

The Global Effects of Carbon Border Adjustment Mechanisms

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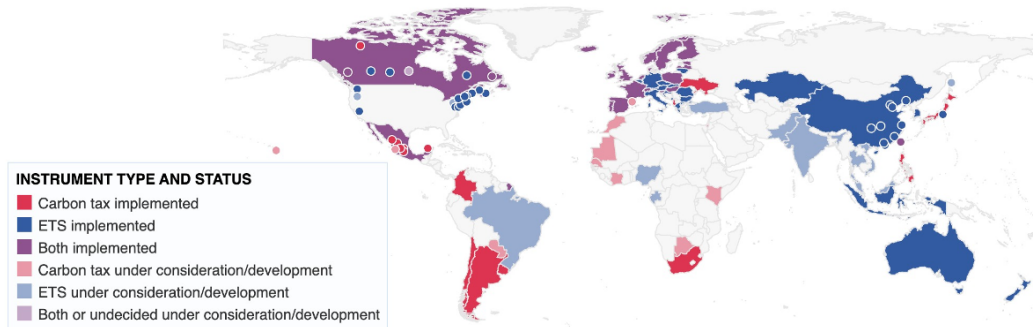
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Carbon pricing around the world (2024)



Carbon border adjustment mechanism (CBAM)

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

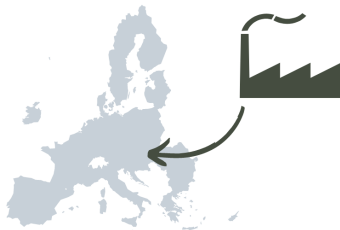


EU Production



90€

EU production is
subject to the **EU-ETS***
*(Assuming an ETS allowance
price of 90€ per tonne of CO₂)*



Non- EU Production



80€

10€

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

EU/UK carbon taxation with a CBAM

- At \$100 (90€) per ton of CO₂
- **Increased competitiveness:** EU/UK producer losses 13% ↓ (\$17.8B to \$15.5B)
- **Reduced leakage:** non-EU/UK emissions increases 42% ↓ (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

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

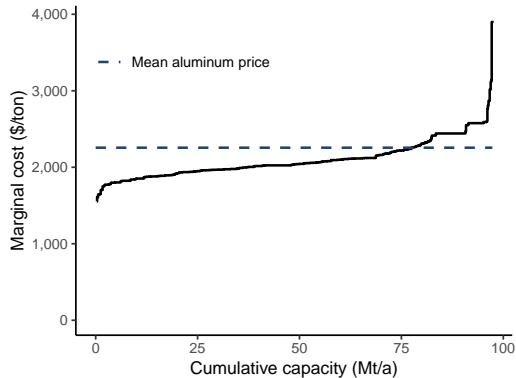
- Globally traded commodities
 - London Metal Exchange reports global prices and facilitates trade
- Aluminum
 - Primary: smelted from alumina with CO₂ from chemistry and electricity
 - Secondary: recycled from scrap with 5-10% emissions
- Steel
 - Primary: blast furnace/basic oxygen furnace (BF-BOF) from iron ore
 - Secondary: electric arc furnace (EAF) from scrap with 35-40% emissions

Global data by plant for 2023

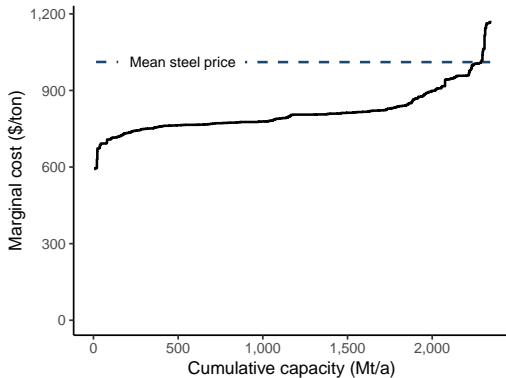
- Aluminum smelters from WoodMac
 - 153 worldwide with some Chinese smelters aggregated
 - Public data and site visits
 - LIC producers: 7% of global production, 9% of global emissions
- Steel mills from Climate TRACE
 - 892 worldwide with capacity above 500k tons
 - Satellite and mill-level sensor data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



