The Global Effects of Carbon Border Adjustment Mechanisms

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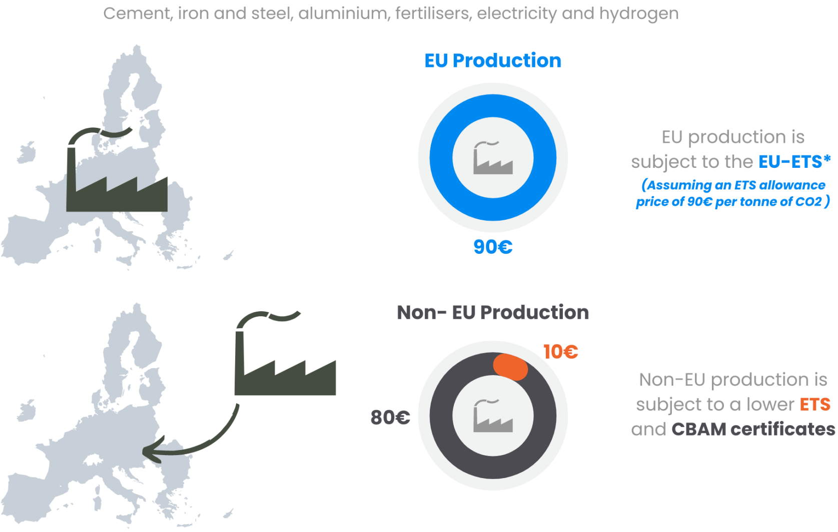
Carbon border adjustment mechanism (CBAM)



Three motivations and one concern

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

- But may disadvantage lower-income trading partners
  - Guardian (2024): "India seeks UK carbon tax exemption in free trade deal talks"
  - Bloomberg (2024): "EU CBAM Damaging ASEAN Businesses?"

This paper

1. Detailed global data on aluminum and steel
   - Key sectors targeted in first phase of EU/UK CBAM
2. Descriptive analysis of emissions
   - Lower-income countries not more emissions-intensive
3. Quantitative equilibrium model of regulation and trade
   - Welfare impacts of carbon taxation and CBAM
4. **Results:** competitiveness $\uparrow$ (13%), leakage $\downarrow$ (42%), green incentives $\uparrow$ (\$251B)
   - With similar incidence across lower- and higher-income countries

Literature

- International climate coordination
  Nordhaus 2015, Böhringer et al. 2016, Kortum & Weisbach 2022, Bourany 2024, Farrokhi & Lashkaripour 2024, Hsiao 2024

- Environmental impacts of trade policy
  Copeland & Taylor 2003, Kortum & Weisbach 2017, Shapiro 2021, Abuin 2024, Harstad 2024, Casey et al. 2025

- CBAMs as a specific policy proposal
  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

Contributions

1. Quantitative global analysis of current CBAM policies
   - Simple equilibrium framework
   - Microdata on key target industries
2. Distributional implications for lower-income countries

Background

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
- Discussed in Canada, Australia, and Taiwan
- Expansion of Chinese ETS to cover target sectors

