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Appendix S1. Institutional background for Canada's 2019 nationwide carbon tax

On April 22, 2016, Canada joined other nations in signing the Paris Agreement, which mandates a commitment to reducing economy-wide greenhouse gas (GHG) emissions (below 2005 levels) by 2030. On October 3, 2016, the federal government launched the *Pan-Canadian Framework on Clean Growth and Climate Change*.[1] This framework encouraged all provinces to plan climate policies. However, there were regional inconsistencies, as some provinces, such as British Columbia, Alberta, Ontario, and Quebec, had already implemented their own climate policies, but others did not. The framework's dependence on the need for provincial cooperation made it vulnerable to political shifts, as changes in provincial leadership could result in the rollback or weakening of climate initiatives, thereby undermining national climate objectives.

On June 21, 2018, the Government of Canada announced the *Greenhouse Gas Pollution Pricing Act* (GGPPA) as a potential step to address the limitations of the Pan-Canadian Framework and establish a consistent national approach to carbon pricing.[2] The GGPPA sought to include two key components: a regulatory charge on fuel and a regulatory trading system for industry. The first part of the GGPPA, called the *Output-Based Pricing System* (OBPS), sets emission limits and charges fees for excess emissions. It applies to industrial facilities that emit 50,000 tonnes or more of CO_2e annually and sets emission standards for each sector based on the national production-weighted average emissions intensity. The second part of the GGPPA, the *Federal Fuel Charge*, commonly referred to as the national carbon tax, was implemented by the federal government in April 2019, with the tax set at C$20 per tonne of carbon dioxide equivalent (CO_2e) and annual increases of C$10, reaching C$50 by 2022.

During its implementation, the GGPPA faced opposition from several stakeholders, which led to it being contested in court. On March 25, 2021, the Supreme Court of Canada (SCC) addressed the constitutionality of the GGPPA in a landmark decision.[3] The court ruled that the GGPPA is constitutional and affirmed that climate change is a critical national issue within federal jurisdiction. The ruling also clarified that while the federal government sets national minimum standards (also known as the "federal benchmark"), provinces retain the authority to design their own carbon pricing systems as long as they meet or exceed the federal benchmarks. If a province decides not to price pollution, or proposes a system that does not meet these standards, the federal system is put in place.[4]

In November 2021, during the 26th United Nations Climate Change Conference (COP26), Canada launched the *Global Carbon Pricing Challenge* (GCPC) to promote international cooperation on carbon pricing. The GCPC seeks to expand the use of carbon pricing by strengthening existing systems and supporting emerging ones, with a collective goal of covering 60% of global emissions by 2030.[5]

[1] "Pan-Canadian Framework on Clean Growth and Climate Change." Retrieved from https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

[2] "Greenhouse Gas Pollution Pricing Act." Retrieved from https://laws-lois.justice.gc.ca/eng/acts/G-11.55/

[3] "References re Greenhouse Gas Pollution Pricing Act." Retrieved from https://www.scc-csc.ca/case-dossier/cb/2021/38663-38781-39116-eng.aspx

[4] "Carbon pollution pricing systems across Canada." Retrieved from https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html

[5] "The Global Carbon Pricing Challenge." Retrieved from https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/pricing-carbon-pollution/global-challenge.html

Appendix S2. List of nationwide carbon taxes

Nationwide Carbon Tax	Jurisdiction	Year of Implementation
Finland carbon tax	Finland	1990
Poland carbon tax	Poland	1990
Sweden carbon tax	Sweden	1991
Norway carbon tax	Norway	1991
Denmark carbon tax	Denmark	1992
Slovenia carbon tax	Slovenia	1996
Estonia carbon tax	Estonia	2000
Latvia carbon tax	Latvia	2004
Liechtenstein carbon tax	Liechtenstein	2008
Albania carbon tax	Albania	2008
Switzerland carbon tax	Switzerland	2008
Iceland carbon tax	Iceland	2010
Ireland carbon tax	Ireland	2010
Ukraine carbon tax	Ukraine	2011
Japan carbon tax	Japan	2012
UK carbon price support	United Kingdom	2013
Spain carbon tax	Spain	2014
Mexico carbon tax	Mexico	2014
France carbon tax	France	2014
Portugal carbon tax	Portugal	January 2015
Chile carbon tax	Chile	January 2017
Colombia carbon tax	Colombia	January 2017
Argentina carbon tax	Argentina	January 2018
Singapore carbon tax	Singapore	January 2019
Canada federal fuel charge	Canada	April 2019
South Africa carbon tax	South Africa	June 2019
Netherlands carbon tax	Netherlands	January 2021
Luxembourg carbon tax	Luxembourg	January 2021
Uruguay CO2 tax	Uruguay	January 2022