Steel



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

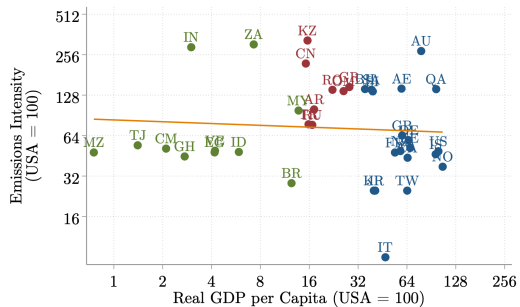
Consumers

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

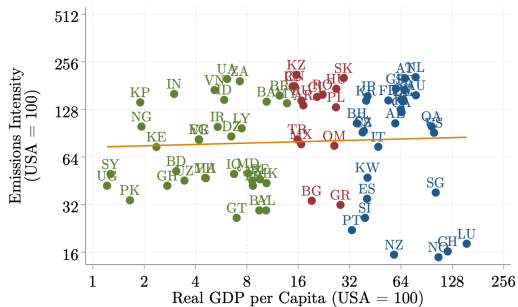
Descriptives

Emissions intensity by income

Aluminum

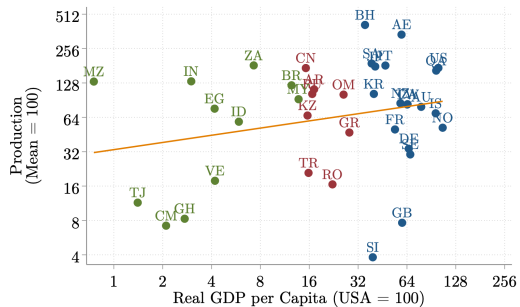


Steel

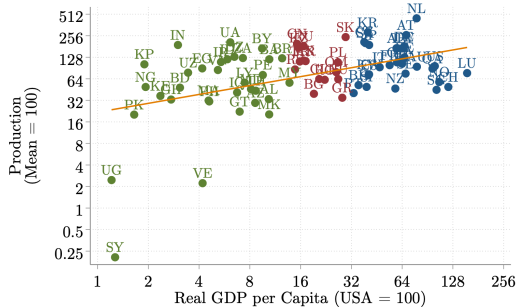


Production scale by income

Aluminum

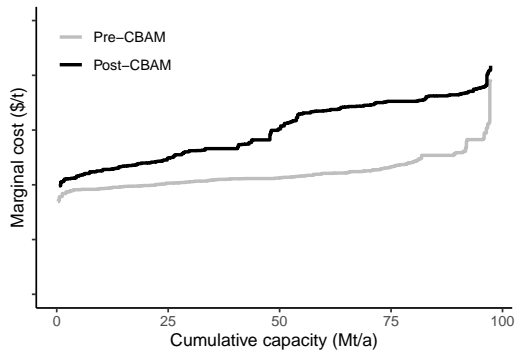


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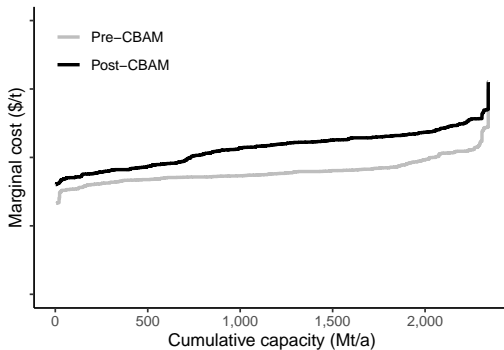


CBAMs add to costs

Aluminum

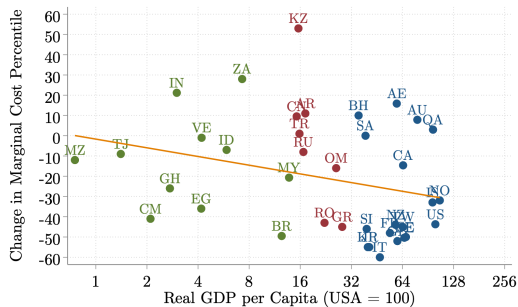


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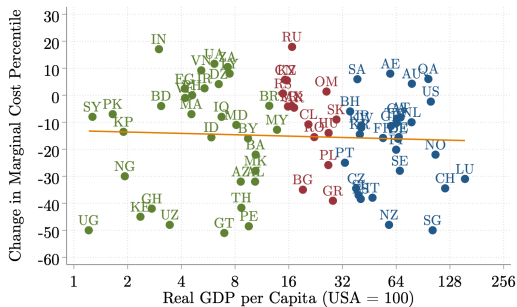