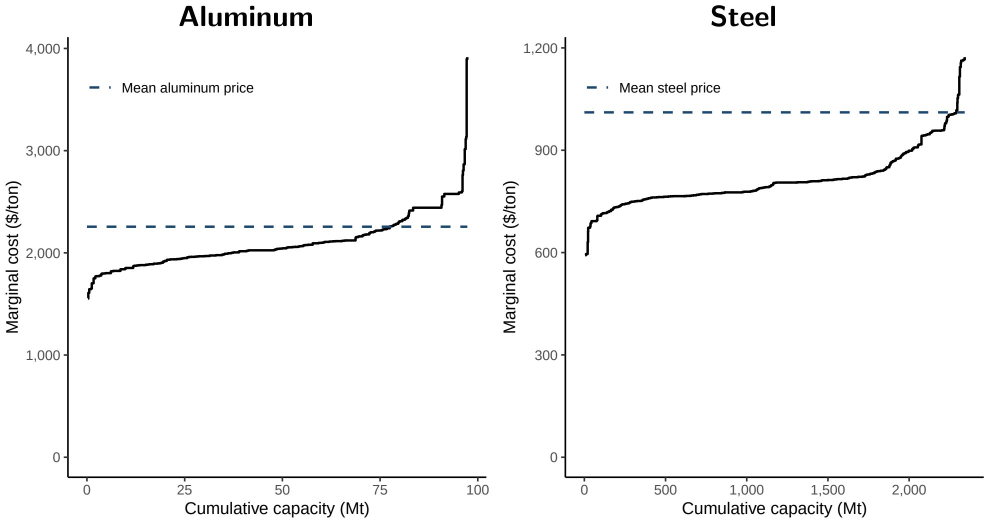
Initial target sectors

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

Global data by plant for 2023

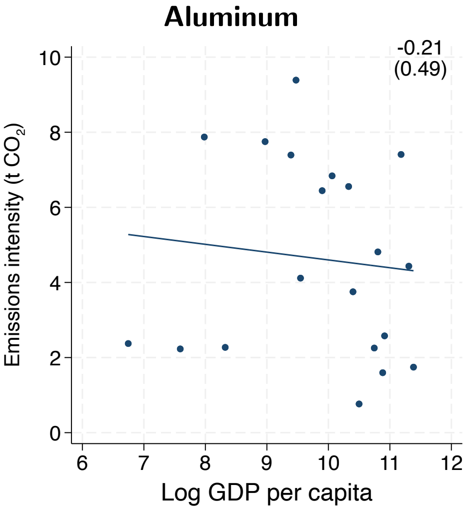
- Aluminum smelters from WoodMac
  - 153 worldwide with some Chinese smelters aggregated
  - Public data and site visits
- Steel mills from Climate TRACE
  - 892 worldwide with capacity above 500k tons
  - Satellite and mill-level sensor data
- Production, capacity, costs, and emissions
  - Primary and secondary plants, Scope 1 and 2 emissions
- China is 50-60% and EU/UK is 5-10% of global production/consumption

