The Global Effects of Carbon Border Adjustment Mechanisms

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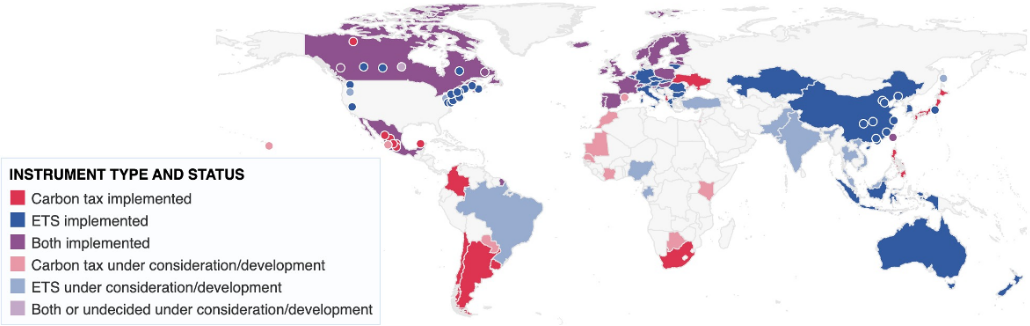
Carbon pricing around the world (2024)



Carbon border adjustment mechanism (CBAM)

Cement, iron and steel, aluminium, fertilisers, electricity and hydrogen

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
  - 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
   - Most emissions-intensive and heavily traded
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

EU/UK carbon taxation with a CBAM

- At \$100 (90€) per ton of CO_2

- **Increased competitiveness:** EU/UK producer losses 13%$\downarrow$ (\$17.8B to \$15.5B)
- **Reduced leakage:** non-EU/UK emissions increases 42%$\downarrow$ (13.6 Mt to 7.87 Mt)
- **Incentives for regulation:** free revenue for non-EU/UK markets (up to \$251B)

- 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: producers respond to tariffs by reallocating sales
   - Microdata on two 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
- In discussion 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

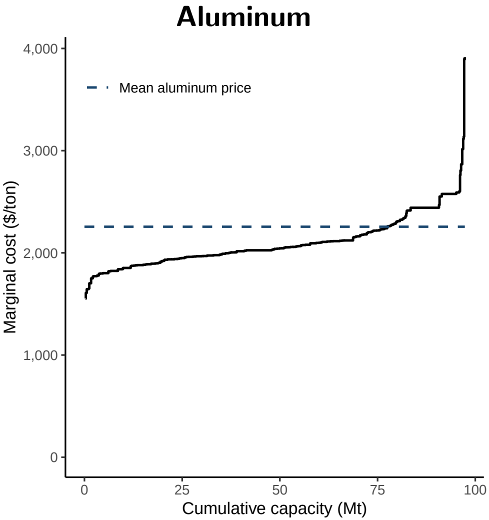
Aluminum and steel

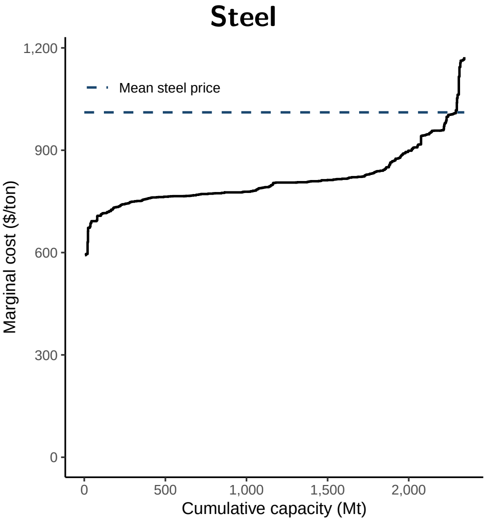
- Globally traded commodities
  - London Metal Exchange reports global prices and facilitates trade
- Aluminum
  - Primary: smelted from alumina with CO_2 from chemistry and electricity
  - Secondary: recycled from scrap with 5-10% emissions
- Steel
  - Primary: blast furnace/basic oxygen furnace (BF-BOF) from iron ore
  - Secondary: electric arc furnace (EAF) from scrap with 35-40% emissions

