses a mix of coal, natural gas, and oil. Data are from the Canada Energy Regulator (CER 2026a).

Figure A.2: Timeline of Announcement and Implementation of Carbon Pricing Policies in Treated Provinces



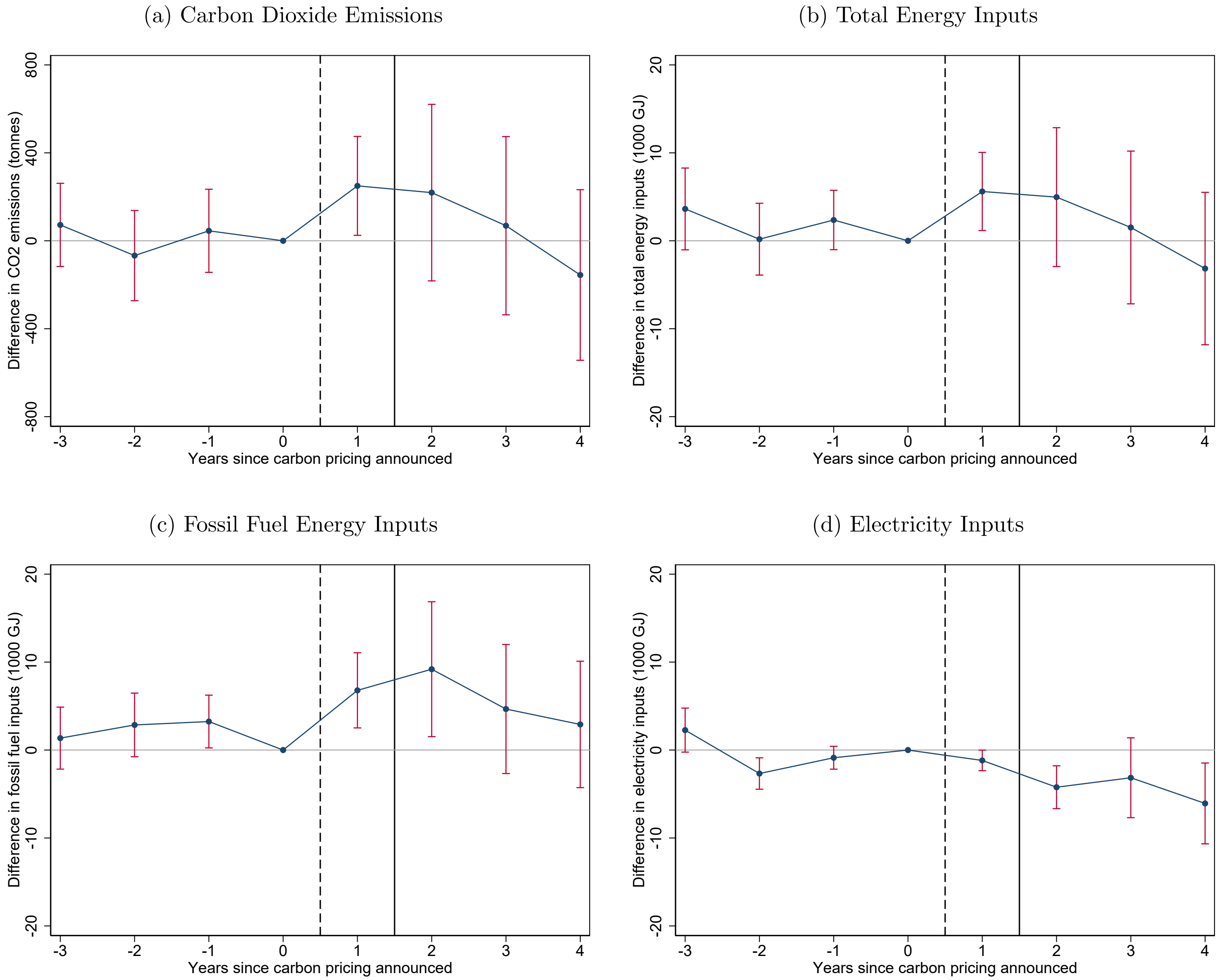
Notes: This figure shows when carbon pricing was announced and implemented in treatment provinces. We define announcement as the date the government officially announced the decision to implement each policy. We define implementation as the date the price increases came into effect.

Figure A.3: The Province-Level Price of Carbon Dioxide



Notes: This figure shows the province-level price of CO_2 emissions over time in the three treatment provinces (Alberta, Ontario, and Quebec). Data are from the International Carbon Action Partnership (ICAP 2026c).