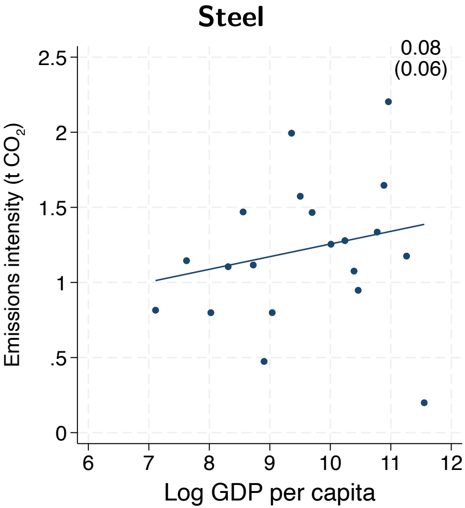
Production costs and capacity



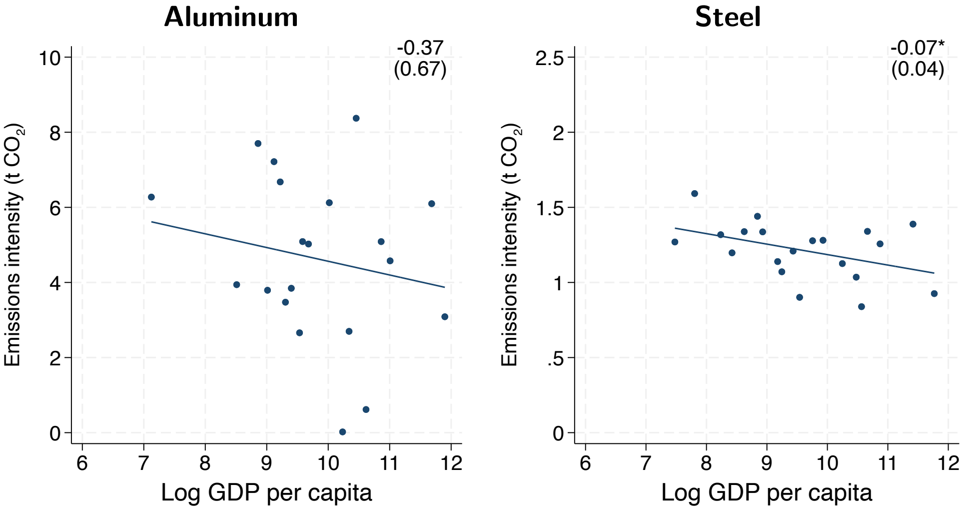
Descriptives

Emissions intensity by income

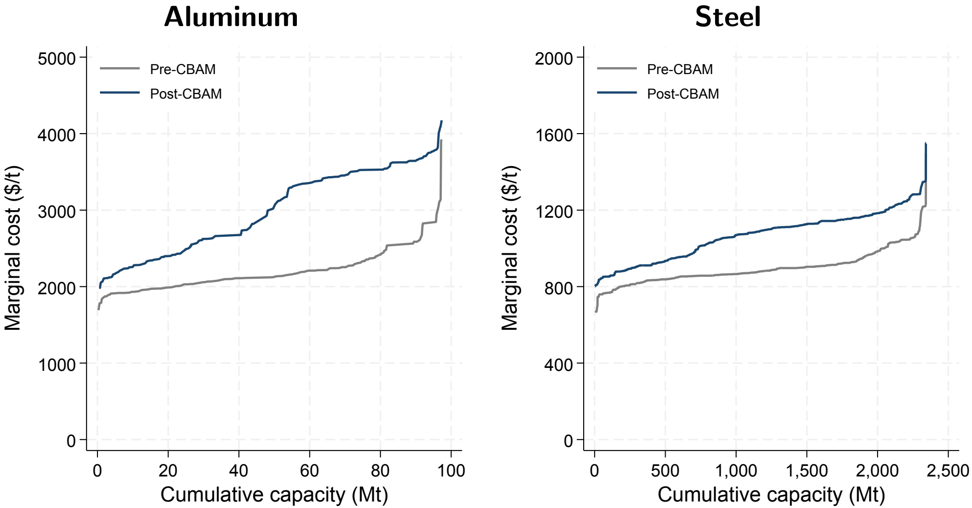




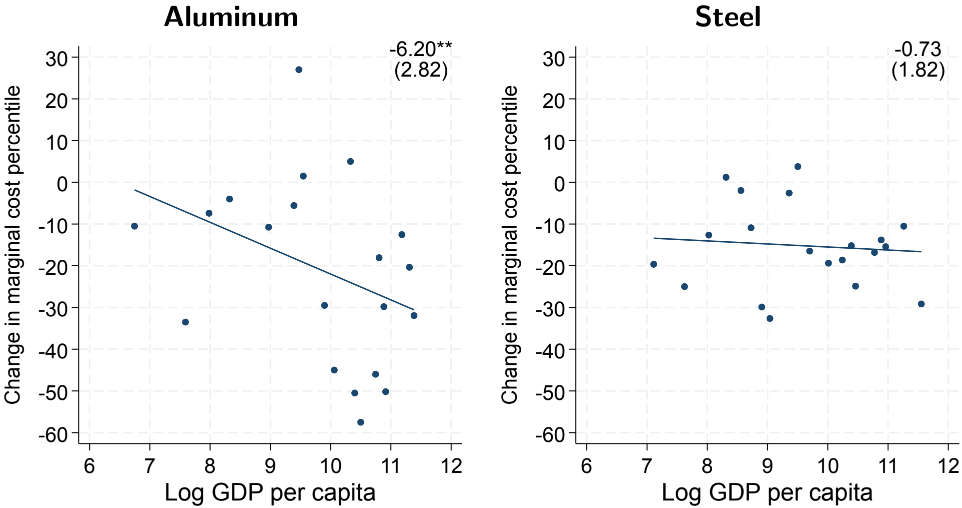
Controlling for compositional differences in production



CBAMs add to costs



CBAM impacts by income



Model

Environmental regulation with global trade

- Demand by market, supply by plant
  - Regulated and unregulated markets R and U
- Regulator in R considers a CBAM
  - Plants can shift sales across markets
  - Will quantify distributional effects