CBAM impacts by income

Aluminum



Steel



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 $\varepsilon^m = -0.25$

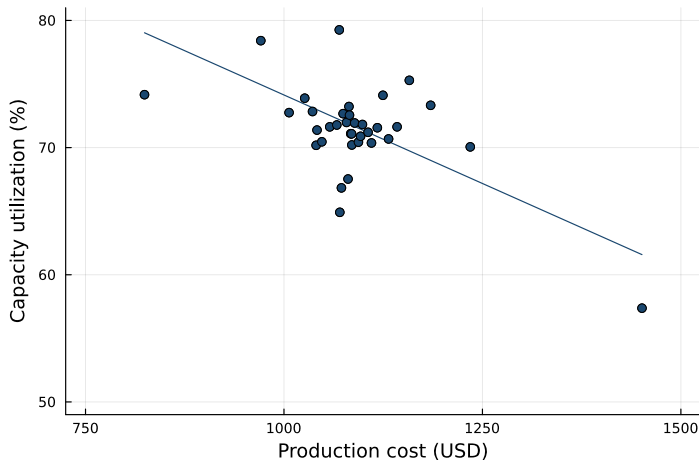
Supply by plant i

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

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

- 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

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

$$p_i^m = \max\{p_i^{mR}, p_i^{mU}\}$$

$$r_i^m = \mathbb{1}(p_i^{mR} > p_i^{mU})$$

$$p_i^{RR} = P^R - \tau^R e_i$$

$$p_i^{RU} = P^U - \tau^R e_i$$

$$p_i^{UR} = P^R - \tau^U e_i$$

$$p_i^{UU} = P^U - \tau^U e_i$$

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

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
 - 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 CO₂

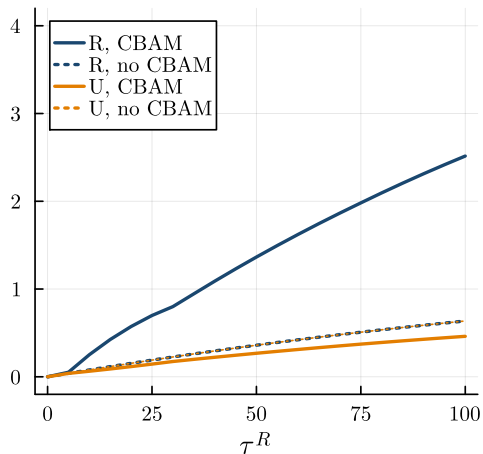
Impact	Pre-CBAM		Post-CBAM	
	<i>R</i>	<i>U</i>	<i>R</i>	<i>U</i>
Price (%)	0.64	0.64	2.52	0.46
Emissions (Mt CO ₂)	-93.2	13.6	-91.3	7.87
Welfare (1B USD)	-0.02	1.02	0.05	0.87
Consumer surplus (1B USD)	-1.22	-11.0	-4.40	-8.20
Producer surplus (1B USD)	-17.8	12.0	-15.5	9.07
Government revenue (1B USD)	19.0	0.00	19.9	0.00

2. Regulation and reallocation effects

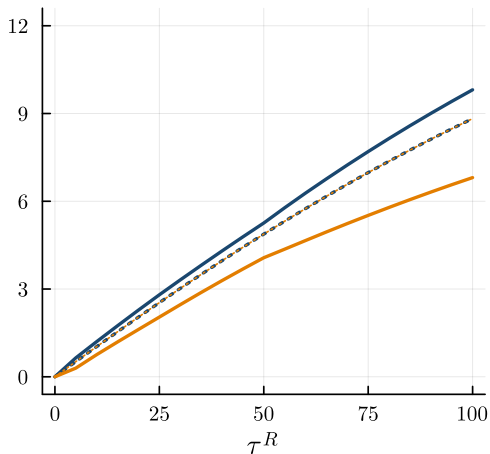
- Without a CBAM, regulation effect alone
 - World price P rises as regulation reduces world supply
- With a CBAM, regulation + reallocation effect
 - Price P^R rises and pulls clean supply to R
 - Price P^U falls as dirty supply pushed to U
- Modest price effects: no more than 10%
- Modest welfare effects: 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 (%)