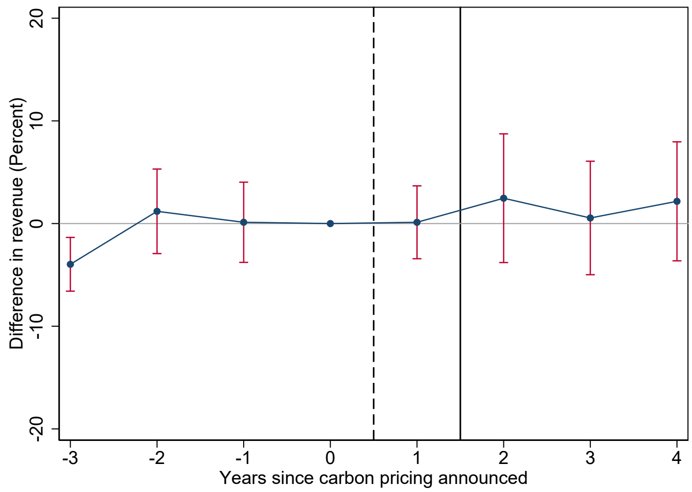
Figure A.4: The Effects of Announcing and Implementing Carbon Pricing on Emissions and Energy Use, Sun and Abraham Sensitivity



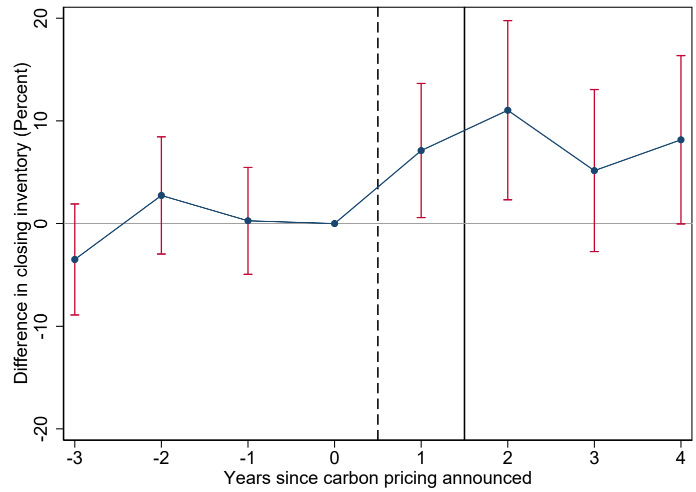
Notes: These graphs show the effects of announcing and implementing carbon pricing on environmental outcomes for treated manufacturing plants relative to control manufacturing plants. The dashed vertical line indicates the timing of the announcement of carbon pricing and the solid vertical line indicates the timing of the implementation of carbon pricing for treated plants. Solid navy dots show the difference in outcomes for treated and control plants relative to the difference in the year before carbon pricing is announced (year 0). The capped maroon lines indicate 95% confidence intervals. Estimates use equation (2) and Sun and Abraham (2021).

Figure A.5: The Effects of Announcing and Implementing Carbon Pricing on Economic Outcomes, Sun and Abraham Sensitivity

