Emission Trading and Overlapping Environmental Support: Installation-level Evidence from the EU ETS

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National Bank of Belgium, October 3, 2024

Motivation

- EU Emissions Trading System (EU ETS) **creates carbon price**
  - Market for tradeable emission permits with progressively tightening cap on annual emissions of large emitters
  - Extensively studied (Fabra and Reguant, 2014; Calel and Dechezleprêtre, 2016; Calel, 2020; Abrell et al., 2022; Dechezleprêtre et al., 2023; Colmer et al., 2024)

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- Increasing number of environmental support policies at **national level**
  - Evidence on effects of some policies in isolation (Martin et al., 2014; Abrell and Kosch, 2022; Ferrara and Giua, 2022; Gerster and Lamp, 2024; Basaglia et al., 2024)

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- Interaction between EU ETS and overlapping national support understudied
  - Simulation-based evidence (Anke et al., 2020; Delarue and Van den Bergh, 2016; Bruninx et al., 2020)
  - **Empirical evidence: this paper**

Motivation

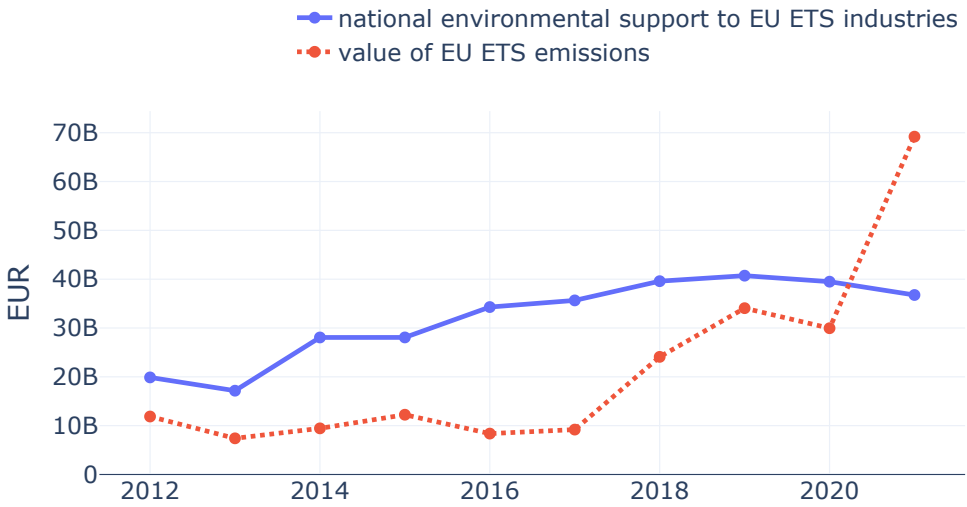
"In the first half of 2017, we decided to retrofit our hard coal-fired power plants Eemshaven and Amer 9 for co-firing with biomass. The Dutch state approved subsidies of up to €2.6 billion for the two plants."

RWE AG, annual report 2017

"The [Memorandum of Understanding] states the commitment of ArcelorMittal and the Government of Spain to transition towards a decarbonised steel industry. [...] The Government of Spain is exploring regulatory instruments to support the industry in the transition process, such as compensation programmes for electricity-intensive industries, tools to promote improved energy efficiency [...]."

ArcelorMittal, press release 13/07/2021

Motivation


national environmental support to EU ETS industries
value of EU ETS emissions
EUR
70B
60B
50B
40B
30B
20B
10B
0
2012
2014
2016
2018
2020

Preview of results

- Exploit regulatory tightening of the EU ETS in 2017 as quasi-experiment
  - On average least efficient installations reduced emissions by 24% compared to most efficient installations after the tightening
  - Considerable effect heterogeneity across sectors (36% in the power sector, 7% in the manufacturing sector)

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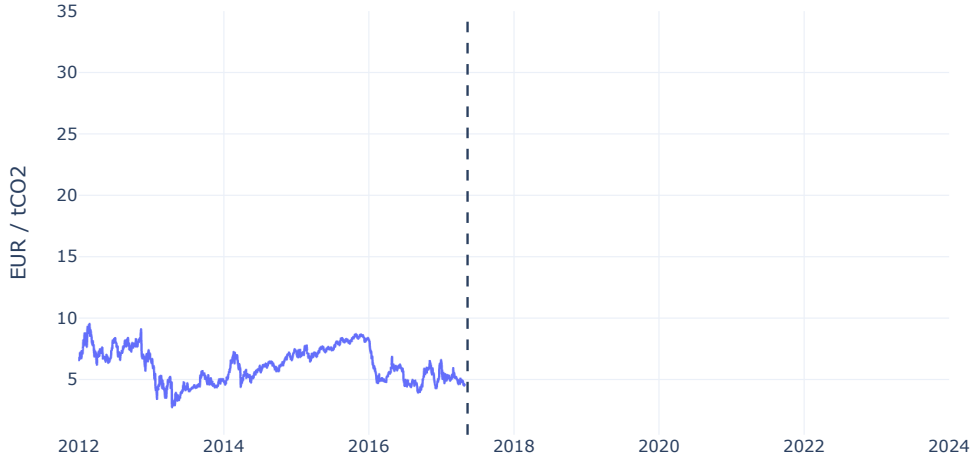
  - On average least efficient installations reduced emissions by 24% compared to most efficient installations after the tightening
  - Considerable effect heterogeneity across sectors (36% in the power sector, 7% in the manufacturing sector)
- National environmental support interacts with tightening of the EU ETS
  - $\pm$ 30 p.p. stronger emission reduction in countries with high levels of renewable energy support to power producers
  - $\pm$ 10 p.p. weaker emission reduction in country-industries with high levels of compensation for energy-intensive manufacturing industries