Notes. This table summarizes the list of nationwide carbon taxes across the world as of 2022 (the end of our observation window). The information is based on the World Bank's Carbon-Pricing Dashboard (https://carbonpricingdashboard.worldbank.org/).

Appendix S3. A brief introduction to Climate TRACE

Accurate measurement of greenhouse gas (GHG) emissions is vital for monitoring and designing effective climate mitigation strategies. Traditional methods of emissions reporting relied heavily on self-reported data, which often suffered from significant delays, incomplete submissions, and omissions of major emission sources (Gurney et al., 2021; Henry et al., 1997). In response to these challenges, Climate TRACE (Tracking Real-Time Atmospheric Carbon Emissions) was launched to provide a real-time source of emissions data across carbon-intensive industries globally (Gore, 2022). This database addresses the spatial and technological limitations of historical emissions reporting by using advanced technologies, including satellite imagery, remote sensing, and artificial intelligence, to provide high-resolution, plant-level emissions data. These advances offer a uniquely valuable opportunity for researchers to accurately quantify the sources of GHG emissions at the plant-month level.

One of the major contributors to global emissions is the steel sector, which accounts for approximately 7-8% of global carbon emissions. Given the sector's importance to the global economy, accurate measurement of emissions from steel production is crucial for global decarbonization efforts. However, tracking carbon emissions from steel production can be challenging, given the diversity of production processes, technologies, and plant locations worldwide. Climate TRACE addresses these challenges by providing monthly emissions data for all steel plants identified in the Global Steel Plant Tracker of the Global Energy Monitor (GEM). It covers the majority (82%) of global crude steel production, which is primarily responsible for carbon emissions during steel manufacturing.

Climate TRACE uses a combination of artificial intelligence and machine learning to analyze data from more than 300 satellites, air- and land-based sensors, and publicly available verifiable data to track emissions from specific sources independently.[6] It uses a standardized bottom-up approach to quantify plant-level emissions and production. For steel plants, Climate TRACE adopts two primary methodologies. First, satellite-derived production data are used to analyze the heat released by steel plants. By processing satellite imagery with machine learning models, thermal anomalies are detected, and emission levels are quantified for individual plants. Second, in cases when satellite data are insufficient for certain plants, a capacity-based approach is applied, where national production data are proportionally allocated among plants with insufficient satellite data to enable estimation of emissions for such plants.

Satellite-derived data come from multispectral images obtained from the European Space Agency (ESA) and the U.S. Geological Survey (USGS), processed through Google Earth Engine. A key metric employed is the Normalized Heat Index (NHI), which identifies thermal anomalies by analyzing temperature patterns associated with industrial processes such as steel manufacturing.

To further ensure accuracy and reliability, Climate TRACE implements a multi-layer validation framework. This includes comparing model outputs against production and emissions data from the GEM database, as well as datasets from agencies like the U.S. Environmental Protection Agency (EPA) and the European Pollutant Release and Transfer Register (E-PRTR). These data are supplemented with publicly available production data to validate the performance of the Climate TRACE data. Thus, Climate TRACE is able to provide reliable, timely, and accurate plant-level production and emissions data for policymakers, researchers, and practitioners, without having to rely on self-reported figures.

[6] For further details, please refer to https://climatetrace.org/news/more-than-70000-of-the-highest-emitting-greenhouse-gas.