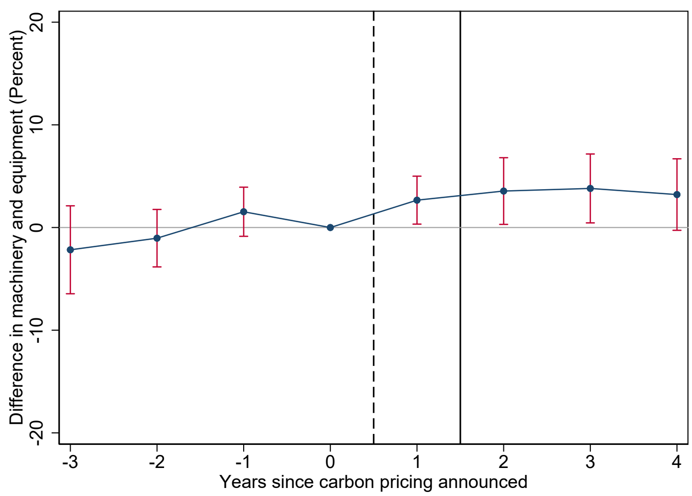
(a) Revenue



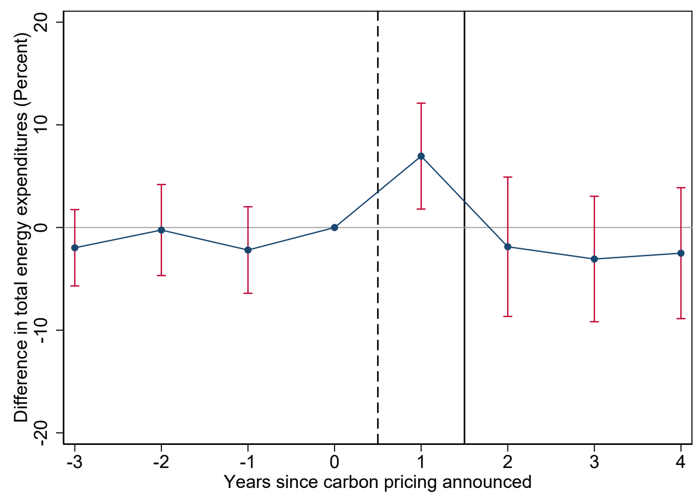
(b) Closing Inventory Book Value



(c) Machinery and Equipment Book Value



(d) Energy Expenditures



Notes: These graphs show the effects of announcing and implementing carbon pricing on the log of economic outcomes for treated manufacturing plants relative to control manufacturing plants. Inventories and investment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. The dashed vertical line indicates the timing of the announcement of carbon pricing and the solid vertical line indicates the timing of the implementation of carbon pricing for treated plants. Solid navy dots show the difference in outcomes for treated and control plants relative to the difference in the year before carbon pricing is announced (year 0). The capped maroon lines indicate 95% confidence intervals. Estimates use equation (2) and Sun and Abraham (2021).

Table A.1: Descriptive Statistics, Pre-Treatment Period

	Treated Plants (1)	Control Plants (2)
Panel A: Environmental Variables		
Total CO_2 Emissions (Tonnes)	2,147.88 (23,303.62)	1,555.02 (15,993.94)
Direct CO_2 Emissions, Fossil Fuel Inputs (Tonnes)	1,947.74 (22,314.95)	1,418.39 (14,713.23)
Embedded CO_2 Emissions, Electricity Inputs (Tonnes)	200.15 (2,226.64)	136.63 (2,606.40)
Total Energy Inputs (1000 GJs)	58.85 (525.84)	39.76 (333.89)
Fossil Fuel Energy Inputs (1000 GJs)	36.82 (412.60)	26.50 (275.80)
Electricity Inputs (1000 GJs)	22.04 (258.72)	13.26 (110.48)
Panel B: Economic Variables		
Total Revenue ($1000s)	42,838.85 (328,198.01)	21,918.91 (166,232.24)
Closing Inventory Book Value ($1000s)	4,508.24 (27,419.27)	2,723.40 (16,844.89)
Machinery and Equipment Book Value ($1000s)	9,082.90 (71,830.96)	4,965.49 (35,546.57)
Total Energy Expenditures ($1000s)	867.77 (6,872.53)	508.11 (3,737.63)
Observations	48,110	52,050

Notes: This table shows means and standard deviations for our main variables for treatment and control plants, averaged over the four years prior to the announcement of carbon pricing. All monetary values are in 1000s of 2024 Canadian dollars. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements.

Table A.2: Difference in Carbon Dioxide Price for Treated Plants Relative to Control Plants

	Carbon Price	
	(1)	(2)
Years Since Announcement		
−3	2.36***	2.02***
	(0.29)	(0.08)
−2	0.62**	0.68***
	(0.26)	(0.05)
−1	0.11	0.36***
	(0.25)	(0.03)
0	—	—
1	-0.16	-0.51***
	(0.26)	(0.03)
2	20.40***	21.34***
	(0.27)	(0.07)
3	21.38***	24.09***
	(0.28)	(0.15)
4	30.65***	30.49***
	(0.28)	(0.11)
Pre-Treatment Dep. Var. Mean	0.00	0.00
Post-Implementation Dep. Var. Mean	24.14	25.31
Firm × Cohort FE		Yes
Province × Cohort FE		Yes
Industry × Year × Cohort FE		Yes
Year × Cohort FE	Yes	
Observations	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on the actual price of emitting CO_2 for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Estimates show the difference relative to the difference in the year before carbon pricing is announced (year 0). The outcome variable is the provincial annual average carbon price in 2024 Canadian dollars. Estimates use equation (2) inverse-weighted by the number of observations in each province-year. Column 1 uses only Year × Cohort fixed effects; Column 2 and the event study graph Figure 1 use the full model in equation (2). The pre-treatment dependent variable mean is the average carbon price for treated plants in the four years prior to the announcement of carbon pricing. The post-implementation dependent variable mean is the average carbon price for treated plants after carbon pricing is implemented. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table A.3: Effects of Carbon Pricing Announcement and Implementation on Environmental Outcomes, Sun and Abraham Sensitivity