Outline

The Effect of the EU ETS's Regulatory Tightening

Regulatory tightening of the EU ETS



Regulatory tightening of the EU ETS

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Carbon Price Exposure

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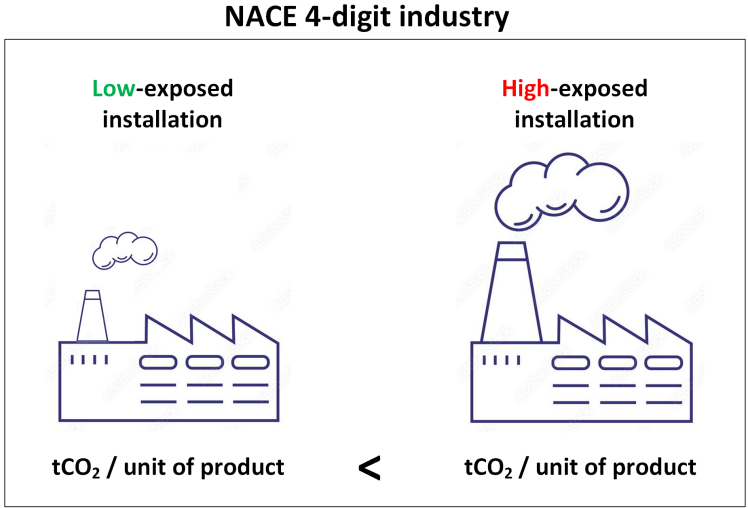

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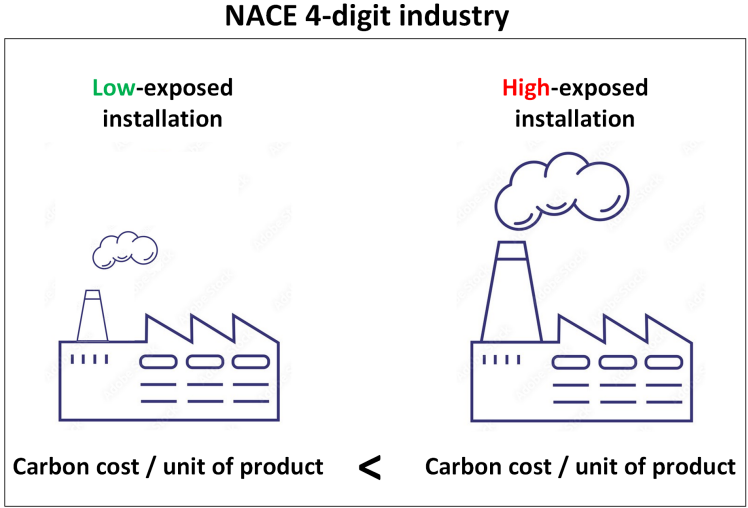

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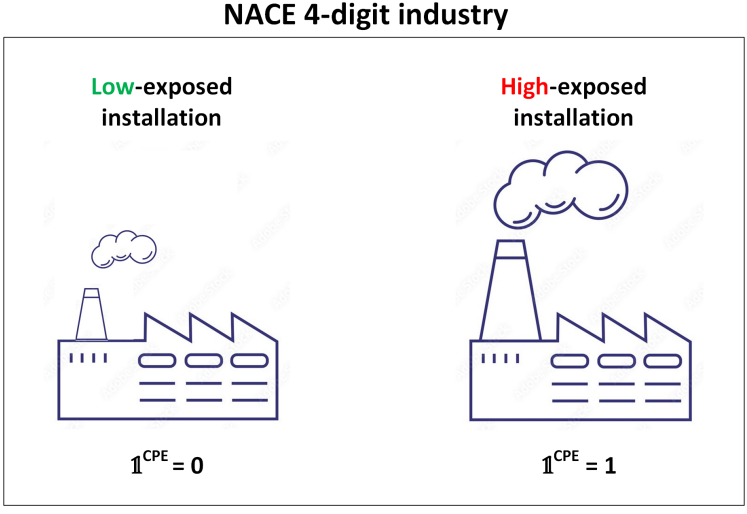