Appendix S4. Countries in the full sample

NO.	Location of Steel Plant	NO.	Location of Steel Plant
1	ALBANIA	35	MEXICO
2	ALGERIA	36	MOLDOVA
3	ARGENTINA	37	MOROCCO
4	AUSTRALIA	38	NETHERLANDS
5	AUSTRIA	39	NEW ZEALAND
6	AZERBAIJAN	40	NIGERIA
7	BANGLADESH	41	NORWAY
8	BELARUS	42	OMAN
9	BELGIUM	43	PAKISTAN
10	BRAZIL	44	PERU
11	BULGARIA	45	PHILIPPINES
12	CANADA	46	POLAND
13	CHILE	47	PORTUGAL
14	CHINA	48	QATAR
15	CROATIA	49	ROMANIA
16	CZECHIA	50	RUSSIA
17	EGYPT	51	SAUDI ARABIA
18	FINLAND	52	SERBIA
19	FRANCE	53	SINGAPORE
20	GERMANY	54	SLOVAK REPUBLIC
21	GREECE	55	SLOVENIA
22	GUATEMALA	56	SOUTH AFRICA
23	HUNGARY	57	SPAIN
24	INDIA	58	SWEDEN
25	INDONESIA	59	SWITZERLAND
26	IRAN	60	THAILAND
27	ITALY	61	TRINIDAD AND TOBAGO
28	JAPAN	62	TURKIYE
29	KAZAKHSTAN	63	UKRAINE
30	KOREA	64	UNITED ARAB EMIRATES
31	KUWAIT	65	UNITED KINGDOM
32	LIBYA	66	UNITED STATES
33	LUXEMBOURG	67	VIET NAM
34	MALAYSIA		

Notes. This table lists the countries where steel plants in the full plant-month sample are located.

Appendix S5. Information on parent firms operating steel plants in Canada

Steel plant	Principal production route	Parent firm	Country where the parent firm is headquartered	Countries in which the parent firm operates steel plants	Does the parent firm own income-generating assets in at least one foreign country (i.e., multinational enterprise)?	Does the parent firm operate steel plants outside Canada (i.e., multinational spread)?
Algoma Steel Plant	BF/BOF	Algoma Steel	Canada	Canada	No	No
Ivaco Rolling Mills Steel Plant	BF/BOF	Heico Companies	United States	Canada	Yes	No
Rio Tinto Fer et Titane Steel Plant	BF/BOF	Rio Tinto	United Kingdom	Canada	Yes	No
Stelco Lake Erie Steel Plant	BF/BOF	Stelco Holdings	Canada	Canada	No	No
ArcelorMittal Dofasco Steel Plant	BF/BOF	ArcelorMittal	Luxembourg	Argentina, Belgium, Brazil, Canada, France, Germany, India, Italy, Kazakhstan, Luxembourg, Mexico, Morocco, Poland, Romania, Spain, and Ukraine	Yes	Yes
ArcelorMittal Montreal Steel Plant	EAF	ArcelorMittal	Luxembourg	Argentina, Belgium, Brazil, Canada, France, Germany, India, Italy, Kazakhstan, Luxembourg, Mexico, Morocco, Poland, Romania, Spain, and Ukraine	Yes	Yes
Evraz Regina Steel Plant	EAF	Evraz	United Kingdom	Canada, Russia, and the United States.	Yes	Yes
Gerdau Whitby Steel Mill	EAF	Gerdau	Brazil	Argentina, Brazil, Canada, Mexico, and the United States	Yes	Yes

Notes. BF/BOF refers to the blast furnace/basic oxygen furnace route, whereas EAF refers to the electric arc furnace route. The information is based on the Climate TRACE data as of the end of 2022. Algoma Steel Plant was previously owned by Essar; on November 30, 2018, it was acquired by Algoma Steel. This ownership change occurred before Canada's carbon tax in 2019, and our results remain robust when we exclude the Algoma Steel Plant from the analysis. There were no ownership changes for other steel plants in Canada during the observation window.