	(1)	(2)	(3)	(4)
Panel A: Environmental Outcomes				
	CO_2 Emissions	Total Energy	Fossil Fuels	Electricity
Announcement × Treated	228.20**	5.04**	6.36***	-1.32*
	(111.30)	(2.26)	(2.12)	(0.73)
Implementation × Treated	-210.75*	-4.68*	-1.28	-3.41**
	(112.85)	(2.62)	(2.08)	(1.46)
Pre-Treatment Dep. Var. Mean	2,147.88	58.85	36.82	22.04
Panel B: Economic Outcomes				
	log(Revenue)	log(Inventory Value)	log(Machinery and Equipment Value)	log(Energy Expenditures)
Announcement × Treated	-0.000	0.068**	0.027**	0.071***
	(0.018)	(0.033)	(0.012)	(0.026)
Implementation × Treated	0.016	0.010	0.009	-0.093***
	(0.019)	(0.034)	(0.014)	(0.027)
Pre-Treatment Dep. Var. Mean (1000s)	42,838.85	4,508.24	9,082.90	867.77
Firm FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes
Observations	133,630	133,630	133,630	133,630

Notes: This table shows the effects of announcing and implementing carbon pricing on environmental and economic outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. In Panel A, outcome variables are CO_2 emissions in tonnes (Column 1), total energy inputs in 1000 GJs (Column 2), fossil fuel energy inputs in 1000 GJs (Column 3), and electricity inputs in 1000 GJs (Column 4). In Panel B, outcome variables are the logs of total revenue (Column 1), closing inventory book value (Column 2), machinery and equipment book value (Column 3), and total energy expenditures (Column 4). Inventories and machinery and equipment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. Estimates use equation (4) and Sun and Abraham (2021). For comparison to the main estimates, the Implementation × Treated row reports the implementation effect relative to the announcement period, which is the linear combination of coefficients in equation (4). The pre-treatment dependent variable mean is the pre-treatment dependent variable mean for treated plants in the four years prior to the announcement of carbon pricing. All monetary values are in 1000s of 2024 Canadian dollars. Parentheses show standard errors clustered by firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table A.4: Effects of Carbon Pricing Announcement and Implementation on Environmental Outcomes, Sensitivity

	Main Estimates (1)	Add ON 2015 (2)	Drop ON 2015 Controls (3)	Drop BC (4)	Add NS & NB (5)	Drop 2019 (6)	Matched to NALMF (7)	Unweighted (8)	ASML Survey Weights (9)	Stack Weights & ASML Weights (10)	Logs (11)
Panel A: CO_2 Emissions											
Announcement × Treated	217.21**	222.86**	217.17**	235.10	257.51***	223.03**	271.54***	418.01***	394.75***	216.55**	0.024**
	(96.34)	(95.08)	(96.63)	(150.38)	(94.64)	(96.12)	(104.38)	(149.22)	(134.21)	(99.08)	(0.011)
