

# The Global Effects of Carbon Border Adjustment Mechanisms

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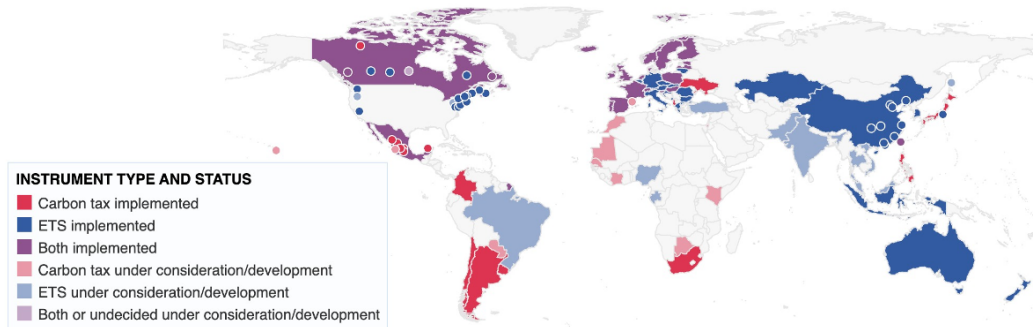
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# Carbon pricing around the world (2024)



# Carbon border adjustment mechanism (CBAM)

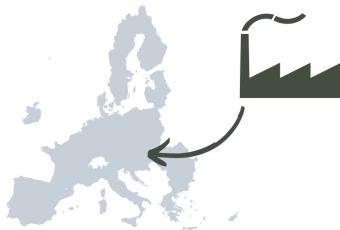
Cement, iron and steel, aluminium, fertilisers, electricity and hydrogen



## EU Production



EU production is subject to the **EU-ETS\***  
*(Assuming an ETS allowance price of 90€ per tonne of CO<sub>2</sub>)*



## 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

## EU/UK carbon taxation with a CBAM

- At \$100 (90€) per ton of CO<sub>2</sub>
- **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

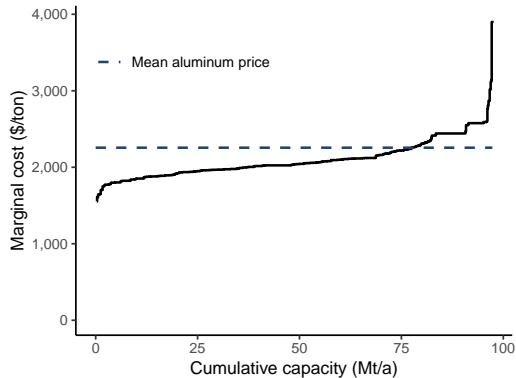
- Globally traded commodities
  - London Metal Exchange reports global prices and facilitates trade
- Aluminum
  - Primary: smelted from alumina with CO<sub>2</sub> from chemistry and electricity
  - Secondary: recycled from scrap with 5-10% emissions
- Steel
  - Primary: blast furnace/basic oxygen furnace (BF-BOF) from iron ore
  - Secondary: electric arc furnace (EAF) from scrap with 35-40% emissions

# Global data by plant for 2023

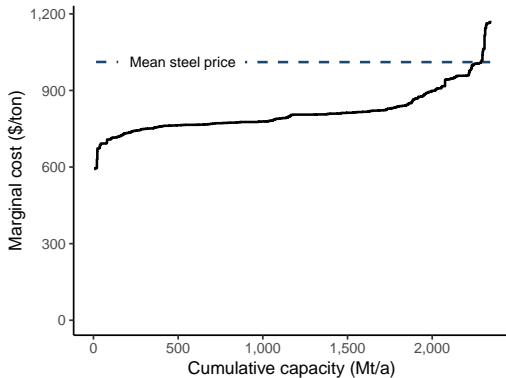
- Aluminum smelters from WoodMac
  - 153 worldwide with some Chinese smelters aggregated
  - Public data and site visits
  - LIC producers: 7% of global production, 9% of global emissions
- Steel mills from Climate TRACE
  - 892 worldwide with capacity above 500k tons
  - Satellite and mill-level sensor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

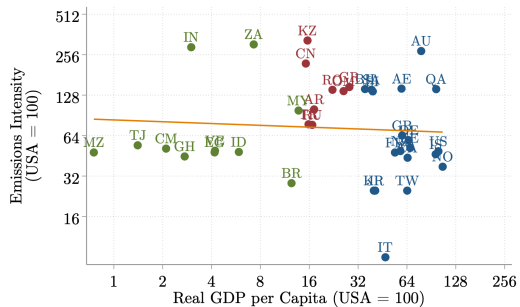
Country	Mt	%
China	827	49
EU + UK	169	10
USA	101	6
India	77	5
Japan	68	4
Rest of world	431	26