Appendix S6. Correlation

Panel A. The sample examining the impact of Canada's carbon tax

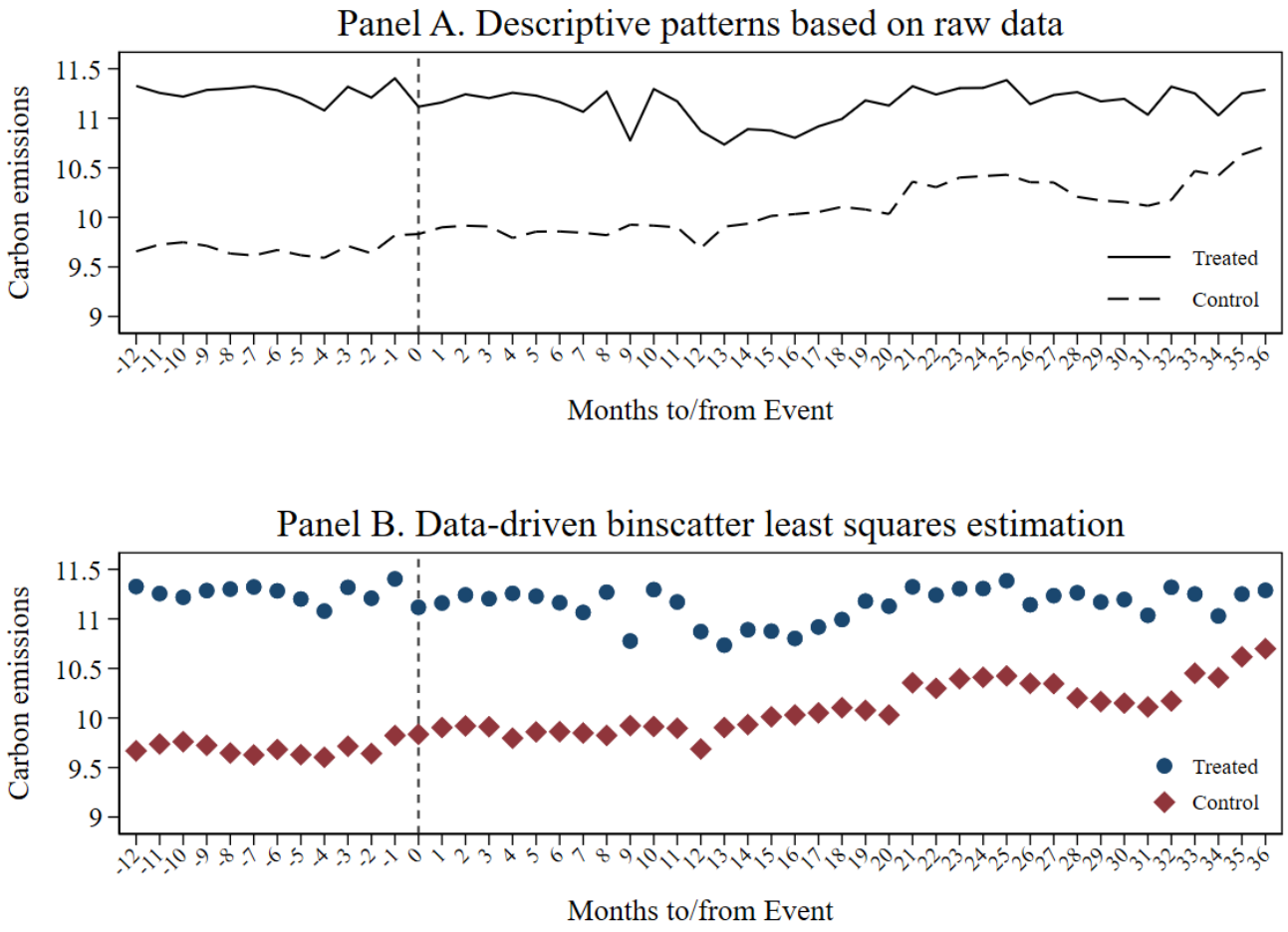
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	Carbon emissions	1.000											
(2)	Asset utilization	0.716	1.000										
(3)	Emissions intensity of production	0.274	0.005	1.000									
(4)	Post	0.106	0.128	-0.036	1.000								
(5)	Treated	0.039	0.042	0.009	0.000	1.000							
(6)	Treated with multinational spread	0.019	0.030	-0.039	0.000	0.705	1.000						
(7)	Treated without multinational spread	0.036	0.029	0.052	0.000	0.705	-0.005	1.000					
(8)	Post × Treated	0.026	0.023	0.009	0.075	0.683	0.481	0.481	1.000				
(9)	Post × Treated with multinational spread	0.012	0.017	-0.026	0.053	0.482	0.684	-0.004	0.706	1.000			
(10)	Post × Treated without multinational spread	0.025	0.015	0.038	0.053	0.482	-0.004	0.684	0.706	-0.002	1.000		
(11)	GDP per capita	0.018	0.100	-0.453	0.155	0.141	0.099	0.099	0.102	0.072	0.072	1.000	
(12)	Population	0.109	0.022	0.551	0.007	-0.144	-0.102	-0.102	-0.097	-0.069	-0.069	-0.480	1.000

