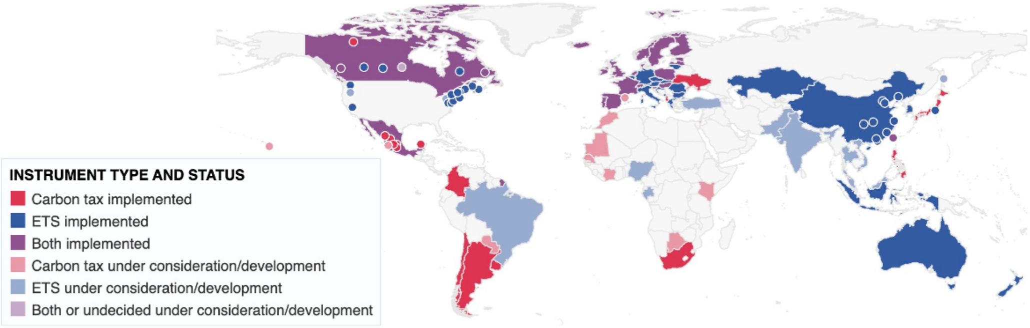
The Global Effects of Carbon Border Adjustment Mechanisms

Kimberly Clausing, UCLA
Jonathan Colmer, Virginia
Allan Hsiao, Stanford
Catherine Wolfram, MIT Sloan

April 7, 2025

Carbon pricing around the world (2024)



Carbon border adjustment mechanism (CBAM)

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

EU Production

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

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

Non- EU Production

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

Potentially regressive for lower-income countries

- Guardian (2024): "India seeks UK carbon tax exemption in free trade deal talks"
- Bloomberg (2024): "EU CBAM Damaging ASEAN Businesses?"

- Center for Global Development (2022): "Mozambique, a large aluminum exporter, could experience a fall of 1.6 percent of its GDP as a result of a shift in demand following the introduction of the CBAM"

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

Carbon taxation with a CBAM

- **Increased competitiveness:** profit losses for regulated producers 15% $\downarrow$
- **Reduced leakage:** emissions increases for unregulated producers 30% $\downarrow$
- **Incentives for regulation:** free revenue for unregulated markets

- Similar incidence across lower- and higher-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

EU CBAM 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

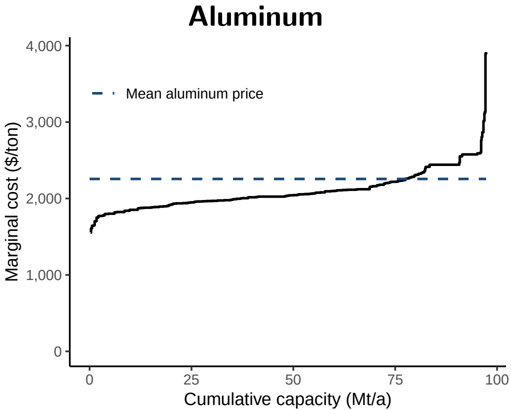
Aluminum and steel

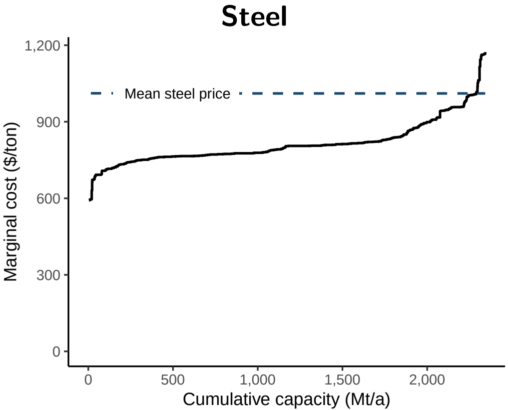
- Globally traded commodities
  - London Metal Exchange reports global prices and facilitates trade
- Aluminum
  - Primary: smelted from alumina with CO_2 from chemistry and electricity
  - Secondary: recycled from scrap with 5-10% emissions
- Steel
  - Primary: blast furnace/basic oxygen furnace (BF-BOF) 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 + site visits
  - LIC producers: 7% of global production, 9% of global emissions
- Steel mills from Climate TRACE
  - Every steel mill 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