Global data by plant for 2023

- Aluminum smelters from WoodMac
  - 153 worldwide with some Chinese smelters aggregated
  - Public data and site visits
  - LIC producers: 7% of global production, 9% of global emissions
- Steel mills from Climate TRACE
  - 892 worldwide with capacity above 500k tons
  - Satellite and mill-level sensor data
  - LIC producers: 7% of global production, 6% of global emissions
- Production, capacity, costs, and emissions
  - Primary and secondary plants, Scope 1 and 2 emissions

Production costs and capacity





Aluminum quantities

Producers

Country	Mt	%
China	48.9	57.9
India	4.7	5.6
EU + UK	4.6	5.5
USA	4.1	4.9
Russia	4.0	4.7
Rest of world	18.1	21.5

Consumers

Country	Mt	%
China	50.8	60.2
EU + UK	9.1	10.8
USA	8.6	10.2
India	3.0	3.6
Japan	2.9	3.4
Rest of world	10.0	11.8

Steel quantities

Producers

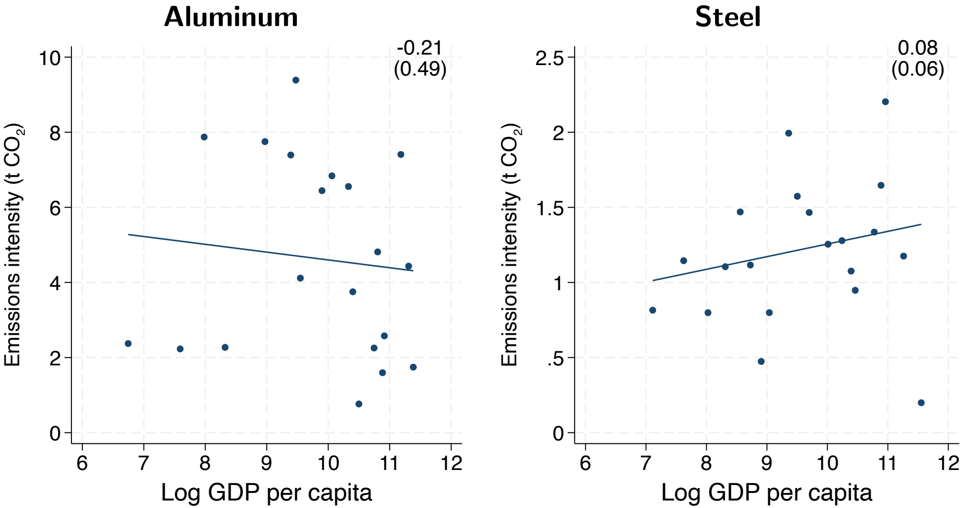
Country	Mt	%
China	860	51
EU + UK	153	9
Japan	88	5
USA	86	5
India	76	5
Rest of world	409	25

Consumers

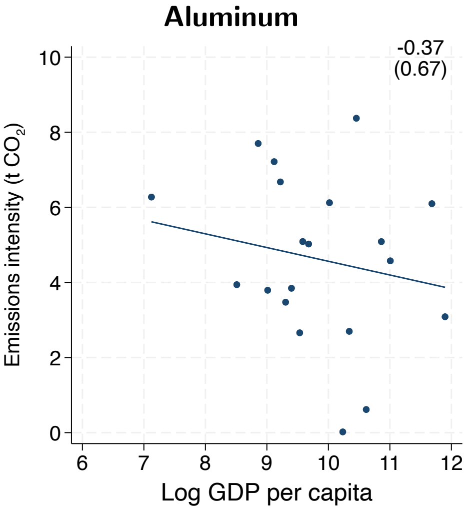
Country	Mt	%
China	827	49
EU + UK	169	10
USA	101	6
India	77	5
Japan	68	4
Rest of world	431	26

