The Global Effects of Carbon Border Adjustment Mechanisms

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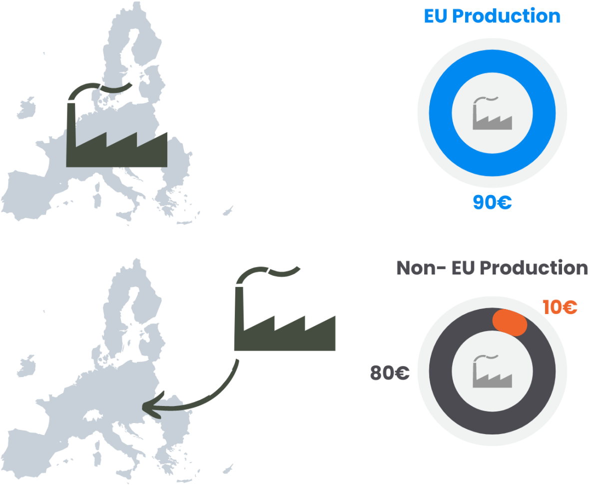
Carbon border adjustment mechanism (CBAM)



EU production is subject to the **EU-ETS***

(Assuming an ETS allowance price of 90€ per tonne of CO2)

Non-EU production is subject to a lower **ETS** and **CBAM certificates**

Three motivations and one concern

- Boost domestic competitiveness
- Curb foreign emissions leakage
- Encourage foreign regulation

- But may disadvantage lower-income trading partners

This paper

- Quantitative analysis of EU/UK CBAM
  - Simple equilibrium framework
  - Microdata on key target sectors
  - Global distributional effects
- Results
  - Competitiveness: domestic profits ↑ by \$2.4B (13%)
  - Leakage: foreign emissions ↓ by 5.8 Mt (43%)
  - Incentives: carbon tax revenue of up to \$251B
  - Incidence: similar for lower-income trading partners

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Literature

- Environmental impacts of trade policy
  Copeland & Taylor 2003, Nordhaus 2015, Böhringer et al. 2016, Kortum & Weisbach 2017, Shapiro 2021, Kortum & Weisbach 2022, Abuin 2024, Bourany 2024, Harstad 2024, Casey et al. 2025, Farrokhi & Lashkaripour 2025, Hsiao 2025
- Leakage and CBAM policy
  Markusen 1975, Copeland & Taylor 1994, 1995, Hoel 1996, Rauscher 1997, Fowlie 2009, Elliott et al. 2010, Fowlie et al. 2016, Kortum & Weisbach 2017, Clausing & Wolfram 2023, Coster et al. 2024

Policy timeline

- **EU CBAM** proposed in 2021
  - Phase-in starting October 1, 2023 with reporting only
  - Full implementation from January 1, 2026 for target sectors
- **UK CBAM** announced in 2023, targeting implementation by 2027
- Discussion in Australia, Brazil, Canada, and Taiwan
- Expansion of Chinese ETS to cover target sectors

Initial target sectors

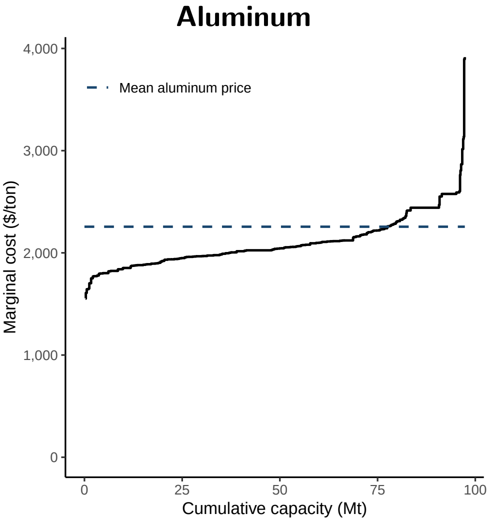
(%)	Trade Intensity	Global Emissions
Aluminum	41	3
Steel	23	11
Electricity	2	33
Fertilizers	60	1
Cement	2	6
Hydrogen	0.1	2