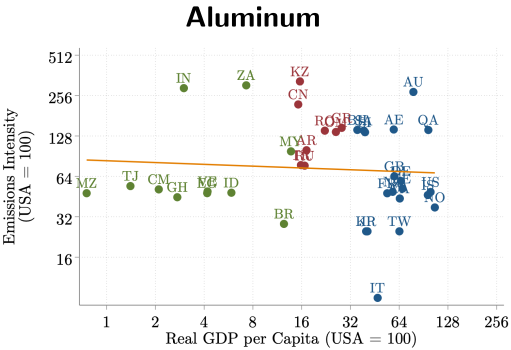
Country	Mt	%
China	860	51
EU + UK	153	9
Japan	88	5
USA	86	5
India	76	5
Rest of world	409	25

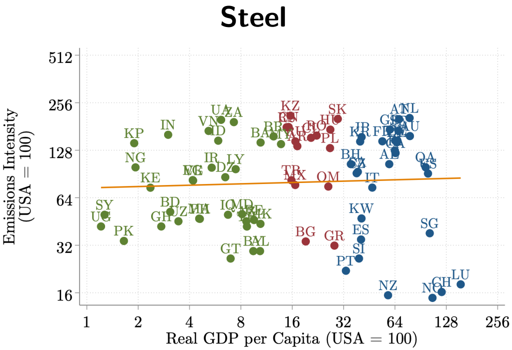
Consumers

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

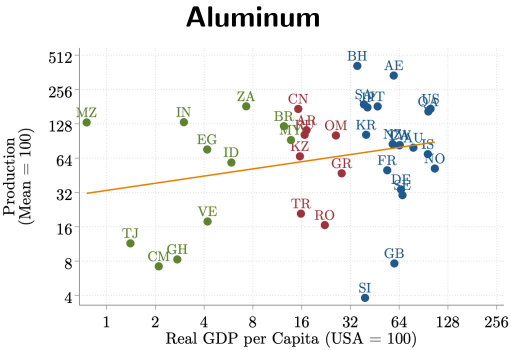
Descriptives

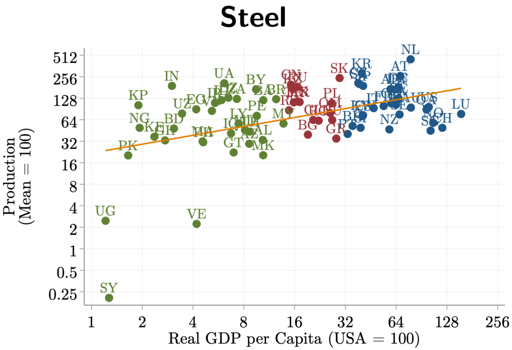
Emissions intensity by income



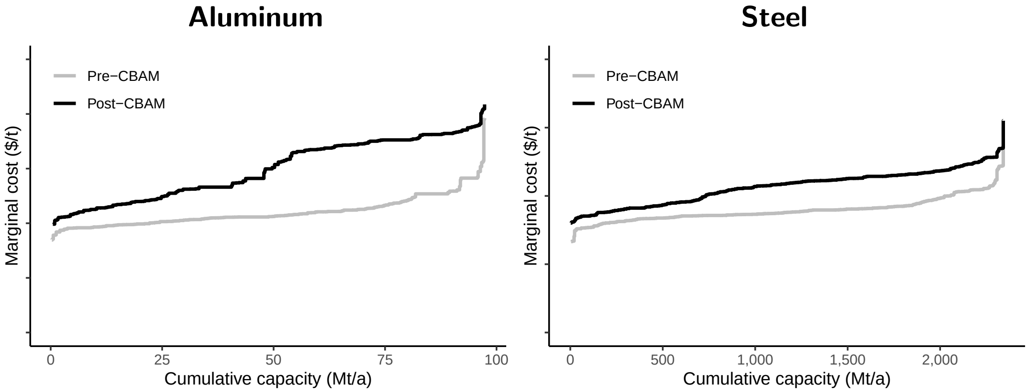


Production scale by income

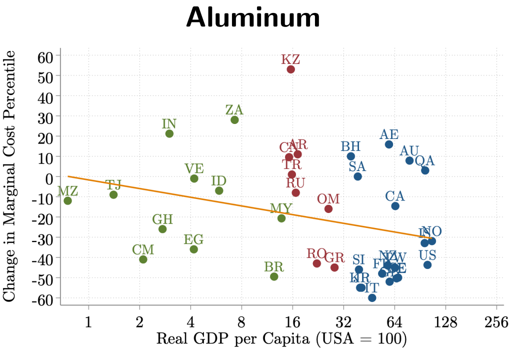


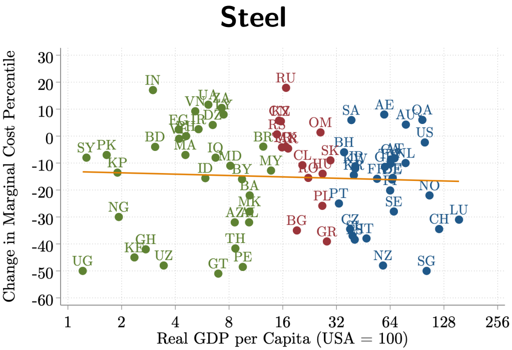


CBAMs add to costs



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 $\varepsilon^m = -0.25$

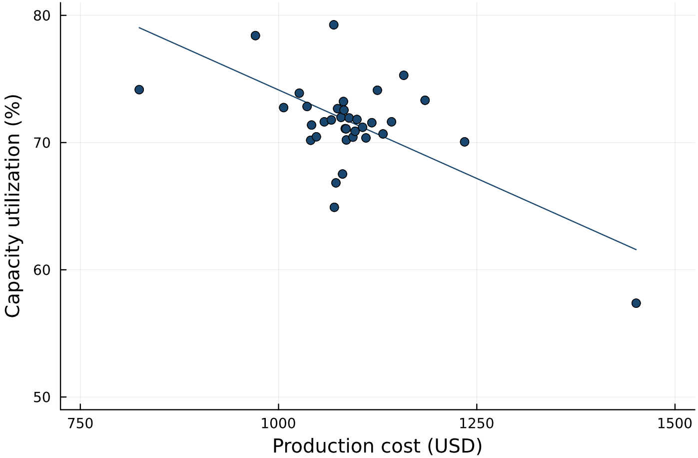
Supply by plant i

$$s_i^m = \bar{s}_i o_i^m, \quad o_i^m = \frac{\exp(v_i^m)}{1 + \exp(v_i^m)}$$

$$u_{il}^m = v_i^m + \epsilon_{il}, \quad v_i^m = \beta(p_i^m - c_i) + \epsilon_i$$

- 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 cost and no market power

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 $D(P^*) = S(P^*)$
- Carbon regulation induces abatement response with calibrated $\gamma = 0.3$

Carbon border adjustment mechanism

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

$$\begin{aligned} p_i^m &= \max\{p_i^{mR}, p_i^{mU}\} & p_i^{RR} &= P^R - \tau^R e_i & p_i^{UR} &= P^R - \tau^R e_i \\ r_i^m &= \mathbb{1}(p_i^{mR} > p_i^{mU}) & p_i^{RU} &= P^U - \tau^R e_i & p_i^{UU} &= P^U - \tau^U e_i \end{aligned}$$

- Plants choose destination market
- Given prices (P^H, P^L) and home regulation (τ^H, τ^L)

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
  - $P^R > P^U$ as R expresses green preference
- 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
  - H: EU + UK [+ China]
  - L: all other countries
  - UL: low and lower-middle income (World Bank)
  - UH: upper-middle and high income (World Bank)