Implementation × Treated	-249.53**	-248.13**	-249.79**	-159.49	-298.49***	-202.66*	-245.43*	-383.29***	-348.56***	-260.52**	-0.071***
	(109.49)	(109.02)	(109.63)	(121.84)	(100.98)	(115.29)	(130.06)	(128.17)	(107.36)	(121.75)	(0.018)
Pre-Treat. Dep. Var. Mean	2,147.88	1,778.54	2,147.88	2,147.88	2,147.88	2,147.88	1,772.36	2,147.88	2,147.88	2,147.88	2,147.88
Panel B: Total Energy											
Announcement × Treated	3.74*	3.60*	3.74*	3.46	4.03**	3.85**	4.79**	7.99***	7.60***	3.70*	0.047***
	(1.96)	(1.94)	(1.97)	(3.13)	(1.89)	(1.95)	(2.12)	(2.99)	(2.69)	(2.01)	(0.017)
Implementation × Treated	-5.55**	-5.62**	-5.56**	-4.41*	-7.08***	-5.10**	-5.88**	-7.93***	-7.13***	-5.88**	-0.133***
	(2.36)	(2.34)	(2.36)	(2.66)	(2.20)	(2.53)	(2.80)	(2.62)	(2.19)	(2.63)	(0.029)
Pre-Treat. Dep. Var. Mean	58.85	49.25	58.85	58.85	58.85	58.85	49.13	58.85	58.85	58.85	58.85
Panel C: Fossil Fuels											
Announcement × Treated	3.75**	3.93**	3.75**	4.40	3.58**	3.85**	4.82**	7.42**	6.98***	3.75**	0.028***
	(1.85)	(1.84)	(1.86)	(2.93)	(1.78)	(1.85)	(2.01)	(2.90)	(2.61)	(1.91)	(0.009)
Implementation × Treated	-3.67*	-3.60*	-3.68*	-2.54	-5.01***	-3.07	-3.82*	-5.95**	-5.47***	-3.78*	-0.023
	(1.92)	(1.92)	(1.92)	(2.35)	(1.76)	(2.02)	(2.28)	(2.33)	(1.96)	(2.13)	(0.015)
Pre-Treat. Dep. Var. Mean	36.82	30.65	36.82	36.82	36.82	36.82	30.43	36.82	36.82	36.82	36.82
Panel D: Electricity											
Announcement × Treated	-0.01	-0.33	-0.01	-0.93	0.45	-0.00	-0.03	0.57	0.62	-0.05	0.047***
	(0.65)	(0.62)	(0.65)	(1.15)	(0.64)	(0.65)	(0.73)	(0.64)	(0.57)	(0.67)	(0.008)
Implementation × Treated	-1.88	-2.03	-1.88	-1.87	-2.07*	-2.04	-2.06	-1.98*	-1.67*	-2.10	-0.016
	(1.27)	(1.25)	(1.27)	(1.22)	(1.22)	(1.44)	(1.54)	(1.14)	(0.91)	(1.43)	(0.013)
Pre-Treat. Dep. Var. Mean	22.04	18.60	22.04	22.04	22.04	22.04	18.70	22.04	22.04	22.04	22.04
Firm × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	178,410	181,710	174,220	127,190	204,730	167,700	149,580	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on environmental outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are CO_2 emissions in tonnes (Panel A), total energy inputs in 1000 GJs (Panel B), fossil fuel energy inputs in 1000 GJs (Panel C), and electricity inputs in 1000 GJs (Panel D). Estimates use equation (1). The pre-treatment dependent variable mean is the pre-treatment dependent variable mean for treated plants in the four years prior to the announcement of carbon pricing. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table A.5: Effects of Carbon Pricing Announcement and Implementation on Economic Outcomes, Sensitivity