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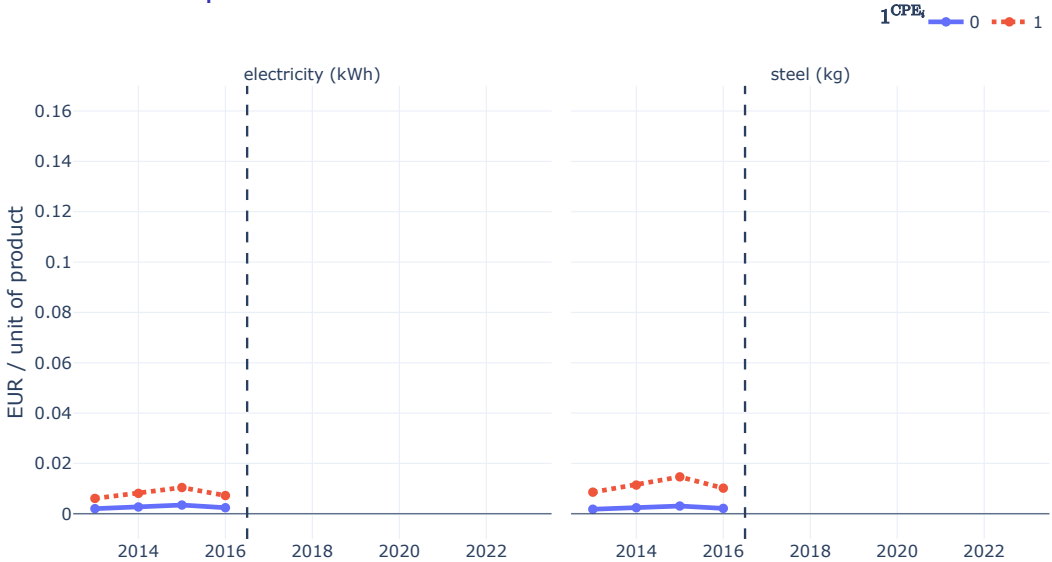
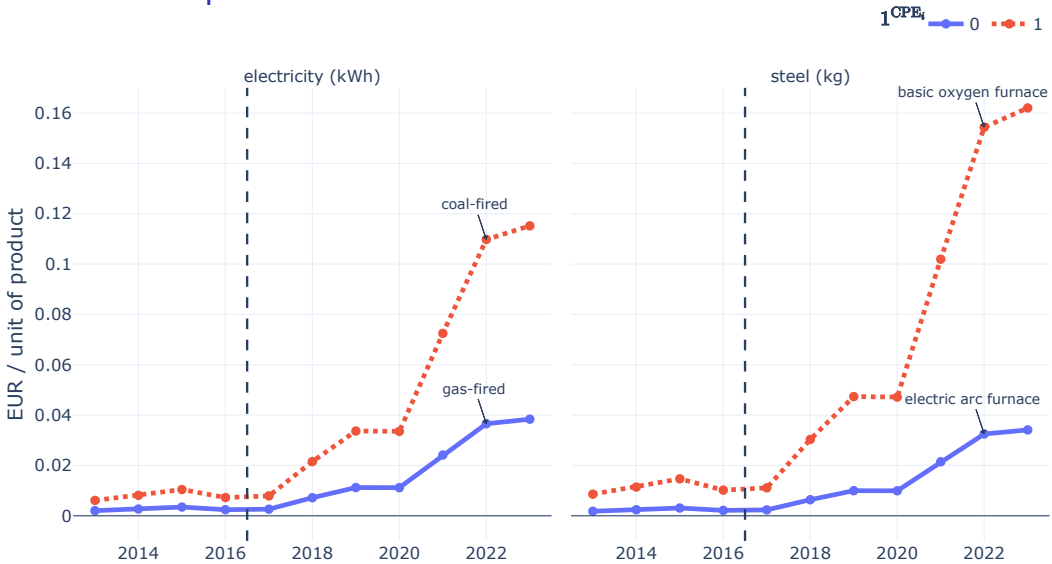


Carbon Price Exposure



Empirical specification

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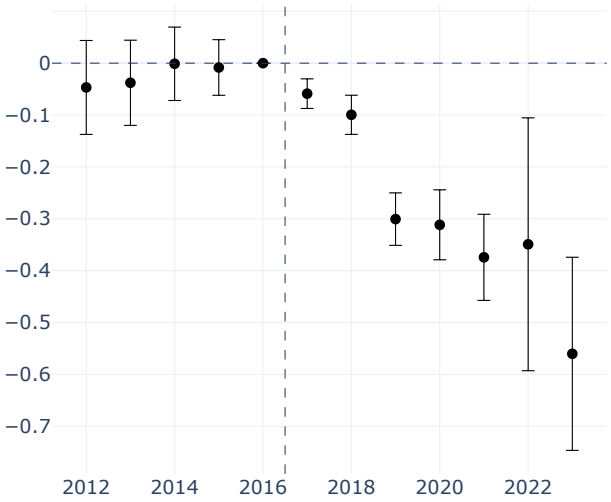
$$\text{Emissions}_{it} = \beta_0 + \sum_{t \neq 2016} \beta_1^s \times \mathbb{1}_{t=s}^{\text{year}} \times \mathbb{1}^{\text{CPE}_i} + X_{it} + \lambda_i + \tau_t + \epsilon_{it}, \tag{1}$$

where

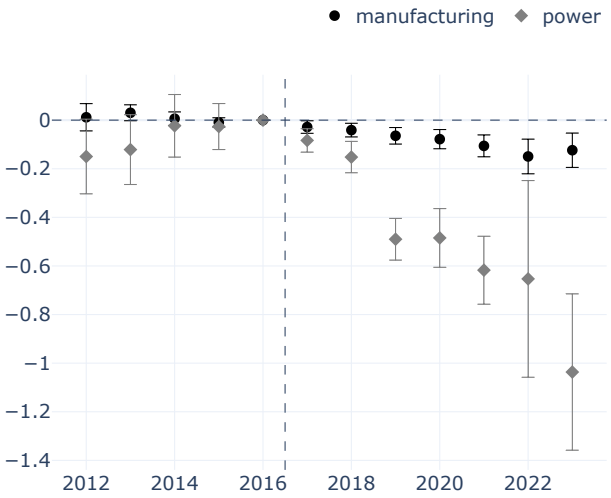
- $\mathbb{1}^{\text{CPE}_i}$ carbon price exposure indicator (1 = high, 0 = low),
- $\mathbb{1}_{t=s}^{\text{year}}$ year dummies,
- $\beta_1^s \approx$ percentage difference in emissions of high-exposed installations compared to low-exposed installations, relative to 2016 levels,
- X_{it}, λ_i, τ_t control variables, installation and year fixed effects

The effect of the carbon price shock (full sample) table



- Common trends before the carbon price shock
- 24% average emission reduction of high-exposed compared to low-exposed installations after 2017