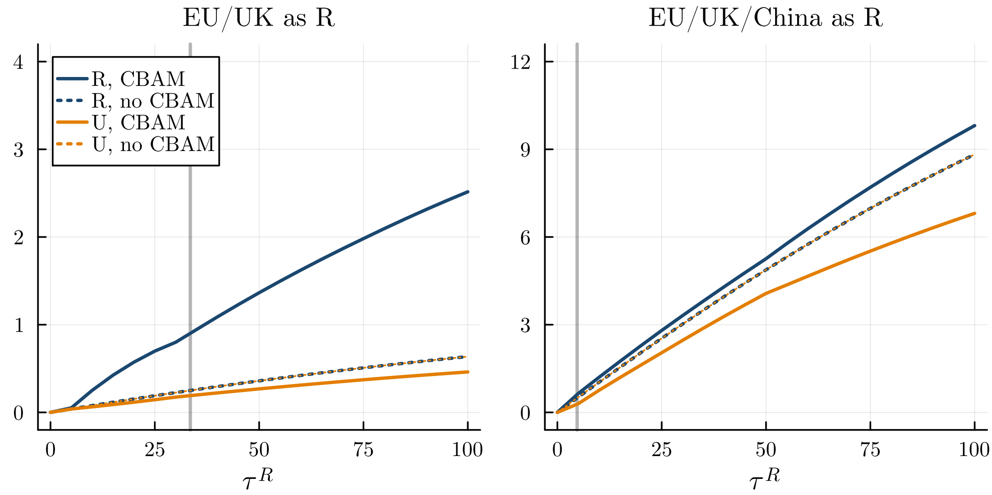
1. Regulation and reallocation

- Without a CBAM, regulation effect alone
  - World price P rises as regulation reduces world supply

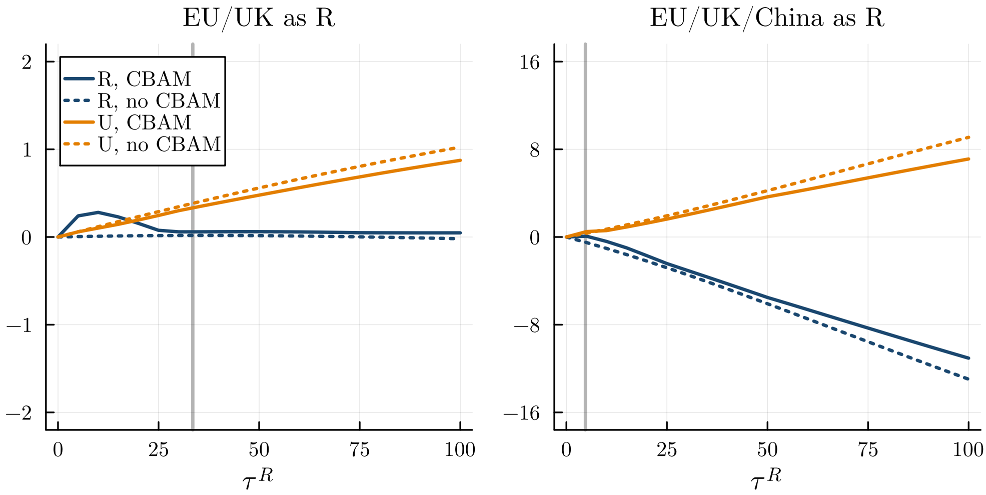
- With a CBAM, regulation + reallocation effect
  - Price P^R rises and pulls clean supply to R
  - Price P^U falls as dirty supply pushed to U

- 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 (%)



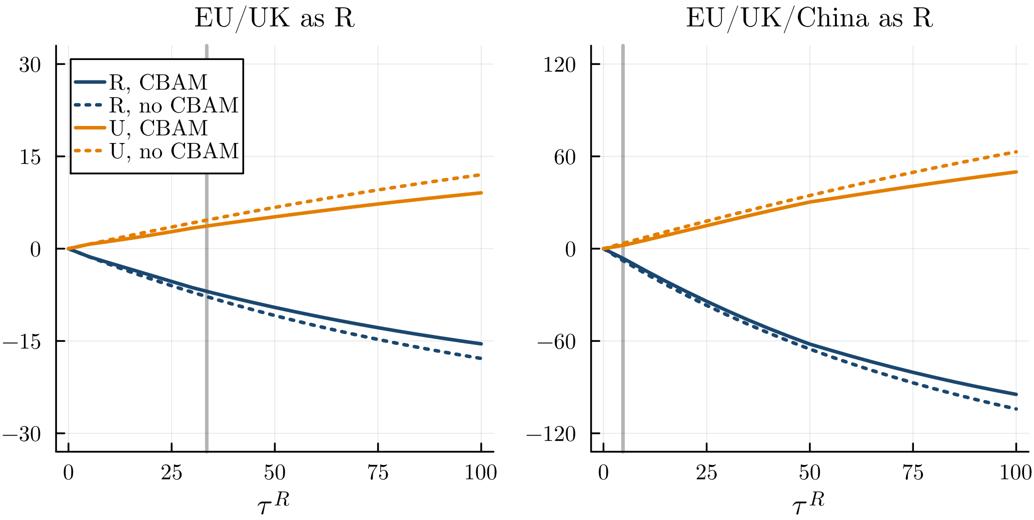
Welfare effects (1B USD)