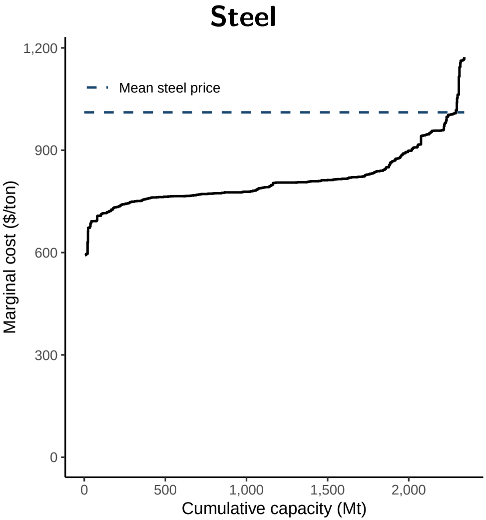
Data

Global data by plant for 2023

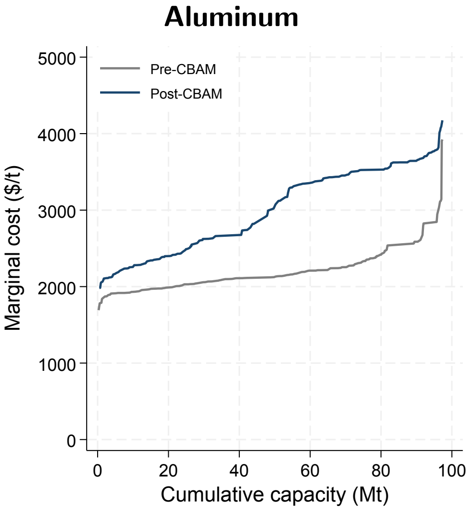
- Aluminum smelters from WoodMac (153 worldwide)
  - Public data and site visits
- Steel mills from Climate TRACE (892 worldwide)
  - Satellite and mill-level sensor data
- Production, capacity, costs, and emissions