	Main Estimates (1)	Add ON 2015 (2)	Drop ON 2015 Controls (3)	Drop BC (4)	Add NS & NB (5)	Drop 2019 (6)	Matched to NALMF (7)	Unweighted (8)	ASML Survey Weights (9)	Stack Weights & ASML Weights (10)	Levels (11)
Panel A: log(Revenue)											
Announcement × Treated	0.002	0.002	0.001	-0.010	0.004	0.001	-0.002	-0.003	-0.011	0.003	442.94
	(0.012)	(0.012)	(0.012)	(0.018)	(0.012)	(0.012)	(0.009)	(0.014)	(0.014)	(0.013)	(665.33)
Implementation × Treated	0.020	0.021	0.021	0.085***	0.035**	0.013	-0.001	0.019	0.023	0.022	1,461.23**
	(0.016)	(0.016)	(0.016)	(0.021)	(0.015)	(0.016)	(0.011)	(0.018)	(0.016)	(0.017)	(738.41)
Pre-Treat. Dep. Var. Mean (1000s)	42,838.85	37,549.93	42,838.85	42,838.85	42,838.85	42,838.85	35,720.30	42,838.85	42,838.85	42,838.85	42,838.85
Panel B: log(Inventory Value)											
Announcement × Treated	0.070**	0.067**	0.069**	0.003	0.051*	0.070**	0.079**	0.065**	0.056*	0.069**	9.27
	(0.029)	(0.029)	(0.029)	(0.037)	(0.027)	(0.029)	(0.032)	(0.028)	(0.031)	(0.030)	(84.29)
Implementation × Treated	0.018	0.016	0.018	0.057	0.033	0.013	0.003	0.008	0.029	0.013	378.31**
	(0.032)	(0.032)	(0.032)	(0.039)	(0.030)	(0.033)	(0.034)	(0.031)	(0.034)	(0.034)	(168.52)
Pre-Treat. Dep. Var. Mean (1000s)	4,508.24	3,984.04	4,508.24	4,508.24	4,508.24	4,508.24	3,778.95	4,508.24	4,508.24	4,508.24	4,508.24
Panel C: log(Machinery and Equipment Value)											
Announcement × Treated	0.029**	0.026**	0.029**	0.011	0.034***	0.029**	0.022*	0.023**	0.011	0.029**	521.12*
	(0.012)	(0.011)	(0.012)	(0.013)	(0.011)	(0.012)	(0.013)	(0.011)	(0.014)	(0.012)	(285.29)
Implementation × Treated	0.023*	0.022	0.024*	0.038**	0.022*	0.027*	0.018	0.015	0.040**	0.023	645.29**
	(0.014)	(0.014)	(0.014)	(0.015)	(0.013)	(0.015)	(0.016)	(0.013)	(0.020)	(0.015)	(255.43)
Pre-Treat. Dep. Var. Mean (1000s)	9,082.90	8,127.05	9,082.90	9,082.90	9,082.90	9,082.90	7,620.02	9,082.90	9,082.90	9,082.90	9,082.90
Panel D: log(Energy Expenditures)											
Announcement × Treated	0.078***	0.078***	0.078***	0.044	0.055***	0.077***	0.085***	0.070***	0.073***	0.077***	-22.82*
	(0.023)	(0.023)	(0.023)	(0.029)	(0.021)	(0.023)	(0.024)	(0.022)	(0.021)	(0.023)	(13.58)
Implementation × Treated	-0.110***	-0.109***	-0.109***	-0.083***	-0.084***	-0.128***	-0.153***	-0.082***	-0.076***	-0.105***	-43.68*
	(0.025)	(0.025)	(0.025)	(0.031)	(0.024)	(0.026)	(0.026)	(0.025)	(0.023)	(0.026)	(23.55)
Pre-Treat. Dep. Var. Mean (1000s)	867.77	745.37	867.77	867.77	867.77	867.77	730.42	867.77	867.77	867.77	867.77
Firm × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	178,410	181,710	174,220	127,190	204,730	167,700	149,580	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on the log of economic outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are the logs of total revenue (Panel A), closing inventory book value (Panel B), machinery and equipment book value (Panel C), and total energy expenditures (Panel D). Inventories and machinery and equipment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. Estimates use equation (1). The pre-treatment dependent variable mean is the pre-treatment dependent variable mean for treated plants in the four years prior to the announcement of carbon pricing. All monetary values are in 1000s of 2024 Canadian dollars. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table A.6: Effects of Carbon Pricing Announcement and Implementation on Environmental Outcomes, Trend Break