Panel B. The sample examining the impact of carbon taxes across countries

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Carbon emissions	1.000							
(2)	Asset utilization	0.703	1.000						
(3)	Emissions intensity of production	0.291	-0.017	1.000					
(4)	Carbon tax	0.042	0.068	-0.120	1.000				
(5)	Multinational spread	0.027	0.109	-0.145	0.293	1.000			
(6)	Carbon tax × Multinational spread	0.045	0.088	-0.110	0.734	0.503	1.000		
(7)	GDP per capita	0.025	0.124	-0.444	0.275	0.314	0.249	1.000	
(8)	Population	0.087	0.000	0.503	-0.361	-0.350	-0.295	-0.515	1.000

Notes. The unit of analysis is plant-month. In Panel A, to estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. The sample comprises 72,384 plant-month observations obtained from 754 steel plants between January 2015 and December 2022. In Panel B, to estimate the effect of carbon taxes across countries, we investigate all steel plants in the data. This full sample includes 84,672 plant-month observations obtained from 882 steel plants across 67 countries between January 2015 and December 2022.

Appendix S7. Descriptive trends in carbon emissions before and after the introduction of Canada's carbon tax



Notes. The unit of analysis is plant-month. To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. Panel A shows descriptive patterns based on raw data. Panel B shows the patterns obtained from data-driven binscatter least squares estimation (Starr & Goldfarb, 2020).

Appendix S8. Addressing potential concerns arising from the small number of treated units for Canada's carbon tax

Panel A. Exact inference for the effect of Canada's carbon tax on carbon emissions

	ATT	n	c	$p = \frac{c}{n}$	95% CI for p
Effect of Canada's carbon tax	-0.205	1000	54	0.054	(0.041, 0.070)

Panel B. Synthetic difference-in-differences estimate of the effect of Canada's carbon tax on carbon emissions

	ATT	t	p	95% CI
Effect of Canada's carbon tax	-0.603	-7.58	0.000	(-0.759, -0.447)