The effect of the carbon price shock (power versus manufacturing) table



- Common trends before the carbon price shock in both subsamples
- Average emission reductions of high-exposed compared to low-exposed installations:
  - 7% in manufacturing sector
  - 36% in power sector

Interactions with National Environmental Support

Quantifying national environmental support

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- EU State aid control generally prohibits aid, defined

  "as an advantage in any form whatsoever conferred by national public authorities to undertakings on a selective basis"[1]

[1] https://competition-policy.ec.europa.eu/state-aid/overview_en

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  "due to the, for example, presence of externalities or other market failures"[2]

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- EU transparency rules require detailed reporting by member states on aid objective, type of instrument, support amounts, and beneficiaries

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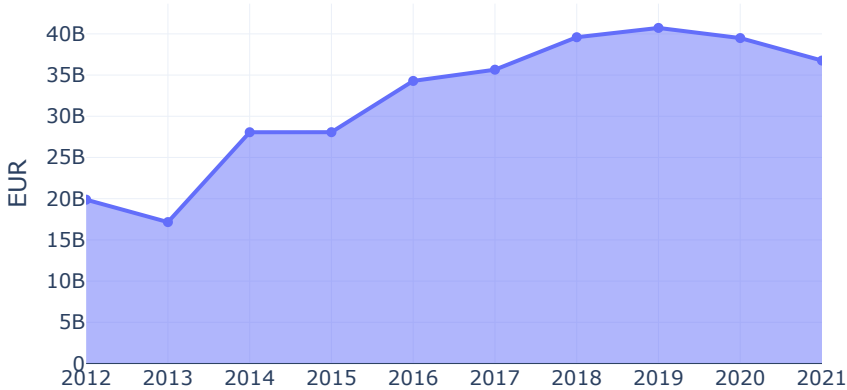

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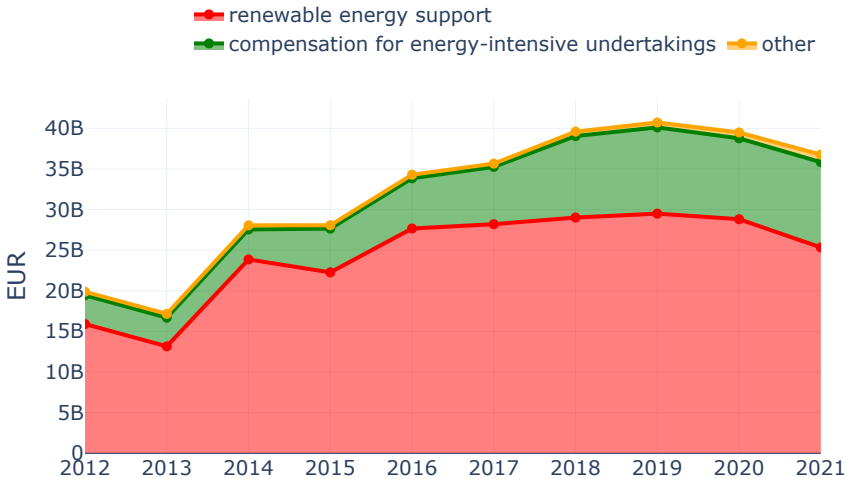


Main national environmental support categories examples

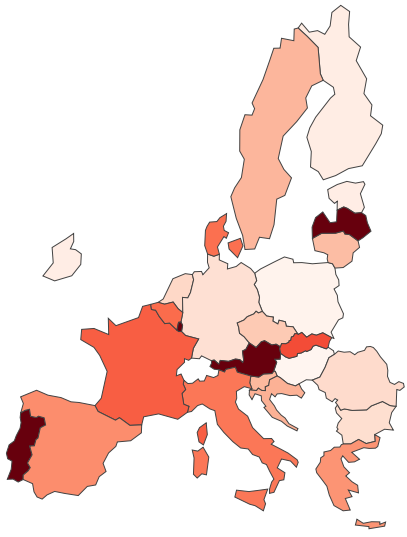
Renewable Energy Support

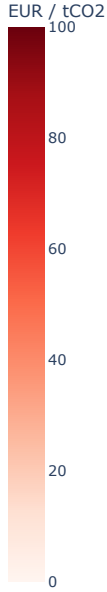
- incentivises production of electricity from renewable sources (wind, solar, biomass)
- e.g., feed-in-tariffs, renewable energy auctions, renewable energy certificates
- on average EUR 40–50 per tCO_2

Compensation for Energy-Intensive Undertakings

- financial support to shield against high energy costs
- e.g., direct transfers or energy tax reductions
- on average EUR 5–10 per tCO_2

Renewable Energy Support (power producers)





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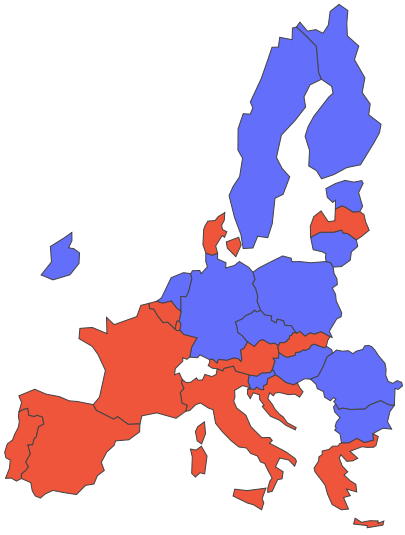