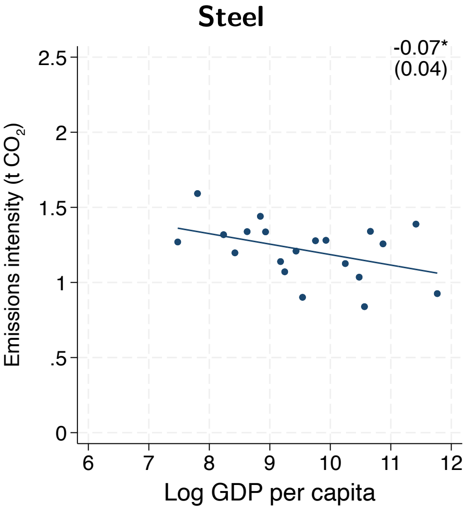
Descriptives

Emissions intensity by income

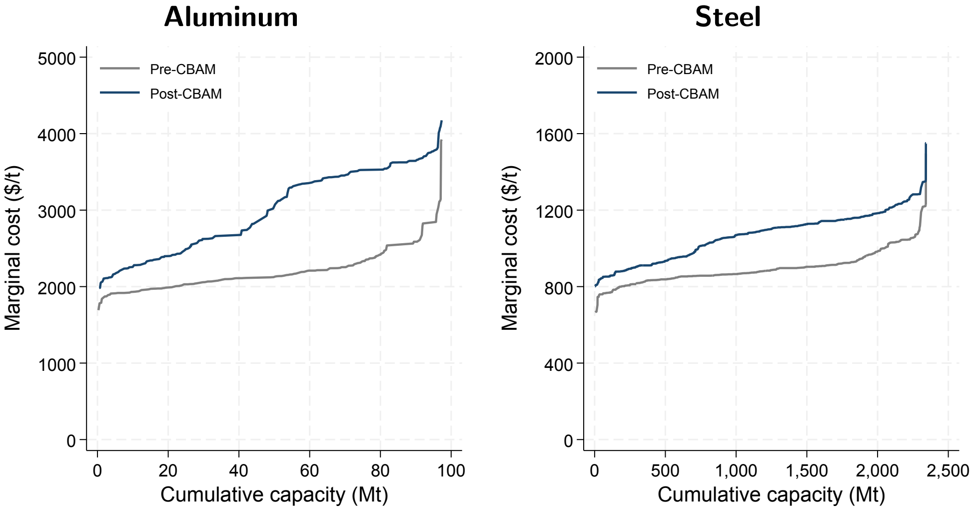


Controlling for compositional differences in production

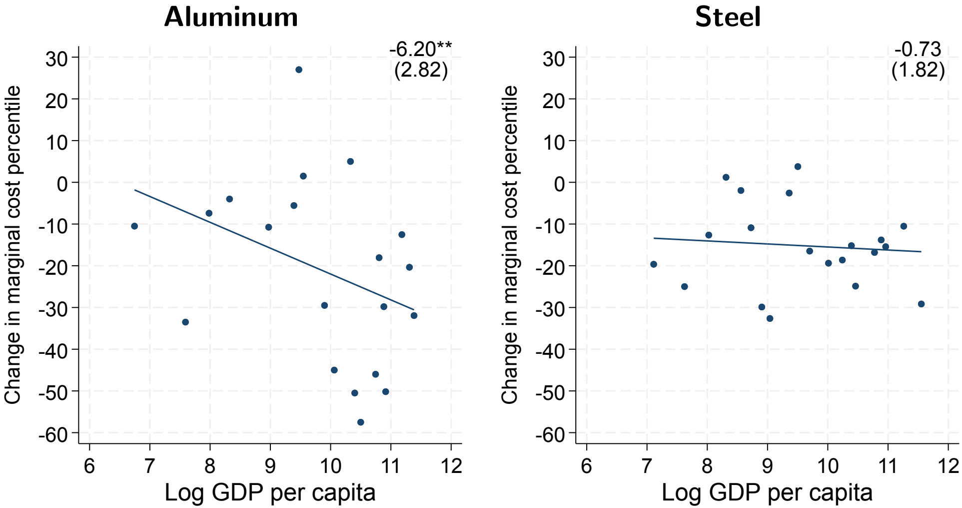




CBAMs add to costs



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)

