Mind the emission gap

Policy Stringency Matters for Emission Reductions in the EU ETS

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Motivation

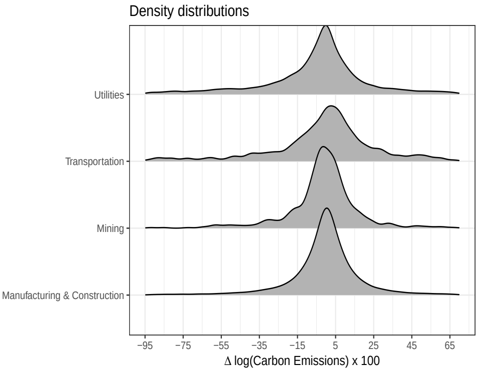
Emissions and allowance, and regulatory pressure

Recent studies often find only a modest relationship between existing measures of *regulatory pressure*, typically defined as the difference between allocated allowances and verified emissions.

Figure: Left plot: change in emissions compared to 2013 across major sectors (Manufacturing and construction, Mining, Transportation, and Utilities) during Phase III of the EU ETS for a panel-balanced sample. Right plot: change in free allowance allocations compared to 2013 over the same period. The sample comprises data from 2013/01/01 to 2021/12/31 in yearly frequency. The panel-balanced sample includes 64.4% (2,520 of 3,913) of the firms from the full database.

Lack of emissions reductions due to...

- **Financial constraints:** Bartram et al. (2022), Carradori et al. (2023)
- **Technological barriers and industry nature:** Calel (2020), Pinkse et al. (2024)
- **Organizational constraints:** Ability to access external funding (Bloom et al., 2010; Martin et al., 2012)



Research question and our contribution

What is in this paper and contribution

- The conventional focus on *current-year compliance* overlooks the forward-looking nature of firms' decisions under market-based regulation.
- Propose a theoretically grounded definition of firm-specific regulatory pressure (compliance gap).
- Examine how policy stringency affects changes in carbon emissions in a panel setup, controlling for firm-level characteristics (fin and tech)
- Simulate emissions through 2030 and assess Fit for 55 alignment

What do we find?

- Firm-level emission reductions are strongly influenced by individual policy stringency across sectors.
- This effect persists after controlling for financial constraints and sector-specific tech. factors.
- Our stringency measure, which accounts for expectations about net-demand and emission prices, is robust to alternative definitions.
- Simulations show CBAM raises stringency in exposed sectors but falls short of Fit for 55. Meeting the target requires a €125 price from 2022.

Policy stringency

Motivating the construction of the 'policy stringency' metric

Abatement decision is an intertemporal problem ▸ model

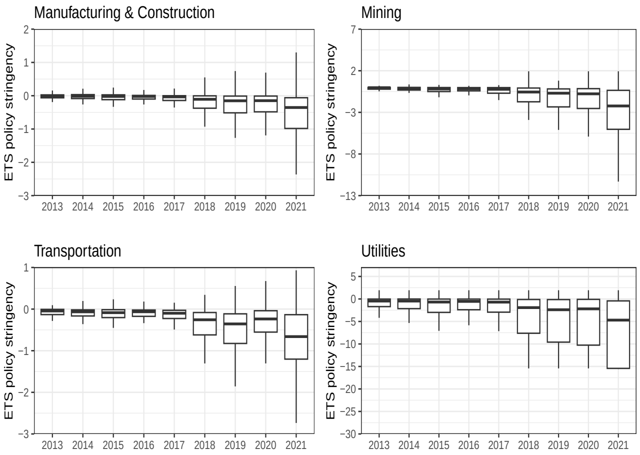
$$PS_{i,t} = \mathbb{E}_t \left(\frac{1}{T} \sum_{k=1}^{T} \left[\frac{1}{\text{Sales}_t} (a_{i,t+k} - e_{i,t+k}) \times P_{t+k} \right] \right) \quad (1)$$

A concrete example of average annual expected compliance cost: ▸ robustness

1. $T = 10$, the 'typical' foresight horizon
2. $\mathbb{E}_t \left[a_{i,t+k} \right] = a_{i,t+k}.$, free allowances decline at 4.4% rate after 2021
3. $\mathbb{E}_t \left[e_{i,t+k} \right] = e_{i,t}$, emissions remain at current level
4. $\mathbb{E}_t \left[P_{t+k} \right] = P_t$, carbon price changes purely random (no trend)

$$PS_{i,t} = \frac{1}{10} \sum_{k=1}^{10} \left[\frac{(a_{i,t+k} - e_{i,t}) \times P_t}{\text{Sales}_{i,t}} \right] \quad (2)$$