Renewable Energy Support (power producers) table

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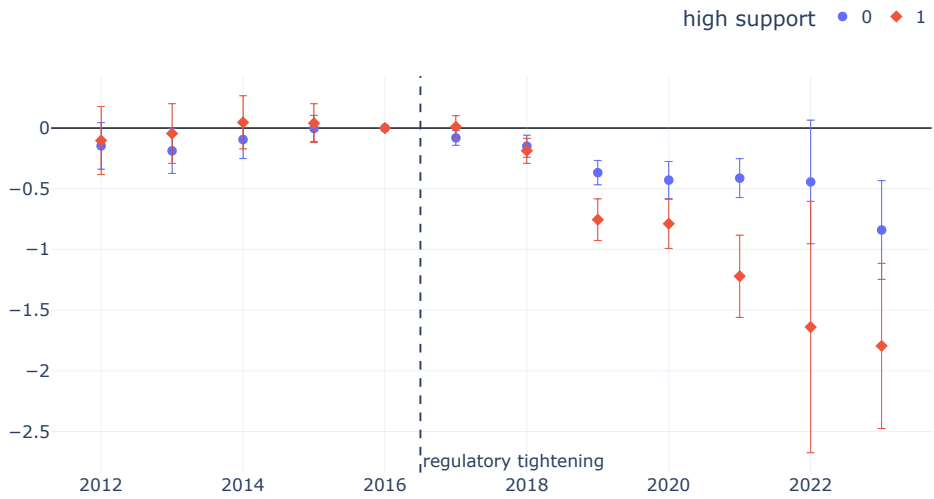

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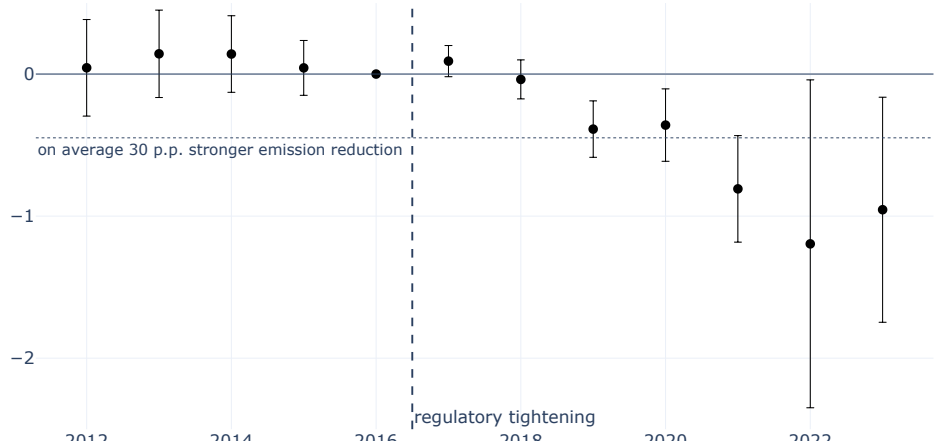

Compensation for Energy-Intensive Undertakings (manufacturing) table

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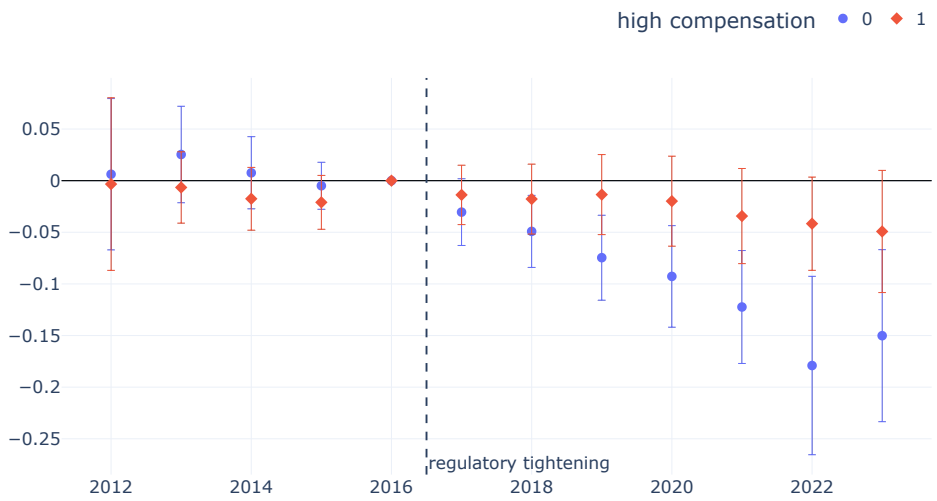

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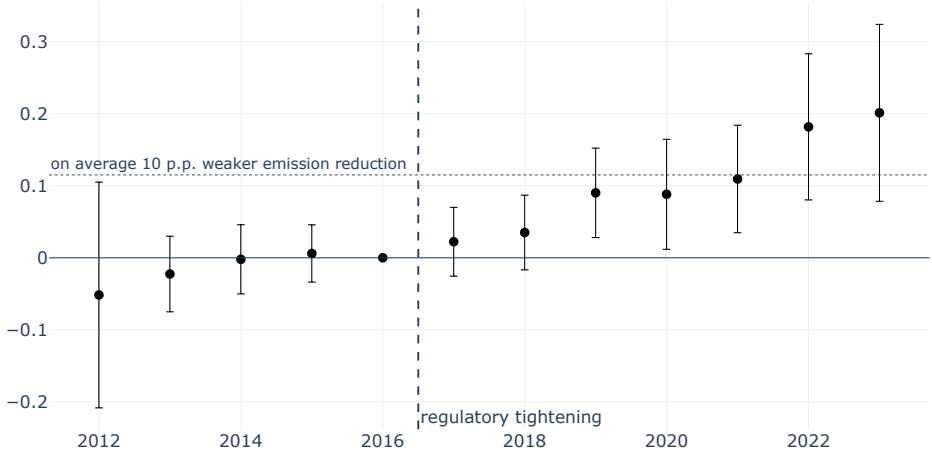