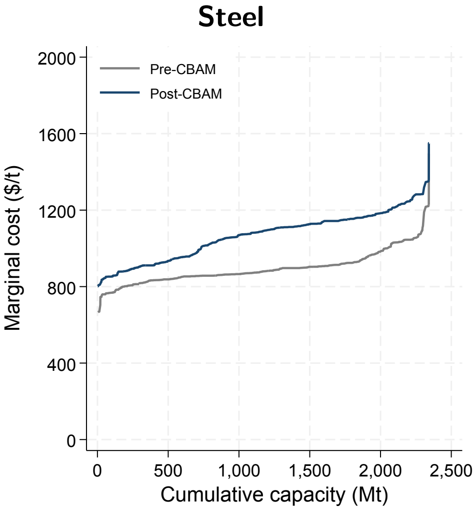
Production costs and capacity



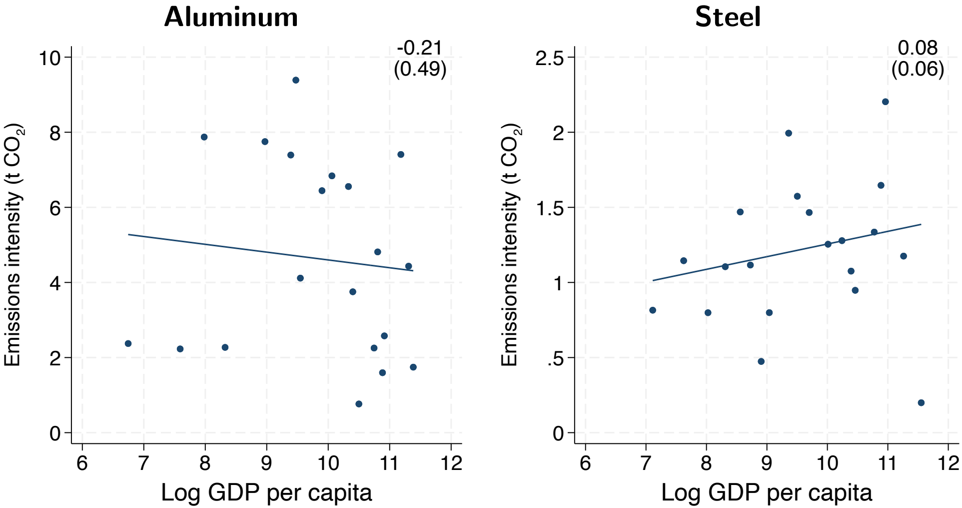


CBAMs add to costs

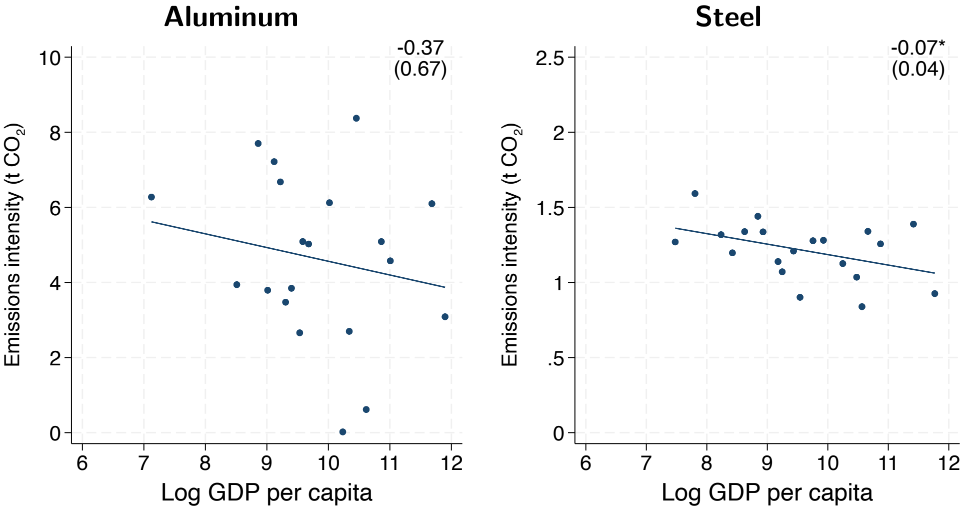




Emissions intensity by income



Controlling for differences in production (primary, scale, SOE, foreign; age)



The emissions-income gradient is relatively flat

Total emissions

	Direct	Indirect
Aluminum	23%	77%
Steel	91%	9%

Electricity emissions vs. income

	Estimate	SE	N	Mean
Elec. Maps (2024)	-3.207	(10.12)	230	314
Ember (2024)	-13.58	(14.25)	196	430
Ang & Su (2016)	-94.59***	(27.91)	54	445
EEA (2023)	-92.33	(68.18)	28	222

Emissions intensity by country

Aluminum

	tCO_2
Kazakhstan	15
South Africa	14
India	14
Australia	13
China	10
Greece	6.8
UAE	6.6
Rest of world	2.9

Steel

	tCO_2
Kazakhstan	2.6
Netherlands	2.5
Slovakia	2.5
Austria	2.5
Ukraine	2.4
South Africa	2.3
China	2.2
Rest of world	1.5

Production by country

Aluminum

	Mt	%
China	49	58
India	5	6
EU + UK	5	5
USA	4	5
Russia	4	5
Canada	3	4
UAE	3	3
Rest of world	12	14

Steel

	Mt	%
China	860	51
EU + UK	153	9
Japan	88	5
USA	86	5
India	76	5
Russia	60	4
South Korea	59	4
Rest of world	290	17

Model

Environmental regulation with global trade

$p_i^R = P - \tau e_i$	carbon tax in **regulated** market R
$p_i^U = P$	no tax in **unregulated** market U
$D(P^*) = S(P^*)$	world market clears at price P (no CBAM)

- Competitiveness: R firms pay τ, but U firms do not
- Leakage: τ raises P, and U firms respond
- Incentives: U government free rides on lower e, higher P

- Incidence: depends on firm **data**

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CBAM pushes sales to U, such that $P^R > P^U$

$$
\begin{aligned}
p_i^R &= \max\{P^R, P^U\} - \tau e_i && \text{R firms choose destination market} \\
p_i^U &= \max\{P^R - \tau e_i, P^U\} && \text{U firms choose subject to \textbf{CBAM}}
\end{aligned}
$$

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D^R(P^{R*}) &= S^R(P^{R*}, P^{U*}) && \text{market R clears at price P^R} \\
D^U(P^{U*}) &= S^U(P^{R*}, P^{U*}) && \text{market U clears at price P^U}
\end{aligned}
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- Competitiveness: τ raises P^R more, helping R firms
- Leakage: τ raises P^U less, hurting U firms
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Empirics

- Demand $D^m(P^m)$ by market m
  - Calibrated elasticity of 0.25 (Söderholm & Ekvall 2020)
- Supply $s_i^m(p_i^m)$ by plant i
  - Using global, plant-level microdata
- Compute welfare: CS^m, PS_i, G^m, E_i