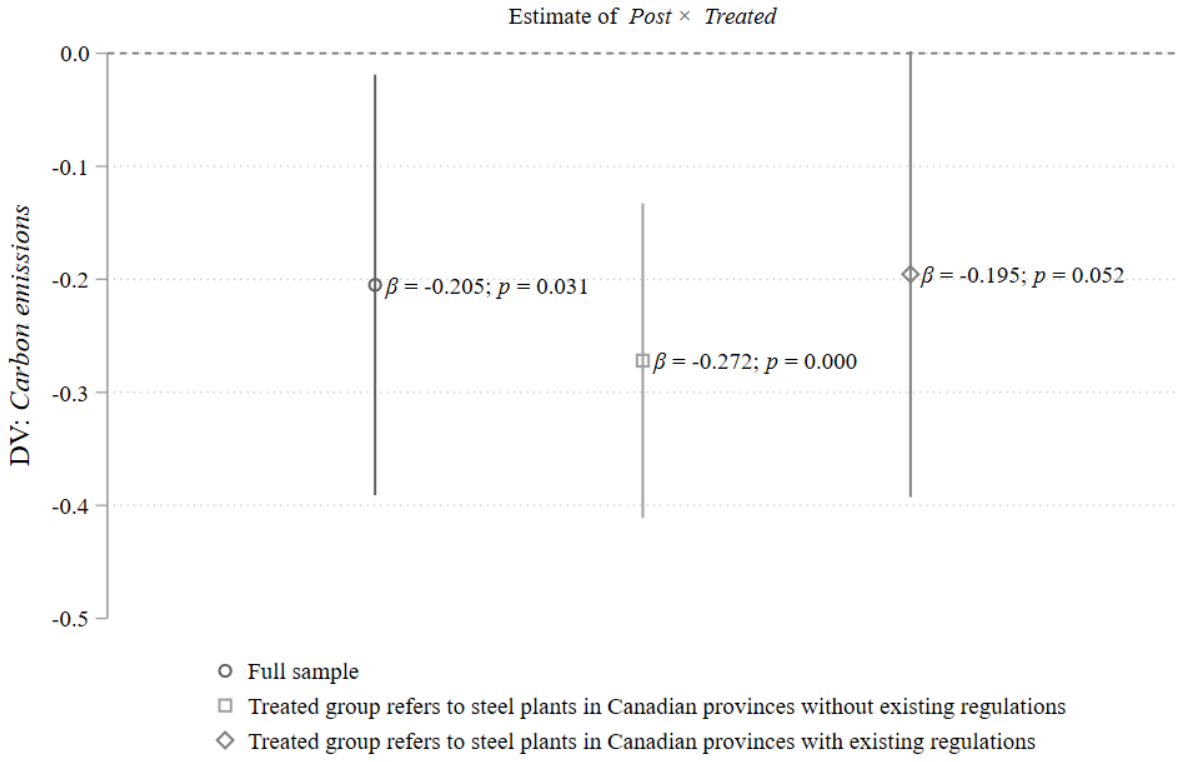
Notes. The unit of analysis is plant-month. To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. In Panel A, we adopt permutation techniques to perform exact inference that overcomes potential challenges arising from the small number of treated units (e.g., Edgington & Onghena, 2007; Heß, 2017). This approach repeatedly reshuffles the treatment assignment in the data to create a placebo distribution of the test statistic under the null hypothesis of no treatment effect. By comparing this placebo distribution to the actually observed treatment effect, the method calculates a p-value, which is an exact measure of statistical inference without relying on large-sample inferential assumptions. The model specification is the same as Column 5 of Table 2. The number of permutations (n) is set to 1000. c is the count of the permutations where the absolute value of the permutated test statistic is at least as extreme as that of the actually observed treatment effect. The p-value is calculated as the proportion of c to n. In Panel B, we conduct the synthetic difference-in-differences analysis (Arkhangelsky et al., 2021) that overcomes potential challenges arising from the small number of treated units. This approach first constructs a synthetic control group by assigning unit weights to untreated plants and time weights to pre-treatment periods so that the weighted outcomes of the synthetic control group closely resemble those of the treated plants before the carbon tax. It then applies a difference-in-differences approach to estimate the average treatment effect on the treated (ATT). Standard errors are computed via nonparametric cluster bootstrapping with 1000 replications. Plant fixed effects and time fixed effects are included.

Appendix S9. Placebo-in-time estimation for the effect of Canada's carbon tax

	Actual event	Placebo event six months before	Placebo event one year before	Placebo event two years before
	(1)	(2)	(3)	(4)
Dependent variable	Carbon emissions	Carbon emissions	Carbon emissions	Carbon emissions
Post × Treated	-0.205*	-0.059	0.011	0.099
	(0.095)	(0.101)	(0.105)	(0.095)
Control variables	Yes	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes	Yes
Observations	72,384	72,384	72,384	72,384
Adjusted R-squared	0.697	0.697	0.697	0.697
Mean of DV	9.771	9.771	9.771	9.771

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** $p<0.01$, * $p<0.05$, † $p<0.1$). To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. Column 1 shows the effect of the actual introduction of the carbon tax in Canada on carbon emissions of steel plants. Columns 2-4 present placebo-in-time tests, in which the placebo carbon tax is introduced six months, one year, and two years before the actual event.