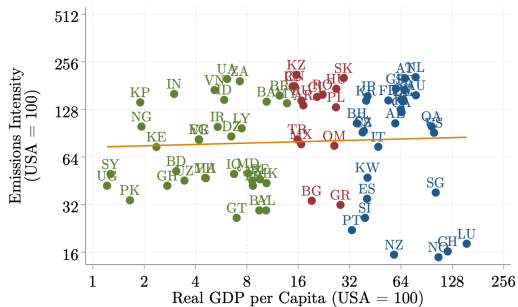
# Descriptives

# Emissions intensity by income

## Aluminum

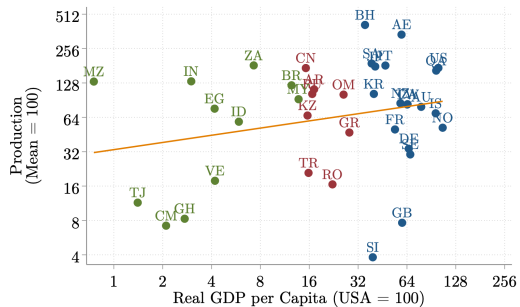


## Steel

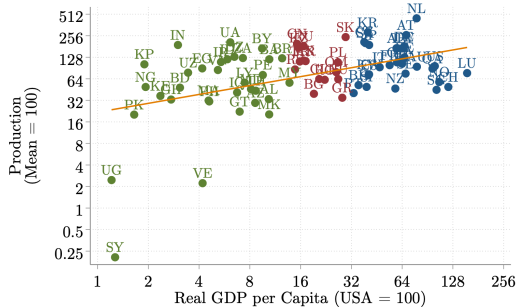


# Production scale by income

## Aluminum

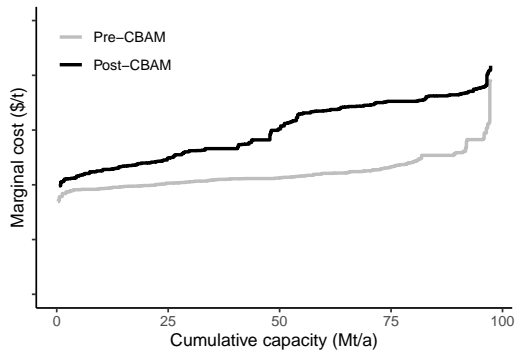


## Steel

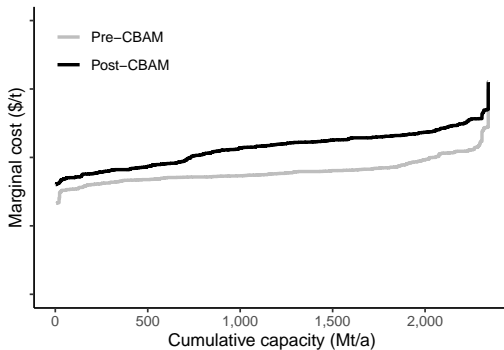


# CBAMs add to costs

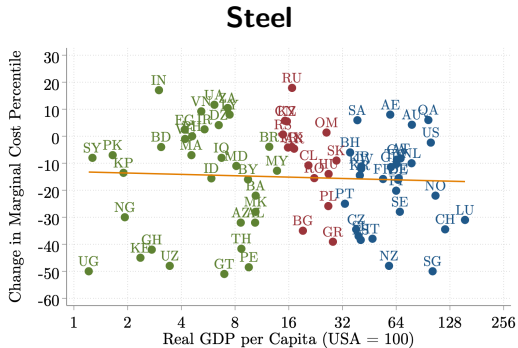
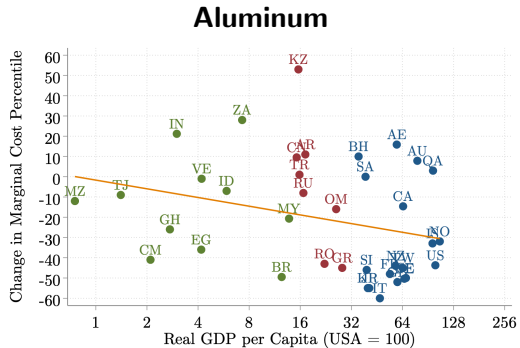
## Aluminum