Robustness

- Account for time-varying country-specific or country-industry-specific shocks table

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- Electricity price controls table

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  - 36% for power producing installations
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- Significant **interactions with overlapping national environmental support**
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Appendix

Free allocation methodology

- Initial free allocation

$$F_i = \text{Benchmark}_p^a \times \text{CLEF}_p^a \times \text{HAL}_i, \tag{2}$$

where HAL_i is the historical activity level (output in units of product p)[3]

- Emission intensity

$$\text{CPE}_i = \frac{\text{HEL}_i}{\text{HAL}_i} \tag{3}$$

$$= \text{Benchmark}_p^a \times \text{CLEF}_p^a \times \frac{\text{HEL}_i}{F_i}, \tag{4}$$

where HEL_i is the historical emission level (in tCO_2)

[3] https://eur-lex.europa.eu/eli/dec/2011/278/oj

Sample description

Sample	Full	Power	Manufacturing
Observations	53,662	15,131	38,531
Firms	3,033	727	2,356
Installations	4,609	1,283	3,326
NACE 4-digit industries	70	1	69
Activities	24	1	23
Countries	27	27	26
Annual installation-level emissions (tCO_2)			
Average	289,099	656,414	144,855
Median	26,845	115,610	19,209
Standard deviation	1,182,877	2,023,869	516,179
Annual firm-level emissions (tCO_2)			
Average	439,392	1,154,370	204,552
Median	27,103	148,284	19,054
Standard deviation	2,490,333	4,762,762	719,143

Empirical specifications

- difference-in-differences

$$\begin{aligned}\text{Emissions}_{it} = \beta_0 + X_{it} + \lambda_i + \tau_t + \epsilon_{it} \\ + \beta_1 \times \text{Post}_t \times \mathbb{1}^{\text{CPE}_i}\end{aligned} \tag{5}$$

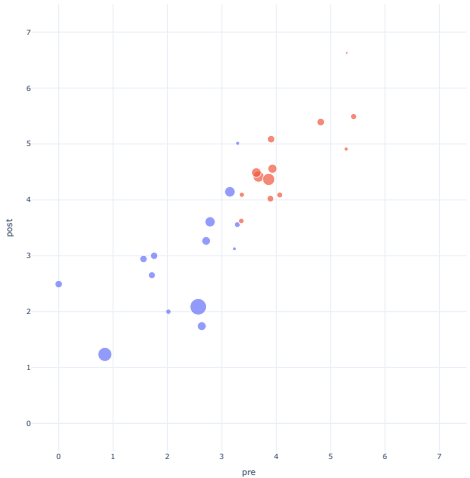
- triple difference

$$\begin{aligned}\text{Emissions}_{it} = \beta_0 + X_{it} + \lambda_i + \tau_t + \epsilon_{it} \\ + \beta_1 \times \text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \\ + \beta_2 \times \text{Post}_t \times \mathbb{1}^{\alpha}_{cj} \\ + \beta_3 \times \text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\alpha}_{cj}\end{aligned} \tag{6}$$

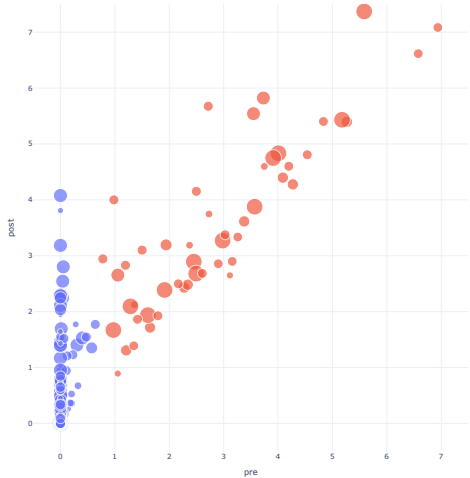
Examples of state aid cases back

- renewable energy support
  - SA.33134: "Green certificates for promoting electricity from renewable sources" (Romania)
  - SA.34411: "SDE+" (Netherlands)
  - SA.49918: "Multi-technology tender 2018-2019" (Denmark)
- compensation for energy-intensive undertakings
  - SA.34287: "Energy and CO2 tax reliefs" (Sweden)
  - SA.41381: "Relief from the EEG surcharge for companies in NACE sectors 25.50 and 25.61" (Germany)
  - SA.41981: "Relief from indirect CO2 costs in electricity in Lithuania" (Lithuania)