Demand by market m

$$\log D^m = \delta^m + \varepsilon^m \log P^m$$

- Log-linear with calibrated $\varepsilon^m = -0.25$ (Söderholm & Ekvall 2020)

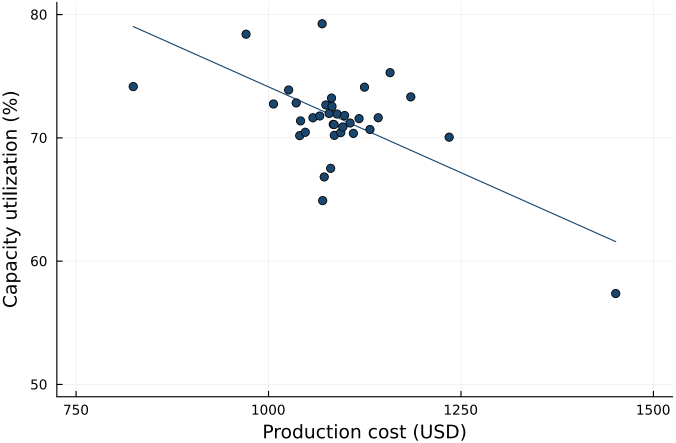
Supply by plant i

$$u_{il}^m = \underbrace{\beta(p_i^m - c_i) + \epsilon_i}_{v_i^m} + \epsilon_{il}, \qquad o_i^m = \frac{\exp(v_i^m)}{1 + \exp(v_i^m)}, \qquad s_i^m = \bar{s}_i o_i^m$$

- Choice to operate lines $\ell \Rightarrow$ capacity utilization $o_i^m \Rightarrow$ production s_i
- Price p_i^m, cost c_i, and observed capacity $\bar{s}_i$

- Constant marginal costs, so only capture heterogeneity *across* plants
- No market power, but have many plants

Logit estimation with metals j, countries k



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

Carbon taxation

$$p_i^m = P^m - \tau^m e_i$$

$$\log e_i = \log \bar{e}_i - \gamma(\tau^m - \bar{\tau}^m)$$

- Without a CBAM, $P^m = P$ and $D(P^*) = S(P^*)$
- Regulation-induced abatement with calibrated $\gamma = 0.3$ (Sen & Vollebergh 2018)
  - Relative to emissions $\bar{e}_i$ and regulation $\bar{\tau}^m$ in the data

Carbon border adjustment mechanism

$$p_i^m = \max\{p_i^{mR}, p_i^{mU}\} \qquad p_i^{RR} = P^R - \tau^R e_i \qquad p_i^{UR} = P^R - \tau^R e_i$$
$$p_i^{RU} = P^U - \tau^R e_i \qquad p_i^{UU} = P^U - \tau^U e_i$$

- Plants choose destination market with best net price p_i^m
  - Given prices (P^R, P^U) and home regulation (τ^R, τ^U)
  - Pay home + border regulation (without export rebate)
  - Adjustment $\alpha^R = \tau^R - \tau^U > 0$

Markets clear

$$D^R(P^{R*}) = S^R(P^{R*}, P^{U*}; \alpha^R)$$
$$D^U(P^{U*}) = S^U(P^{R*}, P^{U*}; \alpha^R)$$

- CBAM induces reallocation and price divergence
  - $P^R > P^U$: R expresses green preference and must pay for it
- Can compute welfare: CS, PS, G, E

Counterfactuals

Policy simulations

- Carbon taxation in market R
  - Relative to zero regulation with $\tau^R = \tau^U = 0$
  - With and without a CBAM

- Evaluate global effects
  - R: EU + UK [+ China]
  - U: all other countries
  - UL: low and lower-middle income (World Bank)
  - UH: upper-middle and high income (World Bank)

Results

1. EU/UK policy evaluation
2. CBAMs boost competitiveness
3. CBAMs curb leakage
4. CBAMs encourage regulation

1. EU/UK policy evaluation

EU/UK carbon taxation at \$100 per ton of CO_2

Impact	No CBAM		With CBAM	
	R	U	R	U
Price (%)	0.64	0.64	2.52	0.46
Emissions (Mt CO_2)	-93.2	13.6	-91.3	7.87
Welfare (1B USD)	-0.02	1.02	0.05	0.87
Consumer surplus (1B USD)	-1.22	-11.0	-4.40	-8.20
Producer surplus (1B USD)	-17.8	12.0	-15.5	9.07
Government revenue (1B USD)	19.0	0.00	19.9	0.00
Welfare with emissions reductions (1B USD)	7.94	1.02	8.39	0.87