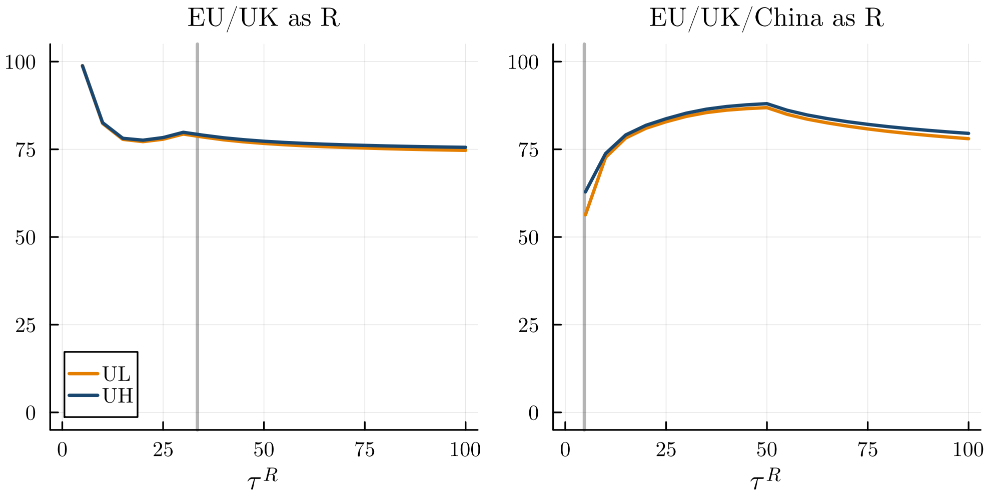
2. CBAMs boost competitiveness

- 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)



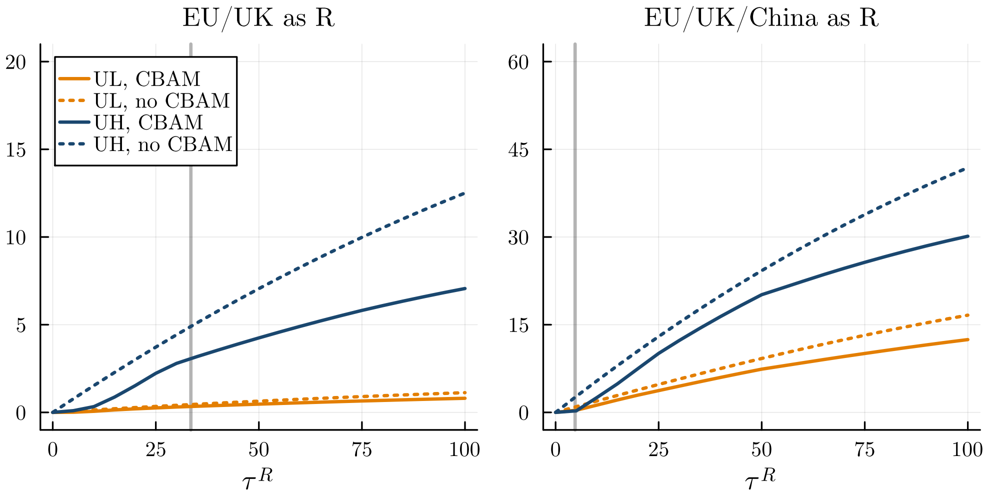
Producer surplus effects (CBAM vs. no CBAM, %)