Environmental support intensity before and after the carbon price shock



renewable energy support



compensation for energy-intensive undertakings

Carbon price shock back

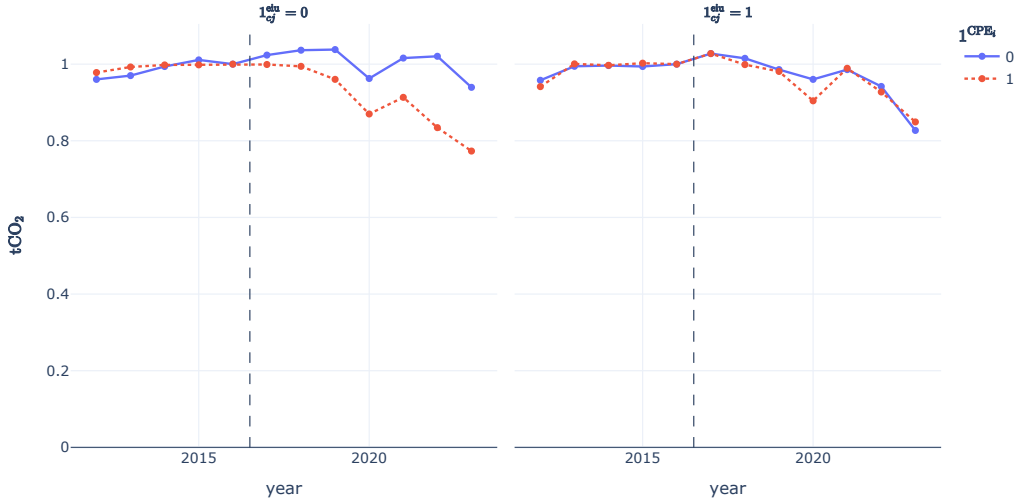
	(1)	(2)	(3)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.279***	-0.067***	-0.449***
	(0.031)	(0.017)	(0.051)
Sample	Full	Manufacturing	Power
Fixed effects	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}
Energy price controls	Yes	Yes	Yes
Cluster variable	Installation	Installation	Installation
Clusters	4,967	3,050	1,247
Observations	57,986	35,366	14,732
Pseudo R^2	0.962	0.981	0.939
RMSE	0.386	0.276	0.419

Renewable energy support

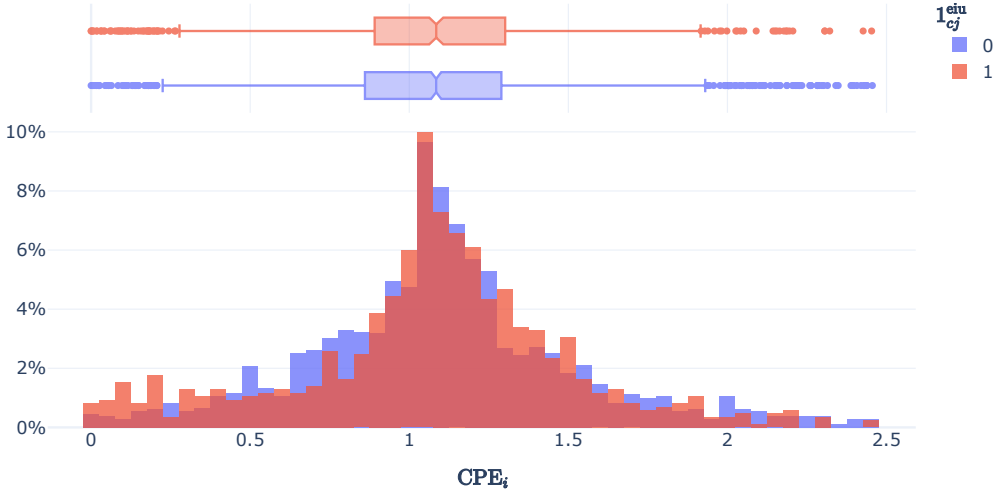
back

	(1)	(2)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.324***	-0.472***
	(0.057)	(0.069)
$\text{Post}_t \times \mathbb{1}^{\text{res}}_{cj}$	0.086	
	(0.070)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{res}}_{cj}$	-0.485***	-0.395***
	(0.096)	(0.105)
Fixed effects	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}, τ^2_{tc}
Energy price controls	Yes	Yes
Cluster variable	Installation	Installation
Clusters	1,247	1,247
Observations	14,732	14,727
Pseudo R^2	0.941	0.945
RMSE	0.414	0.402

Compensation for energy-intensive undertakings – average annual emissions



Compensation for energy-intensive undertakings – carbon price exposure



Compensation for energy-intensive undertakings back

	(1)	(2)	(3)	(4)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.106***	-0.107***	-0.115***	-0.096***
	(0.025)	(0.025)	(0.023)	(0.026)
$\text{Post}_t \times \mathbb{1}^{\text{eiu}}_{cj}$	-0.051**	-0.049**	-0.031	
	(0.024)	(0.023)	(0.043)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{eiu}}_{cj}$	0.101***	0.115***	0.133***	0.077**
	(0.037)	(0.037)	(0.030)	(0.032)
Fixed effects	λ_i, τ_t	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}, τ^2_{tc}	λ_i, τ^3_{tjac}
Energy price controls	No	No	No	No
Cluster variable	Installation	Installation	Installation	Installation
Clusters	3,109	3,047	3,047	2,879
Observations	36,059	35,339	35,339	33,273
Pseudo R^2	0.979	0.981	0.982	0.985
RMSE	0.283	0.275	0.266	0.251

Horse race

	(1)	(2)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.086***	-0.416***
	(0.026)	(0.060)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{LSP}^{\text{eff}}_{cj}}$	-0.017	-0.246
	(0.048)	(0.229)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{LSP}^{\text{eiu}}_{cj}}$	0.086***	
	(0.033)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{LSP}^{\text{res}}_{cj}}$		-0.448***
		(0.100)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{LSP}^{\text{rnd}}_{cj}}$	-0.089	0.227
	(0.069)	(0.260)
Sample	Manufacturing	Power
Cluster variable	Installation	Installation
Clusters	2,872	1,247
Observations	33,200	14,727
Pseudo R^2	0.985	0.945
RMSE	0.251	0.402