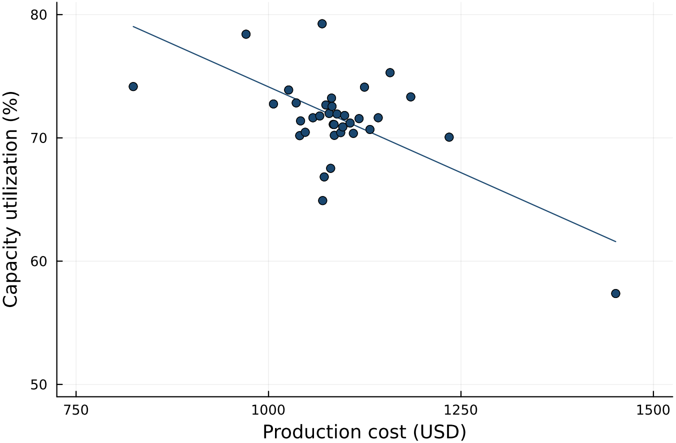
Supply by plant i

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

- Production s_i depends capacity utilization o_i^m via choice to operate lines ℓ
- Observed capacity $\bar{s}_i$, cost c_i, and price p_i^m

- 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

$$\alpha^R = \tau^R - \tau^U > 0$$

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

$$r_i^m = \mathbb{1}(p_i^{mR} > p_i^{mU}) \qquad p_i^{RU} = P^U - \tau^R e_i \qquad p_i^{UU} = P^U - \tau^U e_i$$

- 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)

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. Regulation and reallocation effects
3. CBAMs boost competitiveness
4. CBAMs curb leakage
5. CBAMs encourage regulation

1. EU/UK policy evaluation

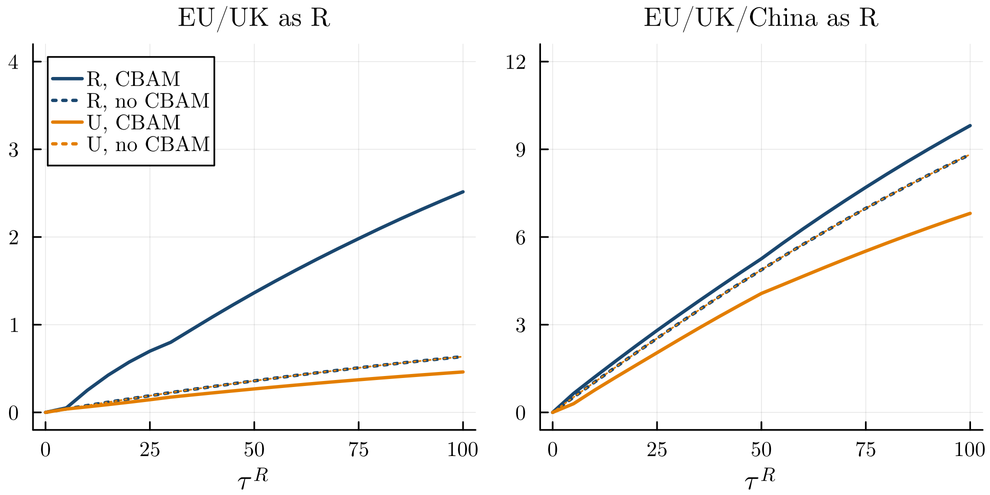
EU/UK carbon taxation at \$100 per ton of CO_2