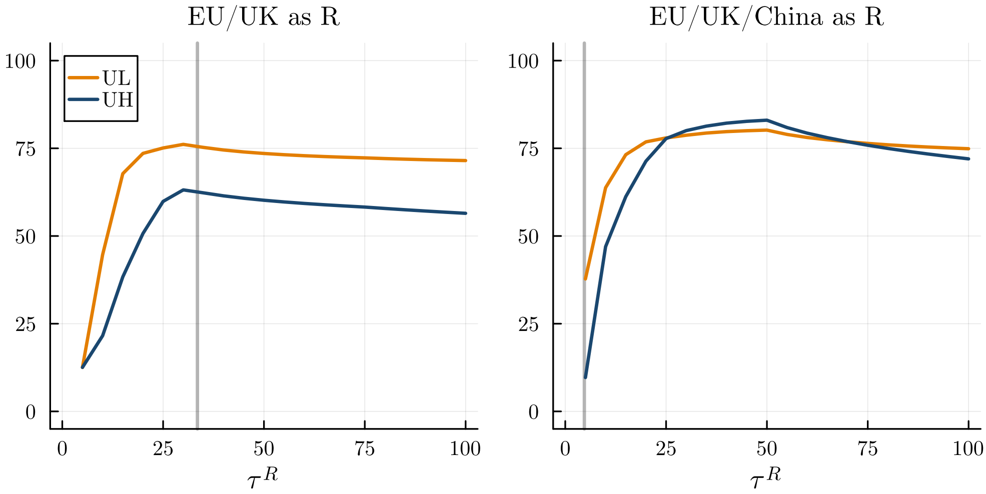
3. CBAMs curb leakage

- 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)



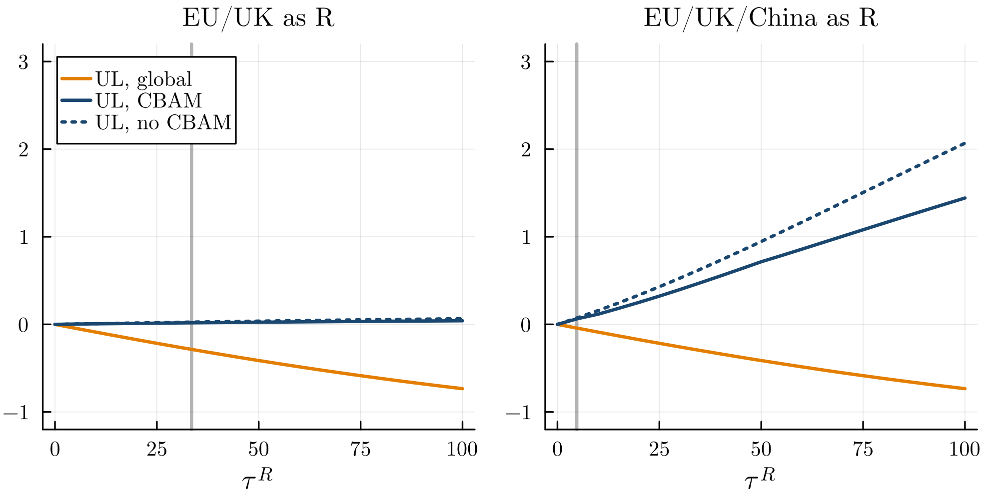
Emissions effects (CBAM vs. no CBAM, %)



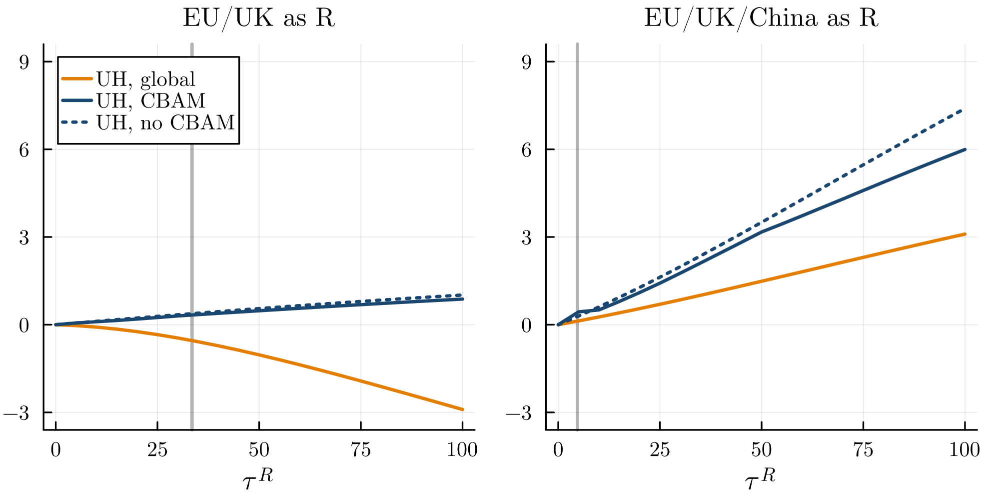
4. CBAMs encourage regulation

- 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
  - Introduces welfare incentives for U
  - Increases emission reductions for U