Alternative fixed effects back

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.440***	-0.440***	-0.056***	-0.057***	-0.678***	-0.669***
	(0.060)	(0.037)	(0.018)	(0.018)	(0.081)	(0.053)
Sample	Full	Full	Manufacturing	Manufacturing	Power	Power
Fixed effects	λ_f, τ^3_{tjac}	λ_i, τ^3_{tjac}	λ_f, τ^3_{tjac}	λ_i, τ^3_{tjac}	λ_f, τ^3_{tjac}	λ_i, τ^3_{tjac}
Energy price controls	Yes	Yes	Yes	Yes	Yes	Yes
Cluster variable	Firm	Installation	Firm	Installation	Firm	Installation
Clusters	2,573	4,050	1,682	2,476	714	1,248
Observations	47,950	47,697	29,084	29,084	14,980	14,739
Pseudo R^2	0.811	0.963	0.900	0.980	0.736	0.945
RMSE	0.934	0.378	0.544	0.248	0.978	0.401

Continuous environmental support measure

back

	(1)	(2)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.094***	-0.465***
	(0.019)	(0.076)
$\text{Post}_t \times \overline{\text{ESP}}^{\alpha}_{cj}$	-0.002**	
	(0.001)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \overline{\text{ESP}}^{\alpha}_{cj}$	0.003**	-0.007***
	(0.001)	(0.002)
Sample	Manufacturing	Power
Fixed effects	λ_i, τ^1_{tja}, τ^2_{tc}	λ_i, τ^1_{tja}, τ^2_{tc}
Energy price controls	No	Yes
Cluster variable	Installation	Installation
Clusters	2,746	1,229
Observations	32,365	14,533
Pseudo R^2	0.983	0.945
RMSE	0.239	0.403

GVA-based support intensity indicator – renewable support

back

	(1)	(2)	(3)	(4)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.344***	-0.475***	-0.339***	-0.512***
	(0.068)	(0.074)	(0.061)	(0.066)
$\text{Post}_t \times \mathbb{1}^{\text{res}}_{cj}$	0.161*		0.117	
	(0.085)		(0.071)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{res}}_{cj}$	-0.381***	-0.510***	-0.305***	-0.345***
	(0.142)	(0.153)	(0.099)	(0.107)
Fixed effects	λ_f, τ^1_{tja}	λ_f, τ^1_{tja}, τ^2_{tc}	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}, τ^2_{tc}
Energy price controls	Yes	Yes	Yes	Yes
Cluster variable	Firm	Firm	Installation	Installation
Clusters	713	713	1,247	1,247
Observations	14,961	14,968	14,732	14,727
Pseudo R^2	0.728	0.733	0.939	0.945
RMSE	0.988	0.986	0.418	0.402

GVA-based support intensity indicator – compensation

back

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.113***	-0.121***	-0.100***	-0.120***	-0.131***	-0.107***
	(0.037)	(0.034)	(0.037)	(0.036)	(0.032)	(0.037)
$\text{Post}_t \times \mathbb{1}^{\text{eiu}}_{cj}$	-0.043	0.035		-0.038	0.020	
	(0.031)	(0.058)		(0.031)	(0.059)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{eiu}}_{cj}$	0.075*	0.083**	0.066	0.076*	0.087**	0.054
	(0.043)	(0.039)	(0.043)	(0.042)	(0.037)	(0.043)
Fixed effects	λ_f, τ^1_{tja}	λ_f, τ^1_{tja}, τ^2_{tc}	λ_f, τ^3_{tjac}	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}, τ^2_{tc}	λ_i, τ^3_{tjac}
Energy price controls	No	No	No	No	No	No
Cluster variable	Firm	Firm	Firm	Installation	Installation	Installation
Clusters	2,138	2,137	1,988	3,040	3,040	2,875
Observations	35,798	35,776	33,293	35,270	35,270	33,231
Pseudo R^2	0.902	0.903	0.899	0.981	0.982	0.985
RMSE	0.567	0.564	0.592	0.276	0.266	0.251

Estimation by OLS back

	(1)	(2)	(3)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.161***	-0.071***	-0.438***
	(0.028)	(0.021)	(0.068)
Sample	Full	Manufacturing	Power
Fixed effects	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}
Energy price controls	Yes	Yes	Yes
Cluster variable	Installation	Installation	Installation
Clusters	4,599	2,858	1,230
Observations	48,384	30,153	13,548
R^2	0.889	0.910	0.846
RMSE	0.748	0.542	0.998

Electricity price controls back

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i}$	-0.100***	-0.104***	-0.086***	-0.097***	-0.105***	-0.090***
	(0.024)	(0.021)	(0.025)	(0.023)	(0.021)	(0.026)
$\text{Post}_t \times \mathbb{1}^{\text{eiu}}_{cj}$	-0.064***	-0.024		-0.044**	-0.027	
	(0.024)	(0.037)		(0.021)	(0.041)	
$\text{Post}_t \times \mathbb{1}^{\text{CPE}_i} \times \mathbb{1}^{\text{eiu}}_{cj}$	0.113***	0.121***	0.092***	0.105***	0.119***	0.074**
	(0.037)	(0.031)	(0.033)	(0.034)	(0.028)	(0.032)
Fixed effects	λ_f, τ^1_{tja}	λ_f, τ^1_{tja}, τ^2_{tc}	λ_f, τ^3_{tjac}	λ_i, τ^1_{tja}	λ_i, τ^1_{tja}, τ^2_{tc}	λ_i, τ^3_{tjac}
Energy price controls	Yes	Yes	Yes	Yes	Yes	Yes
Cluster variable	Firm	Firm	Firm	Installation	Installation	Installation
Clusters	2,143	2,143	1,991	3,047	3,047	2,879
Observations	35,845	35,845	33,335	35,339	35,339	33,273
Pseudo R^2	0.902	0.903	0.899	0.981	0.982	0.985
RMSE	0.567	0.564	0.592	0.275	0.266	0.251

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