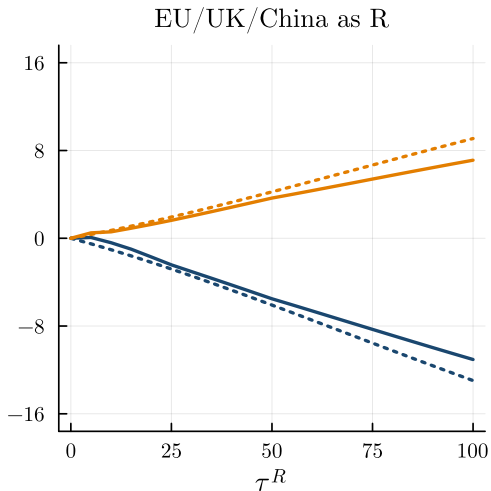
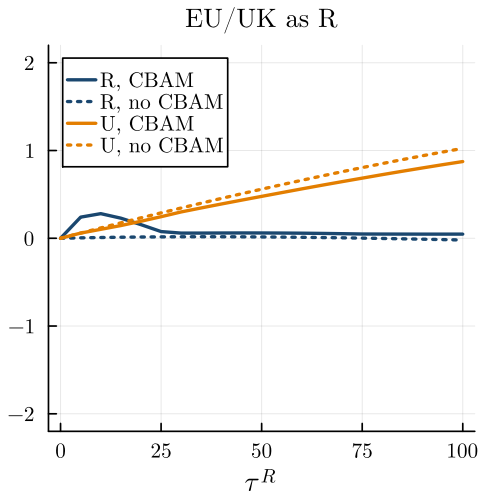
EU/UK as R



EU/UK/China as R



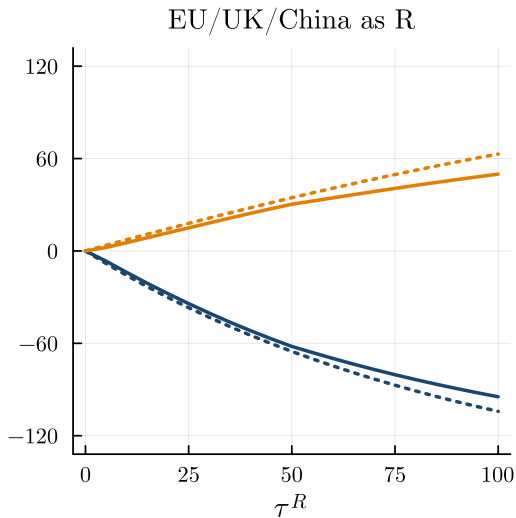
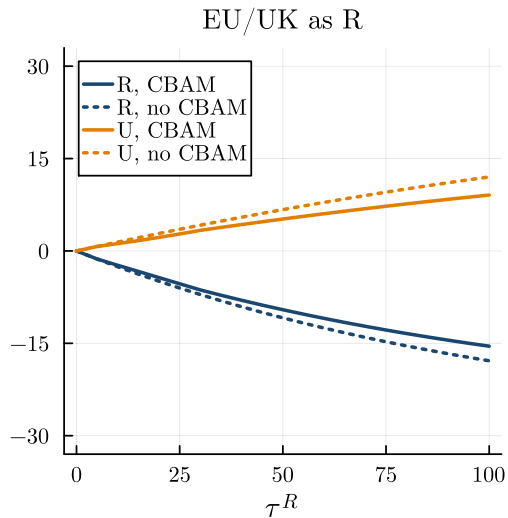
Welfare effects (1B USD)