Appendix S10. Estimating the effect of Canada's carbon tax on steel plants in Canadian provinces with and without pre-existing carbon-pricing regulations



Notes. The unit of analysis is plant-month. To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. The plots show the estimated effect of *Post* × *Treated* with 95% confidence intervals in the full sample, the subsample where the treated group refers to steel plants in Canadian provinces without existing regulations, and the subsample where the treated group refers to steel plants in Canadian provinces with existing regulations. The control group remains the same across the three estimations.

Appendix S11. Estimating the effect of Canada's carbon tax after excluding a plant with ownership change from the treated group

	(1)	(2)	(3)
Dependent variable	Carbon emissions	Asset utilization	Emissions intensity of production
Post × Treated with multinational spread	-0.246*	-12.097**	-26.849**
	(0.104)	(3.742)	(10.396)
Post × Treated without multinational spread	-0.199*	-11.335**	17.557
	(0.090)	(2.934)	(12.359)
Control variables	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes
Observations	72,288	72,288	72,288
Adjusted R-squared	0.697	0.636	0.998
Mean of DV	9.768	59.146	990.173
Difference	-0.047	-0.762	-44.405**
	(0.046)	(2.857)	(12.840)

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. We exclude the Algoma Steel Plant, which experienced an ownership change during the observation window, from the treated group in this analysis.

Appendix S12. Estimating the effect of Canada's carbon tax with standard errors clustered at the parent firm level

	(1)	(2)	(3)
Dependent variable	Carbon emissions	Asset utilization	Emissions intensity of production
Post × Treated with multinational spread	-0.215*	-10.018*	-30.353**
	(0.100)	(3.906)	(11.614)
Post × Treated without multinational spread	-0.195*	-11.264**	14.052
	(0.087)	(2.657)	(9.881)
Control variables	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes
Observations	72,384	72,384	72,384
Adjusted R-squared	0.697	0.636	0.998
Mean of DV	9.771	59.169	990.816
Difference	-0.021	1.245	-44.405**
	(0.040)	(2.698)	(9.083)

Notes. The unit of analysis is plant-month. Standard errors are clustered at the parent firm level and reported in parentheses (** $p<0.01$, * $p<0.05$, † $p<0.1$). To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax.

Appendix S13. Estimating the effect of Canada's carbon tax after matching on plant size

	(1)	(2)	(3)
Dependent variable	Carbon emissions	Asset utilization	Emissions intensity of production
Post × Treated with multinational spread	-0.193†	-9.319*	-30.277**
	(0.116)	(3.909)	(10.474)
Post × Treated without multinational spread	-0.173†	-10.565**	14.128
	(0.104)	(3.091)	(11.318)
Control variables	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes
Observations	49,440	49,440	49,440
Adjusted R-squared	0.668	0.626	0.998
Mean of DV	9.363	57.990	867.682
Difference	-0.021	1.245	-44.405**
	(0.051)	(3.175)	(12.850)

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. We employ CEM to match the treated group and the control group based on plant size, measured as a plant's production capacity per year (log-transformed).

Appendix S14. Estimating the effect of Canada's carbon tax after the Supreme Court's decision on constitutionality

	(1)	(2)
Dependent variable	Carbon emissions	Carbon emissions
Post carbon tax before Supreme Court decision	-0.200*	
× Treated	(0.091)	
Post carbon tax after Supreme Court decision	-0.259*	
× Treated	(0.131)	
Post carbon tax before Supreme Court decision		-0.250**
× Treated with multinational spread		(0.093)
Post carbon tax after Supreme Court decision		-0.223
× Treated with multinational spread		(0.141)
Post carbon tax before Supreme Court decision		-0.151†
× Treated without multinational spread		(0.091)
Post carbon tax after Supreme Court decision		-0.295*
× Treated without multinational spread		(0.134)
Control variables	Yes	Yes
Plant fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Country-specific time trends	Yes	Yes
Observations	72,384	72,384
Adjusted R-squared	0.697	0.697
Mean of DV	9.771	9.771

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). To estimate the effect of Canada's carbon tax, we compare the treated group (i.e., plants located in Canada) and the control group (i.e., plants located in countries that have never implemented a carbon tax) after versus before the introduction of the carbon tax. *Post carbon tax before Supreme Court decision* is set to one for the period after the introduction of Canada's carbon tax in April 2019 and before the Supreme Court of Canada ruled on the constitutionality of Canada's carbon tax in March 2021, and zero otherwise. *Post carbon tax after Supreme Court decision* is set to one for the period after the Supreme Court of Canada ruled on the constitutionality of Canada's carbon tax in March 2021 and zero otherwise.