	No CBAM		With CBAM	
Impact	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

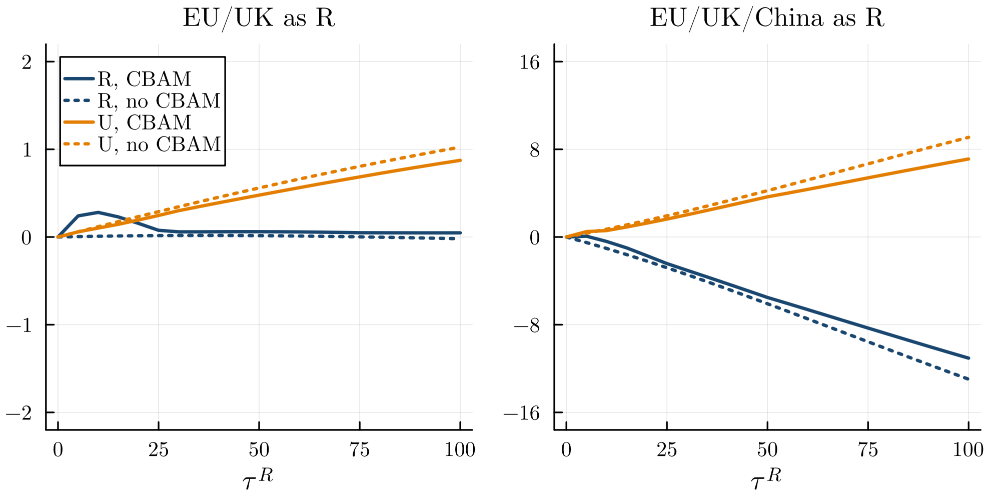
2. Regulation and reallocation effects

- 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: no more than 10%
- Modest welfare effects: sometimes small gain for R, less than \$10B for U
  - But large component effects: up to \$100B for CS and PS, \$200B for G

Price effects (%)



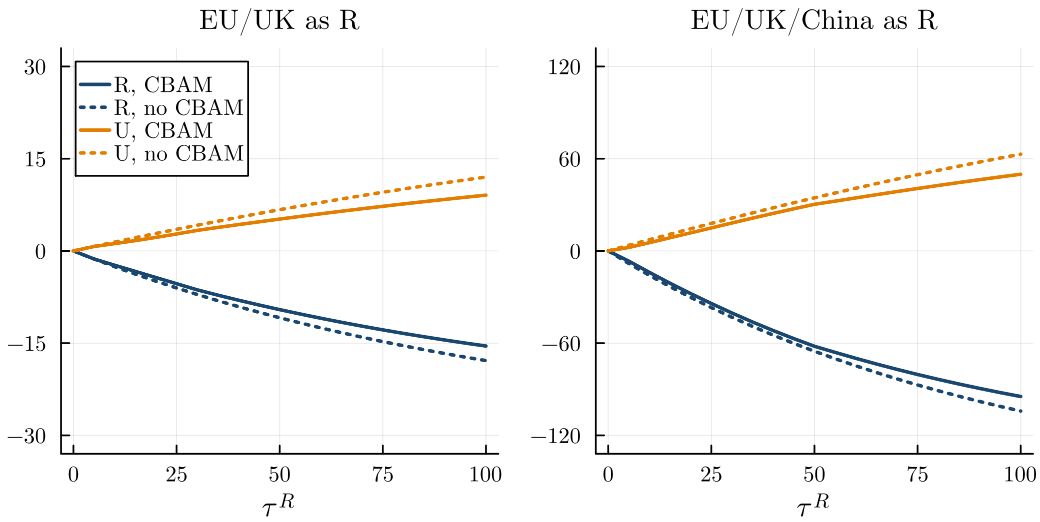
Welfare effects (1B USD)