Welfare effects for UL (1B USD)



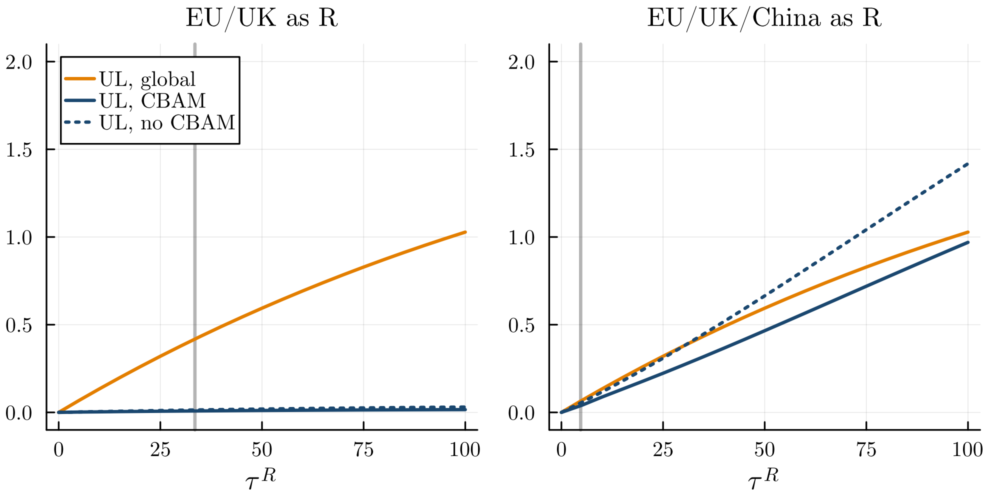
Welfare effects for UH (1B USD)



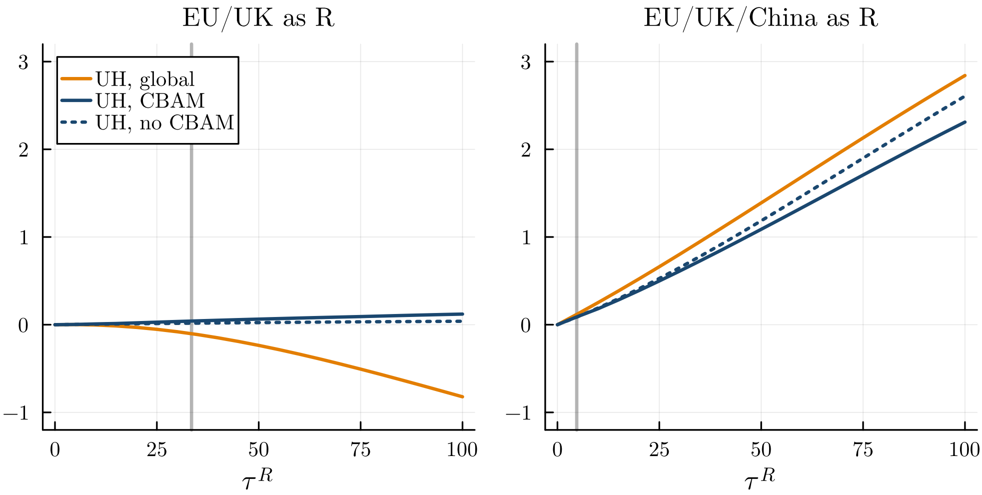
With starker results for aluminum

- For UL, global regulation dominates
  - For all τ^R when R is EU/UK
  - Up to $\tau^R = 25$ when R has China
  - Past $\tau^R = 25$ when R has China + CBAM
- For UH, global regulation dominates
  - For no τ^R when R is EU/UK
  - For all τ^R when R has China

Aluminum welfare effects for UL (1B USD)



Aluminum 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