Appendix S15. Estimating the effect of carbon taxes across countries using stacked DID after accounting for COVID-19 pandemic-related mobility restrictions

Dependent variable	(1) Carbon emissions	(2) Asset utilization	(3) Emissions intensity of production	(4) Carbon emissions	(5) Asset utilization	(6) Emissions intensity of production
Carbon tax	-0.137	-1.516	-5.243**	-0.718	-7.891*	3.754
	(0.278)	(2.158)	(1.374)	(0.557)	(3.808)	(5.735)
Carbon tax × Multinational spread				1.139	12.500†	-17.641†
				(0.751)	(6.728)	(10.167)
Community mobility	0.006*	0.223**	-0.006	0.006*	0.223**	-0.006
	(0.003)	(0.026)	(0.044)	(0.003)	(0.026)	(0.044)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	227,904	227,904	227,904	227,904	227,904	227,904
Adjusted R-squared	0.728	0.717	0.999	0.728	0.717	0.999

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). The stacked DID design follows Cengiz et al. (2019). *Community mobility* measures the relative change of visitors to workplaces at the country-month level. This measure compares daily visitors relative to the baseline level before the pandemic outbreak (i.e., the median value over the five-week period from January 3 to February 6, 2020). The data are obtained from Google's COVID-19 Community Mobility Reports (https://www.google.com/covid19/mobility/).[7] By construction, this measure is set to zero before the pandemic outbreak.

[7] Also see Hannah Ritchie (2020) "Google Mobility Trends: How has the pandemic changed the movement of people around the world?" Retrieved from: https://ourworldindata.org/covid-mobility-trends.

Appendix S16. Estimating the effect of carbon taxes across countries using stacked DID with standard errors clustered at the parent firm level

Dependent variable	(1) Carbon emissions	(2) Asset utilization	(3) Emissions intensity of production	(4) Carbon emissions	(5) Asset utilization	(6) Emissions intensity of production
Carbon tax	-0.311	-5.150**	-4.852	-0.883*	-11.923**	6.005
	(0.274)	(1.984)	(4.137)	(0.369)	(3.223)	(5.183)
Carbon tax × Multinational spread				1.122†	13.277†	-21.282**
				(0.578)	(6.767)	(8.212)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific time trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	431,808	431,808	431,808	431,808	431,808	431,808
Adjusted R-squared	0.696	0.636	0.998	0.696	0.636	0.998

Notes. The unit of analysis is plant-month. Standard errors are clustered at the parent firm level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). The stacked DID design follows Cengiz et al. (2019). In this additional estimation, we cluster standard errors at the parent firm level.

Appendix S17. Estimating the effect of carbon taxes across countries on plant shutdown using stacked DID

	(1) Shutdown	(2) Shutdown
Carbon tax	1.046	2.592**
	(0.870)	(0.905)
Carbon tax × Multinational spread		-2.849**
		(0.989)
Control variables	Yes	Yes
Plant fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Country-specific time trends	Yes	Yes
Observations	147,552	147,552
Pseudo R-squared	0.329	0.329

Notes. The unit of analysis is plant-month. Standard errors are clustered at the plant level and reported in parentheses (** p<0.01, * p<0.05, † p<0.1). The stacked DID design follows Cengiz et al. (2019). The dependent variable, *Shutdown*, is an indicator set to one if the steel production of a plant is zero in a given year-month and zero otherwise. As the dependent variable is a non-negative binary variable with a distribution containing several zeros, a Poisson Pseudo-Maximum Likelihood (PPML) estimator is employed (Chen & Roth, 2024; Correia et al., 2020; Wooldridge, 1999, p. 82). The number of observations in this analysis is smaller than in the main manuscript because PPML systematically detects separated observations and removes them from estimation for correct inference.

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