Regulation and reallocation effects

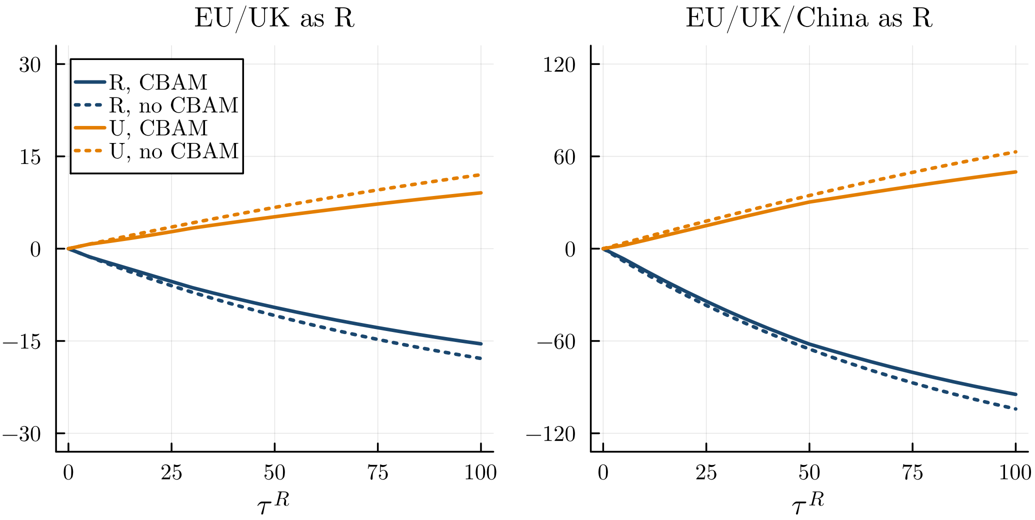
- Without a CBAM, regulation effect alone
  - World price P rises as regulation reduces world supply
- With a CBAM, regulation + reallocation effect
  - Price P^R rises and pulls clean supply to R
  - Price P^U falls as dirty supply pushed to U
- Modest price effects because EU/UK is small
- Modest welfare effects mask large CS/PS/G effects

2. CBAMs boost competitiveness

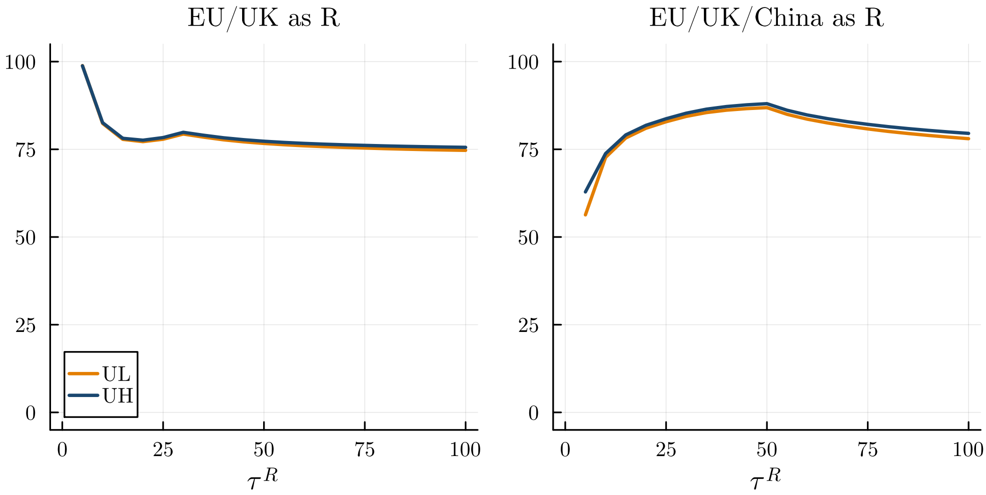
- Regulation in R hurts producers in R, helps producers in U
  - Profits losses in R of up to \$15B (EU/UK), \$100B (+China)