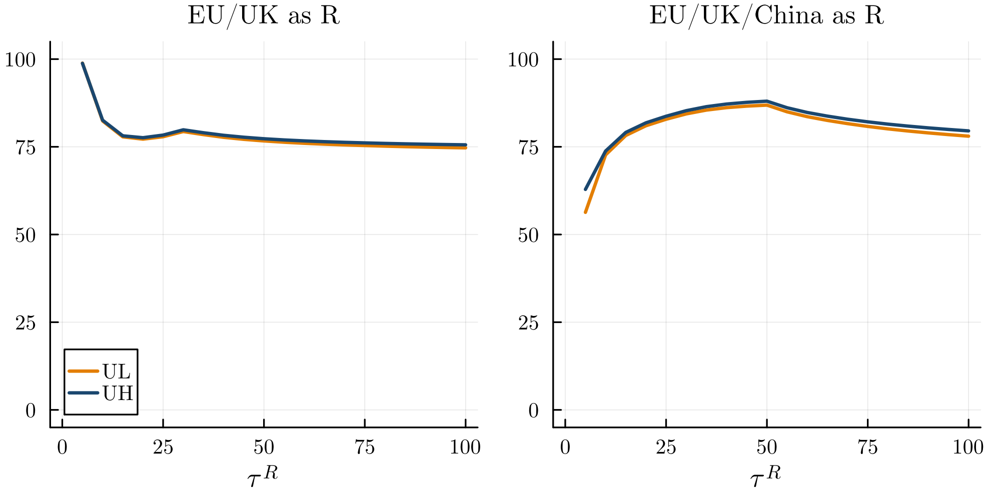
3. CBAMs boost competitiveness

- 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)



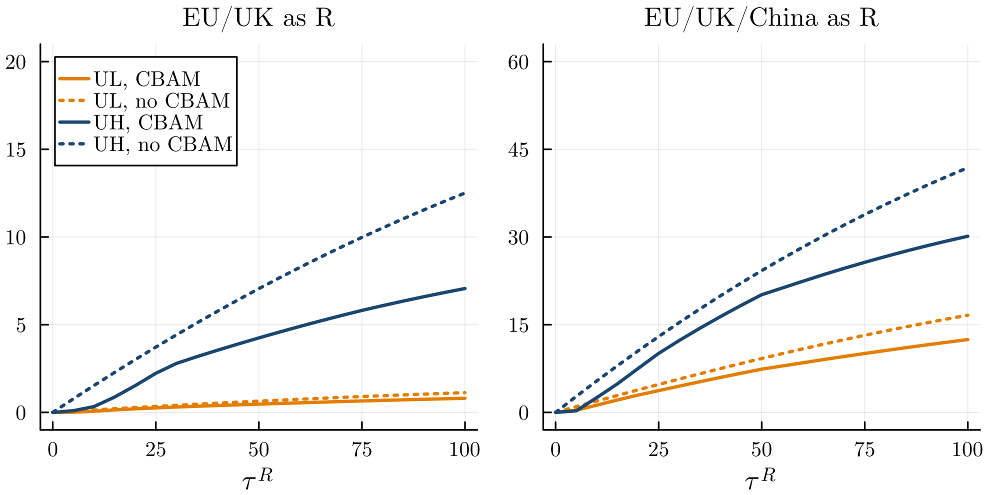
Producer surplus effects (CBAM vs. no CBAM, %)



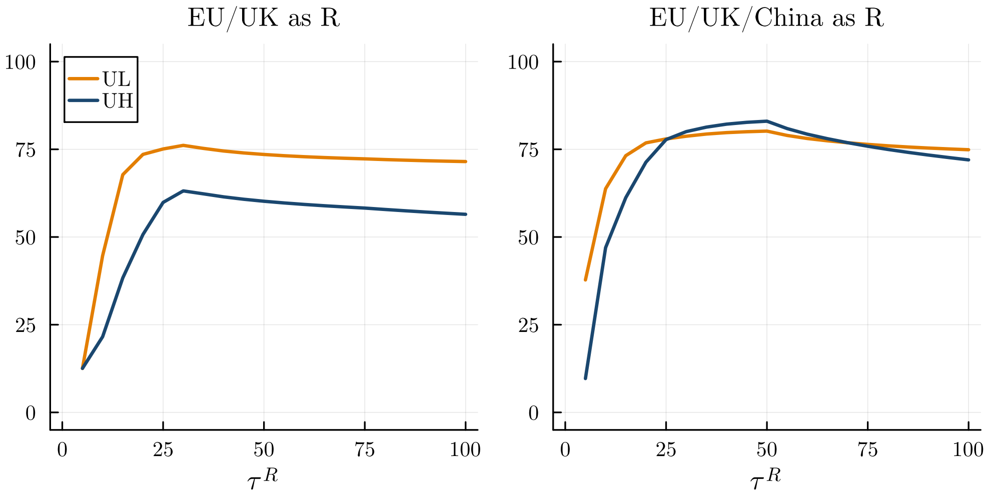
4. CBAMs curb leakage

- 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, %)