	Main Estimates (1)	Add ON 2015 (2)	Drop ON 2015 Controls (3)	Drop BC (4)	Add NS & NB (5)	Drop 2019 (6)	Matched to NALMF (7)	Unweighted (8)	ASML Survey Weights (9)	Stack Weights & ASML Weights (10)	Logs (11)
Panel A: CO_2 Emissions											
Trend Before Announcement	-0.16	-4.52	0.92	-16.72	1.71	-4.83	-6.04	3.03	3.29	0.44	-0.003
	(35.35)	(33.83)	(35.53)	(59.97)	(34.02)	(35.39)	(37.34)	(49.62)	(47.53)	(35.88)	(0.005)
Announcement Jump	382.86***	394.57***	380.49***	315.31*	421.94***	378.48***	500.39***	673.31***	607.99***	391.96***	0.032**
	(127.99)	(127.90)	(127.73)	(162.26)	(126.69)	(134.97)	(137.88)	(194.64)	(169.39)	(133.50)	(0.015)
Trend After Implementation	-145.49**	-140.75**	-146.34**	-53.34	-161.18***	-128.89*	-164.68**	-229.26***	-200.14***	-154.68**	-0.018*
	(61.44)	(60.21)	(61.42)	(70.73)	(59.75)	(70.60)	(69.04)	(87.82)	(77.40)	(65.76)	(0.010)
Pre-Treat. Dep. Var. Mean	2,147.88	1,778.54	2,147.88	2,147.88	2,147.88	2,147.88	1,772.36	2,147.88	2,147.88	2,147.88	2,147.88
Panel B: Total Energy											
Trend Before Announcement	-0.33	-0.11	-0.31	-0.95	-0.48	-0.42	-0.37	-0.23	-0.21	-0.32	0.009
	(0.75)	(0.72)	(0.75)	(1.32)	(0.71)	(0.75)	(0.80)	(0.99)	(0.95)	(0.76)	(0.007)
Announcement Jump	7.68***	7.22***	7.64***	6.11*	8.40***	8.53***	10.06***	13.42***	12.10***	7.95***	0.031
	(2.56)	(2.60)	(2.55)	(3.25)	(2.52)	(2.88)	(2.77)	(3.85)	(3.34)	(2.69)	(0.023)
Trend After Implementation	-2.80**	-3.06**	-2.81**	-0.85	-3.16**	-3.11*	-3.45**	-4.31**	-3.69**	-3.06**	-0.044***
	(1.41)	(1.37)	(1.41)	(1.63)	(1.37)	(1.77)	(1.62)	(1.81)	(1.59)	(1.53)	(0.015)
Pre-Treat. Dep. Var. Mean	58.85	49.25	58.85	58.85	58.85	58.85	49.13	58.85	58.85	58.85	58.85
Panel C: Fossil Fuels											
Trend Before Announcement	-0.52	-0.63	-0.50	-1.07	-0.73	-0.59	-0.60	-0.80	-0.75	-0.51	-0.004
	(0.66)	(0.64)	(0.67)	(1.15)	(0.64)	(0.66)	(0.70)	(0.94)	(0.90)	(0.67)	(0.004)
Announcement Jump	7.38***	7.63***	7.33***	6.52**	7.58***	7.66***	9.72***	13.04***	11.83***	7.52***	0.041***
	(2.44)	(2.46)	(2.44)	(3.15)	(2.39)	(2.54)	(2.63)	(3.76)	(3.27)	(2.55)	(0.012)
Trend After Implementation	-1.82	-1.69	-1.83*	0.11	-2.00*	-1.80	-2.34*	-2.90*	-2.48*	-1.94	-0.005
	(1.11)	(1.10)	(1.11)	(1.34)	(1.09)	(1.24)	(1.24)	(1.63)	(1.45)	(1.18)	(0.008)
Pre-Treat. Dep. Var. Mean	36.82	30.65	36.82	36.82	36.82	36.82	30.43	36.82	36.82	36.82	36.82
Panel D: Electricity											
Trend Before Announcement	0.19	0.52*	0.19	0.12	0.25	0.16	0.22	0.56*	0.54*	0.19	0.009***
	(0.30)	(0.28)	(0.30)	(0.45)	(0.29)	(0.30)	(0.33)	(0.30)	(0.28)	(0.31)	(0.003)
Announcement Jump	0.30	-0.41	0.31	-0.41	0.83	0.88	0.34	0.38	0.26	0.43	0.044***
	(0.78)	(0.82)	(0.78)	(0.91)	(0.81)	(1.24)	(0.92)	(0.75)	(0.63)	(0.86)	(0.010)
Trend After Implementation	-0.98	-1.36*	-0.98	-0.96	-1.16	-1.31	-1.11	-1.41*	-1.21*	-1.12	-0.018***
	(0.84)	(0.78)	(0.84)	(0.79)	(0.80)	(1.21)	(1.00)	(0.76)	(0.63)	(0.93)	(0.007)
Pre-Treat. Dep. Var. Mean	22.04	18.60	22.04	22.04	22.04	22.04	18.70	22.04	22.04	22.04	22.04
Firm × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	178,410	181,710	174,220	127,190	204,730	167,700	149,580	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on environmental outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are CO_2 emissions in tonnes (Panel A), total energy inputs in 1000 GJs (Panel B), fossil fuel energy inputs in 1000 GJs (Panel C), and electricity inputs in 1000 GJs (Panel D). Estimates use equation (5). The pre-treatment dependent variable mean is the pre-treatment dependent variable mean for treated plants in the four years prior to the announcement of carbon pricing. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).