An illustration of policy stringency



Annual expected compliance cost as a fraction of its current sales

Analysis

Empirical analysis

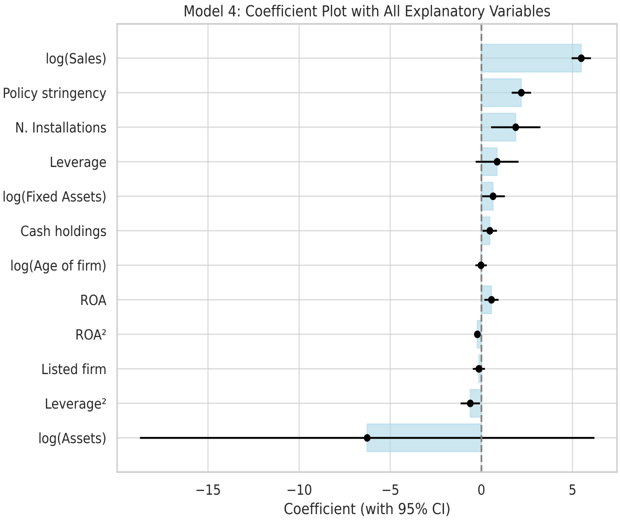
Firms periodically revise reduction decisions based on updated expectations:

$$\Delta \log \mathrm{E}_{i,t} = \beta_1' PS_{1i,t-1} + \boldsymbol{\beta_2}'\mathbf{X}_{2i,t-1} + \boldsymbol{\beta_3}'\mathbf{X}_{3i,t} + \mu_t + \gamma_s + \zeta_c + \gamma_s \times \mu_t + \varepsilon_{i,t}$$

Change in Emissions ($\Delta \log \mathrm{E}_{i,t}$) depends on:

- Policy stringency PS
- Financial (lagged): leverage, fixed assets, ROA, cash holding, listed dummy
- Scale of operations: Δ sales, total assets, Δ nr. installations, age
- μ_t and ζ_c time and country fixed effects.
- γ_s NACE two-digit sector fixed effects
- $\gamma_s \times \mu_t$ NACE two-digit sector-time interaction fixed effects

Full sample analysis



Sectorial analysis

	Dependent variable: $\Delta\log(e)\times 100$				
Variables	Full sample	Mining (B)	Industry (C + F)	Utilities (D+E)	Transportation (H)
Policy stringency					
ETS Policy stringency	2.19^{***}	5.77^{***}	5.65^{***}	1.99^{***}	4.71^{*}
	(0.27)	(1.74)	(0.82)	(0.34)	(2.61)
Num. obs.	27,177	495	17,539	8,302	841
R^2	0.12	0.27	0.11	0.10	0.34
AIC	258,947.39	4,469.58	159,074.88	83,713.85	8,363.93
BIC	262,305.33	4,818.55	161,266.63	84,331.98	8,733.23
Log Lik.	-129,064.70	-2,151.79	-79,255.44	-41,768.92	-4,103.97

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

▸ Extra analysis: which family of factors matter the most?

Decomposing the policy stringency metric

$$\frac{1}{10}\sum_{k=0}^{9}\left[\frac{(a_{i,t+k}-e_{i,t})\times P_t}{\text{Sales}_{i,}}\right] = \frac{P_t}{\text{Sales}_{i,t}}\Bigg(\underbrace{(a_{i,t}-e_{i,t})}_{\substack{\text{current allowance}\\\text{to emission gap}}} + \underbrace{\frac{1}{9}\sum_{k=1}^{9}(a_{i,t+k}-e_{i,t})}_{\substack{\text{forward looking}\\\text{allowance to emission gap}}}\Bigg)$$

Constructing the policy stringency metric:

1. Current allowance-to-emission gap (ECB 2022, Carradori 2023): $(a_{i,t} - e_{i.t})$
2. Cost of current allowance-to-emission gap: $P_t(a_{i,t} - e_{i,t})$
3. Current policy stringency: $\frac{P_t}{\text{Sales}_{i,t}}[(a_{i,t} - e_{i,t})]$

Decomposing policy stringency

	Dependent variable: $\Delta\log(e)\times 100$			
Policy stringency definition	Current A2E	Cost CA2E	Current PS	Policy stringency
Current gap	0.63***			
	(0.18)			
Cost current gap		0.70***		
		(0.19)		
Current policy stringency			1.33***	
			(0.25)	
Current and future policy stringency				2.19***
				(0.27)
Num. obs.	27,177	27,177	27,177	27,177
R^2	0.12	0.12	0.12	0.12
AIC	259,013.00	259,012.69	258,991.92	258,947.39
BIC	262,370.94	262,370.63	262,349.86	262,305.33
Log Lik.	-129,097.50	-129,097.35	-129,086.96	-129,064.70