- CBAM reduces losses for R by 15% (EU/UK) and 10% (+China)
  - Also reduces gains for U by roughly 25%
  - But with equal incidence on lower- and higher-income countries

Producer surplus effects (1B USD)



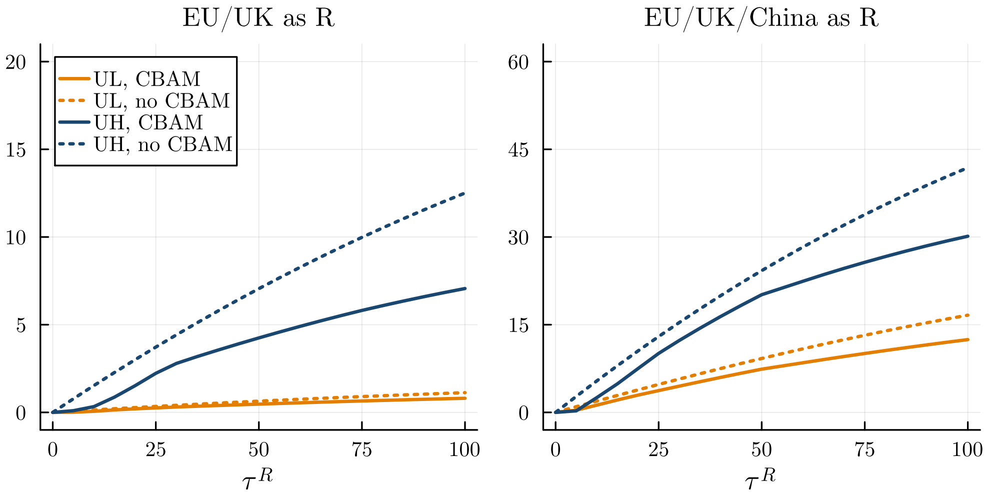
Producer surplus effects (CBAM vs. no CBAM, %)



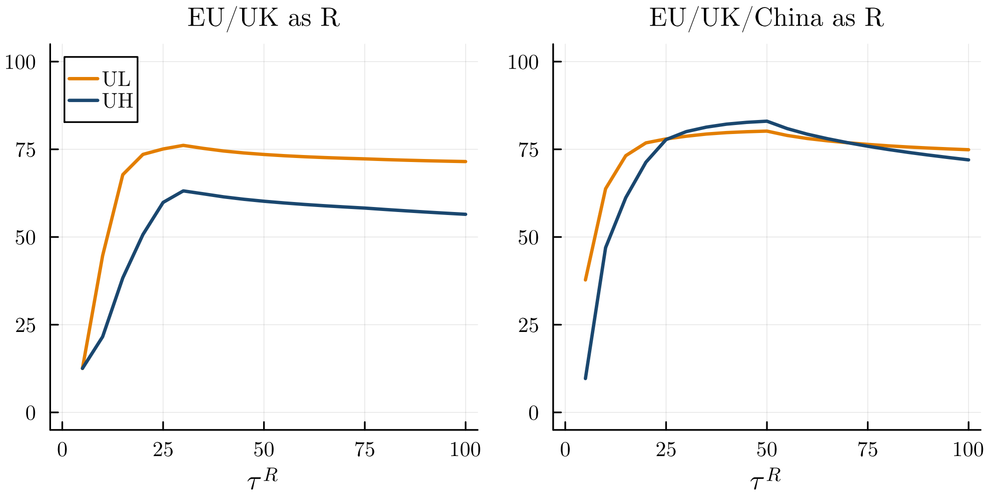
3. CBAMs curb leakage

- Regulation in R lowers emissions in R, raises emissions in U
  - Because of higher world price P
- CBAM reduces emissions increases in R by 25-50%
  - With similar pressure on lower- and higher-income countries
- Despite leakage, total emissions reductions are large
  - Up to 1 Gt when R includes China and $\tau^R = 100$ per ton of CO_2
  - Relative to 3.9 Gt in our baseline data