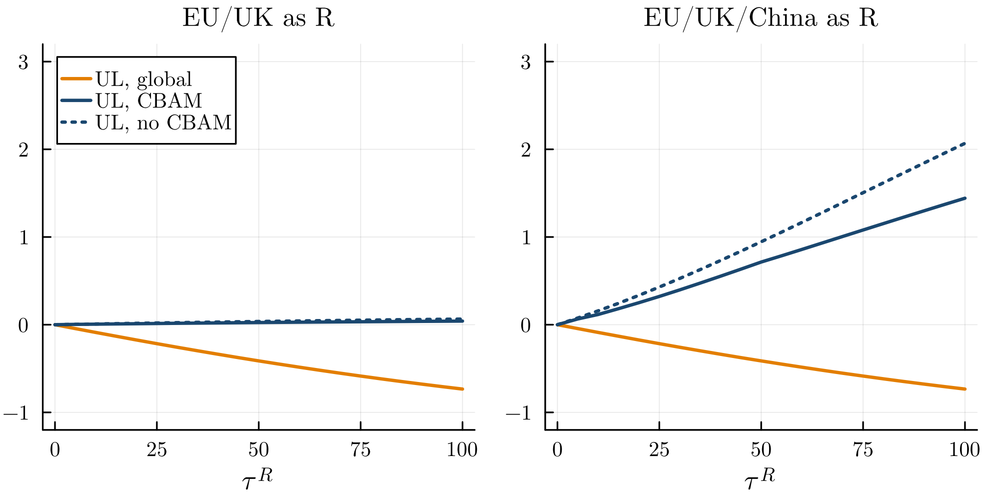


5. CBAMs encourage regulation

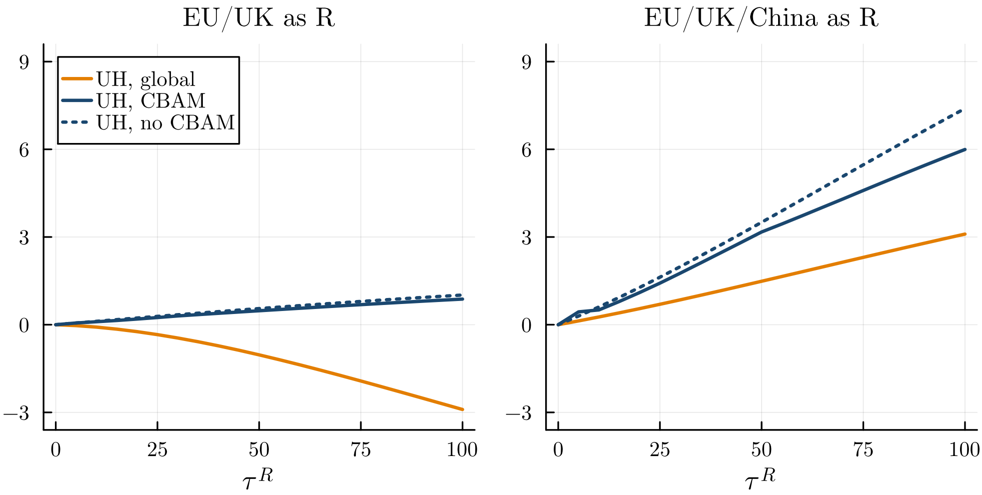
- Joining in regulation is mostly unappealing for U
  - Especially given carbon regulation by R, which helps U
  - U gains up to \$7B in welfare by not regulating

- 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