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

Impact of the EU "Fit for 55"

Counterfactual analysis: Gradual phase-out free allowances

- How the planned phase-out of FA alters regulatory pressure?
- Assess whether these are sufficient to meet emission reduction targets

How do we construct counterfactual analysis:

- Translate Fit for 55 target into an implied average annual reduction rate
- Annual decline of approximately 2% in aggregate emissions 2021-2030
- Assumed constant carbon price of €80
- Identify CBAM affected firms

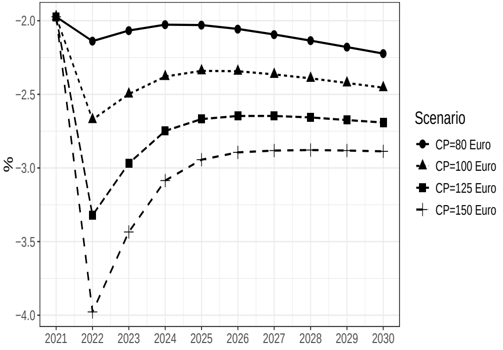
Main result:

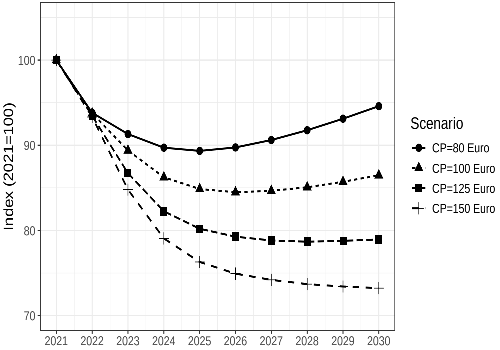
Illustration counterfactual CBAM

- Phase-out insufficient to reach annual aggregate emission reduction 2%

Counterfactual analysis: Higher carbon prices

- Conduct "what-if" experiment, simulating firm-level emissions under four allowance price scenarios starting in 2022: €80, €100, €125, and €150





Conclusions

Conclusions

- Firm-level emission cuts shaped by firm-specific policy stringency (PS)
- PS: (allowance-emission) gap, adjusted by price and scaled by sales.
- PS is the main driver of reductions across industries, independent of finance or technology constraints (data: 6,273 EU-ETS firms, 2013–2021).
- Forward-looking component of PS crucial for explaining reductions.
- Counterfactual: CBAM phase-out lowers emissions, but meeting 2030 target requires €125/t carbon price now.

Appendix

Data - EU firms subject to EU ETS scheme (2013-2021)

- Installation-level (i) verified emissions and (ii) allocated allowances (source: EU-ETL):
- Firm-level financial data and characteristics (source: Orbis Bvd):
  - NACE sectoral classification
  - Matching installations to firms (Letout (2021))
  - Total assets, fixed assets ratio
  - Return on assets (ROA)
  - Firm cash holding, debt-to-asset ratio, listing status
  - Firm age, changes in number of installations, geographical location
- Macro variable (Source: LSEG):
  - European Union Allowances carbon price futures (yearly average)

Policy stringency

Mind the compliance gap: firms' emissions reduction decisions

- Firm's compliance problem:

$$\min_{\alpha,\beta} \mathbb{E}\left[\sum_{t=0}^{T} C(\bar{e}_t - e_t(p_t, \bar{e}_t)) + p_t \cdot \beta_t\right] \text{ s.t. } E_T - A_T = \sum_{t=0}^{T} \alpha_t + \sum_{t=0}^{T} \beta_t$$

- Solving, the per-unit cost of compliance at each $t \rightarrow C'(\alpha_t) = p_t$
- At year $t = 0$ the total expected compliance cost for the firm is

$$\sum_{t=0}^{T} \left(\alpha_t + \beta_t\right) \cdot p_t = \sum_{t=0}^{T} (e_t - a_t) \cdot p_t$$

- Firms periodically revise compliance strategies based on updated expectations

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Decomposition

Which family of factors matter the most?