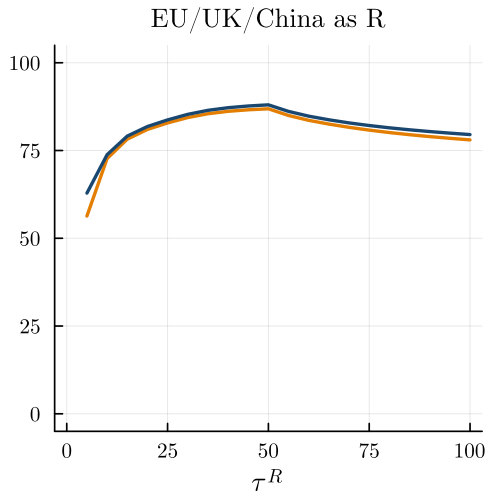
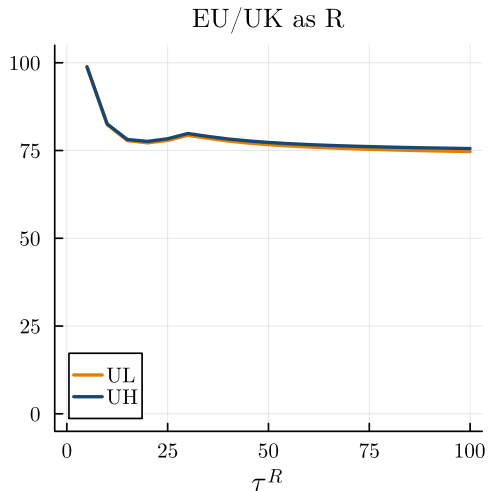
3. CBAMs boost competitiveness

- 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)



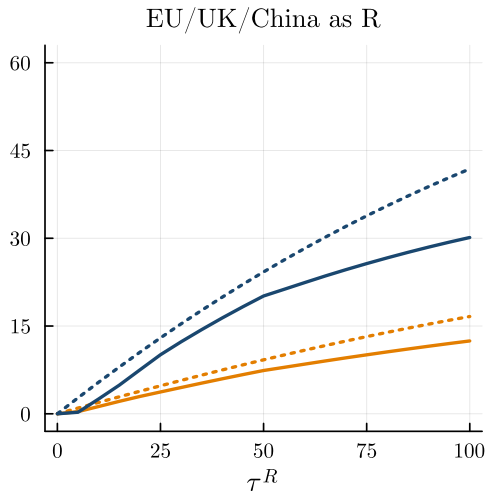
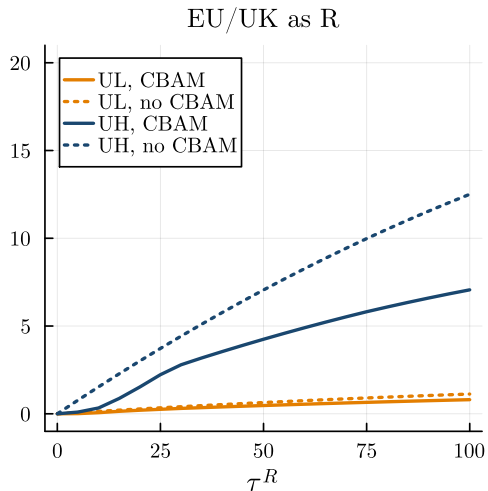
Producer surplus effects (CBAM vs. no CBAM, %)



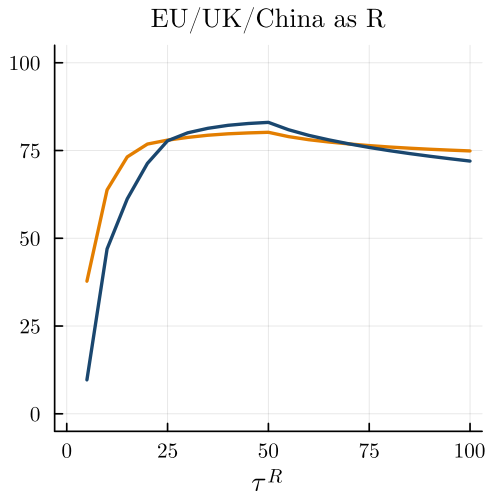
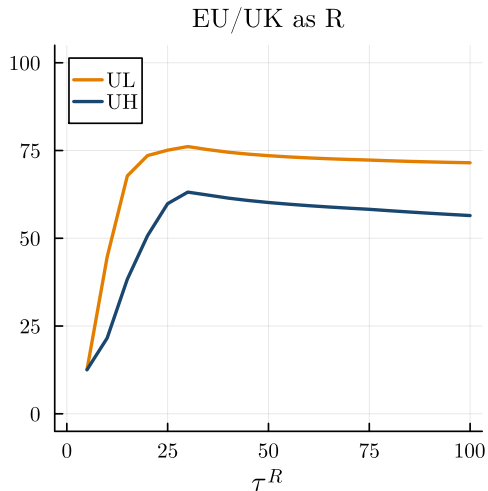
4. CBAMs curb leakage