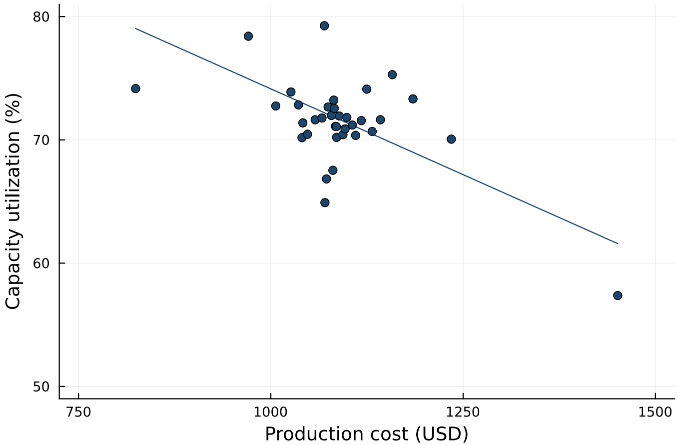
Supply by plant i

$$
\begin{aligned}
u_{i\ell}^m &= \overbrace{\beta(p_i^m - c_i) + \epsilon_i}^{v_i^m} + \epsilon_{i\ell} && \text{choice to operate lines } \ell \\
o_i^m &= \exp(v_i^m)/[1+\exp(v_i^m)] && \text{capacity utilization} \\
s_i^m &= \bar{s}_i o_i^m && \text{production}
\end{aligned}
$$

- Price p_i^m, cost c_i, logit shocks $\epsilon_{i\ell}$, capacity $\bar{s}_i$

- Constant marginal costs: heterogeneity across plants, not across lines (CRS)
- No market power, but have many plants (and firms)

Logit estimation with metals j, countries k



$$\log\left(\frac{o_{ijk}}{1-o_{ijk}}\right) = \beta(P_j - \bar{\tau}_k \bar{e}_{ijk} - c_{ijk}) + \mu_j + \mu_k + \epsilon_{ijk}$$

Counterfactuals

Policy simulations

- EU/UK carbon tax at $100 per ton of CO_2
  - With vs. without a CBAM in place
- Evaluate welfare relative to zero regulation
  - R: EU + UK
  - U: all other countries
  - UL: low and lower-middle income (World Bank classification)
  - UH: upper-middle and high income (World Bank classification)
- In the paper, $\tau^R \in [0, 100]$ and coalition with China

Equilibrium price effects

EU/UK: $\tau^R = 100$

ΔP (%)	Market	
	R	U
Without CBAM	0.64	0.64
With CBAM	2.52	0.46

- Without CBAM, regulation effect alone ($P \uparrow$)
- With CBAM, regulation + reallocation effects ($P^R > P^U$)
- Modest magnitudes because EU/UK is small

Aggregate welfare effects

EU/UK: $\tau^R = 100$

ΔW (1B USD)	$SCC^R = 100$			$SCC^R = 0$	
	World	R	U	R	U
Without CBAM	8.96	7.93	1.03	-0.03	1.03
With CBAM	9.27	8.39	0.88	0.04	0.88

- Without CBAM, R gains less and U gains more
- With CBAM, world gains \$307M more (3%) at cost to U
- R gains even if $SCC^R = 0$, as CBAM improves terms of trade

CBAMs boost competitiveness

EU/UK: $\tau^R = 100$

ΔPS (1B USD)	Market			
	R	U	UL	UH
Without CBAM	-17.8	12.0	0.93	11.1
With CBAM	-15.4	9.04	0.70	8.34

- Without CBAM, R firms lose and U firms gain
- With CBAM, R loses \$2.4B less (13%) at cost to U
- Incidence: UL gains 26% less, UH 25% less

CBAMs curb leakage

EU/UK: $\tau^R = 100$

ΔE (Mt CO_2)	Market			
	R	U	UL	UH
Without CBAM	-93.2	13.6	1.12	12.5
With CBAM	-91.3	7.79	0.80	6.99

- Without CBAM, R emissions fall and U emissions rise
- With CBAM, U rises by 5.8 Mt less (43%) but R falls less too
- Incidence: UL rises 29% less, UH 44% less
- If China joins R, world emits 0.8 Gt less (10x impact) vs. 3.9 Gt observed

CBAMs encourage regulation

EU/UK: $\tau^R = 100$

ΔW (1B USD)	Market		
	U	UL	UH
Without CBAM	1.03	0.06	0.97
With CBAM	0.88	0.04	0.84
Global tax	-4.20	-0.79	-3.41

- Without CBAM, U prefers not to regulate
- With CBAM, U still prefers not to regulate but by \$153M less (3%)
- Incidence: UL prefers non-regulation 3% less, UH 3% less
- For U, less gain from free-riding + revenue incentive

Conclusion

Summary

- Quantitative equilibrium analysis of EU/UK CBAM
  - CBAM boosts competitiveness, curbs leakage, and encourages regulation
  - Without disproportionate impacts on lower-income countries

- Domestic advantages may help
  - To establish carbon regulation in the first place
  - To coordinate internationally