	Excl. Financials	Excl. Stringency	Excl. Sectors	Full model
ETS Policy stringency	2.20*** (0.27)	–	2.32*** (0.22)	2.19*** (0.27)
Financial variables				
Leverage_{t-1}	–	1.03* (0.60)	0.84 (0.61)	0.86 (0.60)
Leverage^2_{t-1}	–	-0.61** (0.27)	-0.64** (0.27)	-0.61** (0.27)
$\text{Cash holdings}_{t-1}$	–	0.45** (0.20)	0.40** (0.20)	0.46** (0.20)
Listed firm (Yes)	–	-0.14 (0.17)	-0.17 (0.17)	-0.14 (0.17)
ROA_{t-1}	–	0.66*** (0.20)	0.51** (0.20)	0.55*** (0.20)
ROA^2_{t-1}	–	-0.24*** (0.09)	-0.19** (0.09)	-0.22** (0.09)
Company-level characteristics				
$\log(\text{Assets})_{t-1}$	-2.59 (6.27)	-9.47 (6.30)	-6.96 (5.89)	-6.27 (6.36)
$\log(\text{Fixed Assets})_{t-1}$	0.40 (0.32)	0.80** (0.32)	0.57* (0.31)	0.64** (0.33)
$\Delta\log(\text{Sales})\times 100$	5.47*** (0.27)	5.41*** (0.27)	5.86*** (0.27)	5.48*** (0.27)
log(Age of firm)	0.12 (0.16)	0.05 (0.16)	0.17 (0.16)	-0.02 (0.16)
ΔN. Installations	1.88*** (0.69)	1.87*** (0.69)	2.08*** (0.71)	1.88*** (0.69)
Num. obs.	27,177	27,177	27,177	27,177
R^2	0.12	0.12	0.08	0.12
AIC	258973.36	259019.79	259285.59	258947.39
BIC	262282.04	262369.52	259679.68	262305.33

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Robustness analysis

Robustness analysis

1. Control for potential endogeneity using instrumental variable model (Baltagi, 2021): similar point estimates
2. Alternative compliance horizons: $H \in \{3, 5, 7\}$; $H = 10$ provides better fit
3. Alternative assumptions on expected carbon prices (perfect foresight): similar results compared to the baseline
4. Accounting for a proxy of banked allowances: shift downward regulatory pressure compared to the baseline specification

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Simulation Fit for 55

Gradual phase-out free allowances

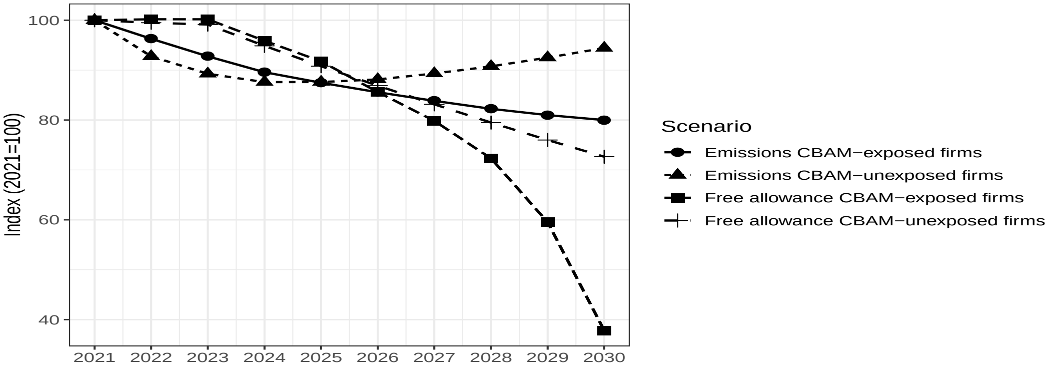

Figure: Projected emissions under CBAM

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Gradual phase-out free allowances

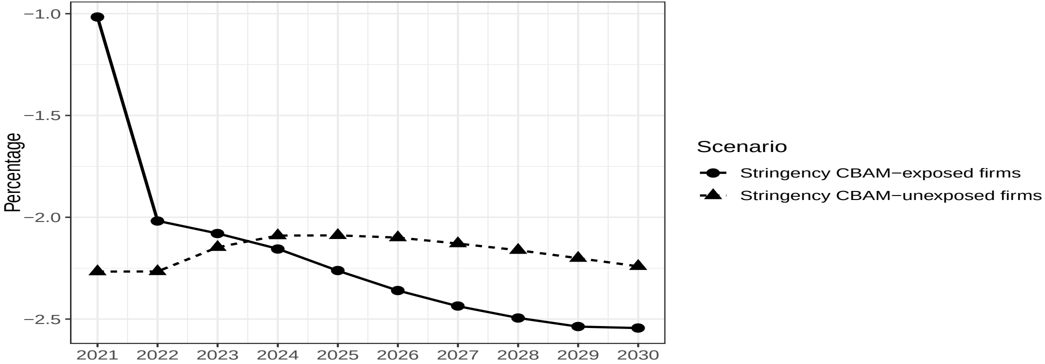

Figure: Policy stringency under CBAM

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