Table A.7: Effects of Carbon Pricing Announcement and Implementation on Economic Outcomes, Trend Break

	Main Estimates (1)	Add ON 2015 (2)	Drop ON 2015 Controls (3)	Drop BC (4)	Add NS & NB (5)	Drop 2019 (6)	Matched to NALMF (7)	Unweighted (8)	ASML Survey Weights (9)	Stack Weights & ASML Weights (10)	Levels (11)
Panel A: log(Revenue)											
Trend Before Announcement	0.008*	0.007*	0.007	0.004	0.008*	0.008*	0.010***	0.006	0.004	0.009**	236.05
	(0.004)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(191.15)
Announcement Jump	-0.022	-0.020	-0.020	-0.058**	-0.026	-0.014	-0.018*	-0.023	-0.027	-0.021	-1,293.30
	(0.017)	(0.017)	(0.017)	(0.024)	(0.016)	(0.016)	(0.010)	(0.020)	(0.018)	(0.017)	(809.93)
Trend After Implementation	0.003	0.004	0.004	0.039***	0.011	-0.003	-0.010	0.005	0.007	0.002	815.06**
	(0.009)	(0.008)	(0.009)	(0.011)	(0.008)	(0.008)	(0.006)	(0.009)	(0.009)	(0.009)	(382.02)
Pre-Treat. Dep. Var. Mean (1000s)	42,838.85	37,549.93	42,838.85	42,838.85	42,838.85	42,838.85	35,720.30	42,838.85	42,838.85	42,838.85	42,838.85
Panel B: log(Inventory Value)											
Trend Before Announcement	0.001	0.003	-0.001	-0.002	0.003	0.001	0.006	-0.003	-0.005	0.003	-47.75
	(0.008)	(0.008)	(0.008)	(0.012)	(0.008)	(0.008)	(0.008)	(0.009)	(0.010)	(0.008)	(35.53)
Announcement Jump	0.061*	0.055	0.062*	-0.024	0.031	0.062	0.073*	0.064*	0.064	0.060	-156.83
	(0.037)	(0.036)	(0.037)	(0.046)	(0.035)	(0.039)	(0.039)	(0.036)	(0.041)	(0.037)	(103.75)
Trend After Implementation	0.008	0.005	0.009	0.031	0.014	0.005	-0.006	0.007	0.012	0.002	262.00***
	(0.016)	(0.016)	(0.016)	(0.021)	(0.015)	(0.018)	(0.017)	(0.016)	(0.019)	(0.016)	(91.36)
Pre-Treat. Dep. Var. Mean (1000s)	4,508.24	3,984.04	4,508.24	4,508.24	4,508.24	4,508.24	3,778.95	4,508.24	4,508.24	4,508.24	4,508.24
Panel C: log(Machinery and Equipment Value)											
Trend Before Announcement	0.007	0.010*	0.007	0.006	0.007	0.007	0.007	0.006	0.004	0.008	-26.60
	(0.006)	(0.005)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(77.00)
Announcement Jump	0.017	0.011	0.017	-0.004	0.019	0.008	0.012	0.016	0.012	0.016	160.44
	(0.014)	(0.013)	(0.014)	(0.016)	(0.013)	(0.015)	(0.015)	(0.013)	(0.018)	(0.014)	(342.45)
Trend After Implementation	-0.001	-0.004	-0.001	0.007	0.001	0.005	-0.002	-0.003	0.005	-0.002	390.16**
	(0.009)	(0.009)	(0.009)	(0.010)	(0.008)	(0.010)	(0.010)	(0.008)	(0.010)	(0.009)	(153.10)
Pre-Treat. Dep. Var. Mean (1000s)	9,082.90	8,127.05	9,082.90	9,082.90	9,082.90	9,082.90	7,620.02	9,082.90	9,082.90	9,082.90	9,082.90
Panel D: log(Energy Expenditures)											
Trend Before Announcement	0.004	0.003	0.002	-0.011	0.004	0.004	0.006	0.004	0.002	0.005	-0.29
	(0.006)	(0.006)	(0.006)	(0.008)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(5.81)
Announcement Jump	0.085***	0.085***	0.087***	0.055	0.053**	0.125***	0.102***	0.070**	0.072***	0.084***	-19.59
	(0.028)	(0.028)	(0.028)	(0.036)	(0.026)	(0.030)	(0.029)	(0.028)	(0.026)	(0.029)	(16.89)
Trend After Implementation	-0.039***	-0.038***	-0.037***	-0.009	-0.028**	-0.067***	-0.060***	-0.029**	-0.024**	-0.039***	-12.79
	(0.012)	(0.012)	(0.012)	(0.015)	(0.011)	(0.014)	(0.012)	(0.012)	(0.011)	(0.013)	(14.24)
Pre-Treat. Dep. Var. Mean (1000s)	867.77	745.37	867.77	867.77	867.77	867.77	730.42	867.77	867.77	867.77	867.77
Firm × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year × Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	178,410	181,710	174,220	127,190	204,730	167,700	149,580	178,410	178,410	178,410	178,410

Notes: This table shows the effects of announcing and implementing carbon pricing on the log of economic outcomes for treated manufacturing plants relative to control manufacturing plants and relative to before carbon pricing is announced. Outcome variables are the logs of total revenue (Panel A), closing inventory book value (Panel B), machinery and equipment book value (Panel C), and total energy expenditures (Panel D). Inventories and machinery and equipment are the closing book values of total intermediate and final goods inventories and of machinery and equipment, respectively. Energy expenditures are the total cost of energy inputs excluding carbon pricing fees. Estimates use equation (5). The pre-treatment dependent variable mean is the pre-treatment dependent variable mean for treated plants in the four years prior to the announcement of carbon pricing. All monetary values are in 1000s of 2024 Canadian dollars. Parentheses show standard errors two-way clustered by treatment cohort and firm. Observation counts are rounded to the nearest 10 according to Statistics Canada disclosure requirements. Asterisks denote p-value less than 0.01 (***), 0.05 (**), 0.10 (*).