Emissions effects (Mt CO_2)



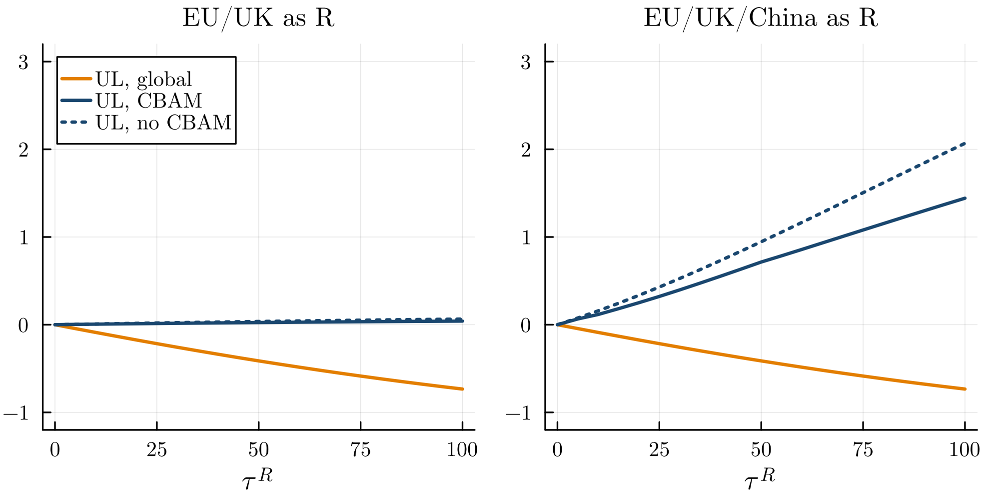
Emissions effects (CBAM vs. no CBAM, %)



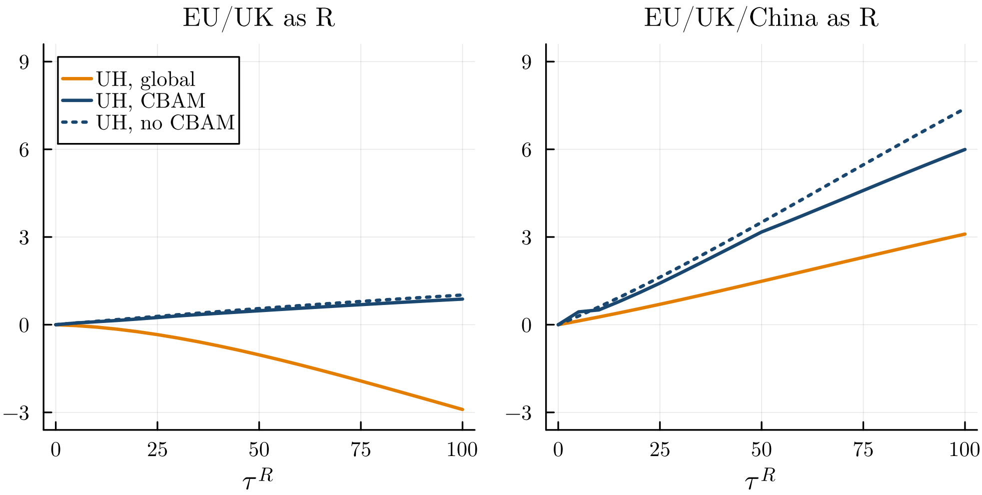
4. CBAMs encourage regulation

- Joining in regulation is mostly unappealing for U
  - Especially given carbon regulation by R, which helps U
  - U gains up to \$7B in welfare by not regulating
- But a CBAM closes the gap for global regulation
  - Reduces welfare gains for U
  - Offers revenue incentives for U
  - Increases emission reductions for U

Welfare effects for UL (1B USD)



Welfare effects for UH (1B USD)



Conclusion

Summary

- Quantitative equilibrium analysis of EU/UK CBAM
  - Emissions intensity not necessarily higher in lower-income countries
- CBAM boosts competitiveness, curbs leakage, and encourages regulation
  - Without disproportionate impacts on lower-income countries
  - Domestic advantages may help to pass carbon regulation