- 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 CO₂)



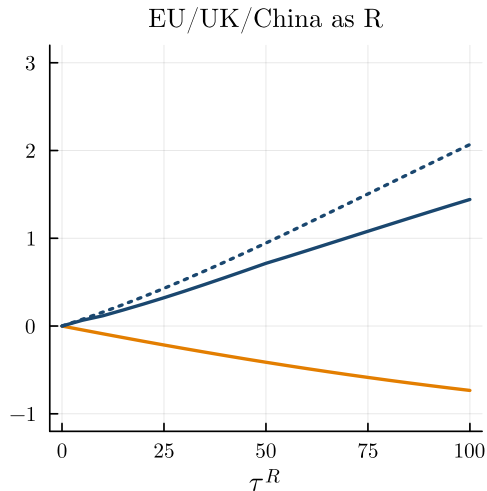
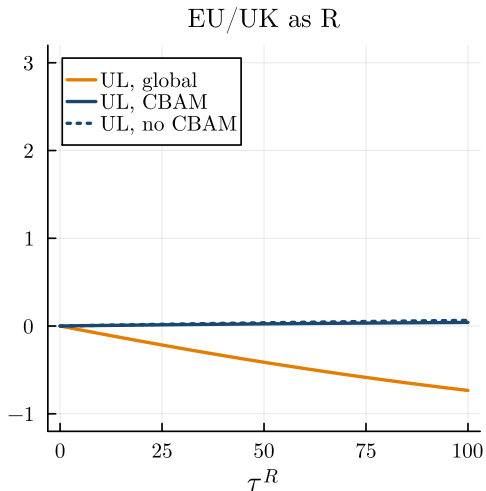
Emissions effects (CBAM vs. no CBAM, %)



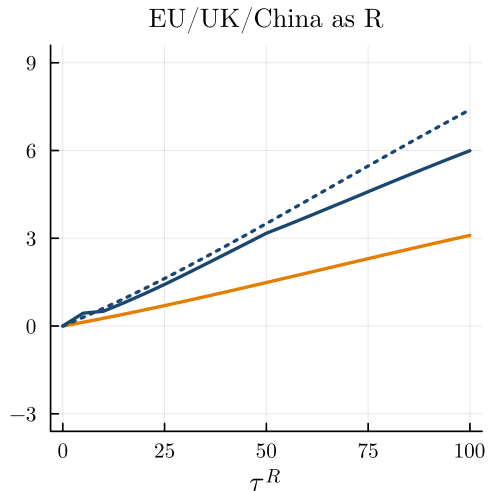
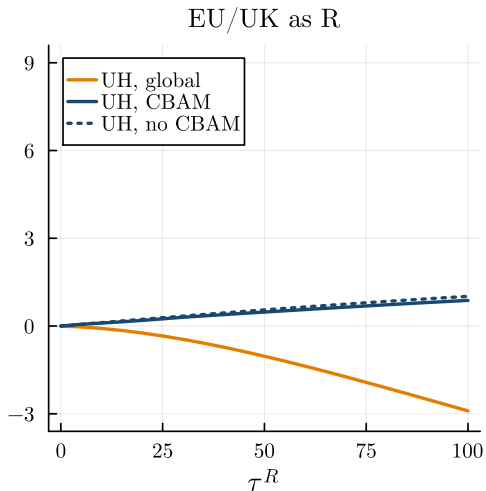
5. CBAMs encourage regulation

- 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
 - Domestic advantages may help to pass carbon regulation
 - Without disproportionate impacts on lower-income countries