## Steel



## 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  $\varepsilon^m = -0.25$



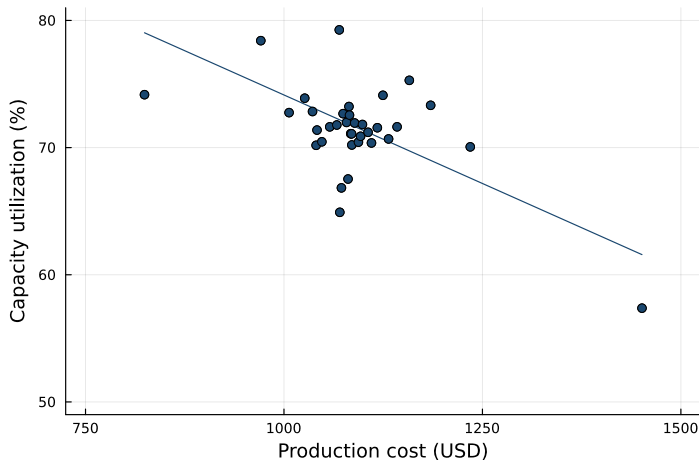
## Supply by plant $i$

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

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

- Production  $s_i$  depends capacity utilization  $o_i^m$  via choice to operate lines  $\ell$
- 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

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

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

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

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

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

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

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

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

## Markets clear

$$\begin{aligned}D^R(p^{R*}) &= S^R(p^{R*}, p^{U*}; \alpha^R) \\ D^U(p^{U*}) &= S^U(p^{R*}, p^{U*}; \alpha^R)\end{aligned}$$

- 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 CO<sub>2</sub>

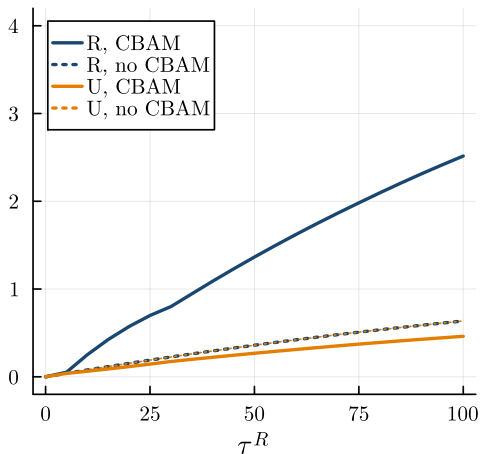
Impact	Pre-CBAM		Post-CBAM	
	<i>R</i>	<i>U</i>	<i>R</i>	<i>U</i>
Price (%)	0.64	0.64	2.52	0.46
Emissions (Mt CO <sub>2</sub> )	-93.2	13.6	-91.3	7.87
Welfare (1B USD)	-0.02	1.02	0.05	0.87
Consumer surplus (1B USD)	-1.22	-11.0	-4.40	-8.20
Producer surplus (1B USD)	-17.8	12.0	-15.5	9.07
Government revenue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

## 2. Regulation and reallocation effects

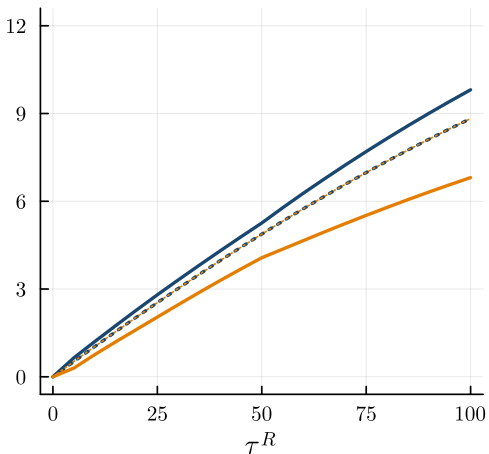
- Without a CBAM, regulation effect alone
  - World price  $P$  rises as regulation reduces world supply
- With a CBAM, regulation + reallocation effect
  - Price  $P^R$  rises and pulls clean supply to  $R$
  - Price  $P^U$  falls as dirty supply pushed to  $U$
- Modest price effects: no more than 10%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

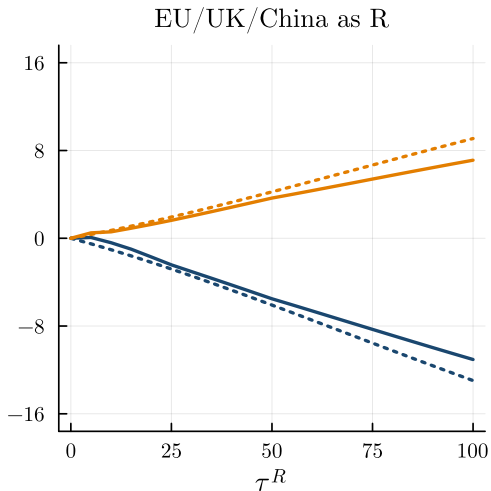
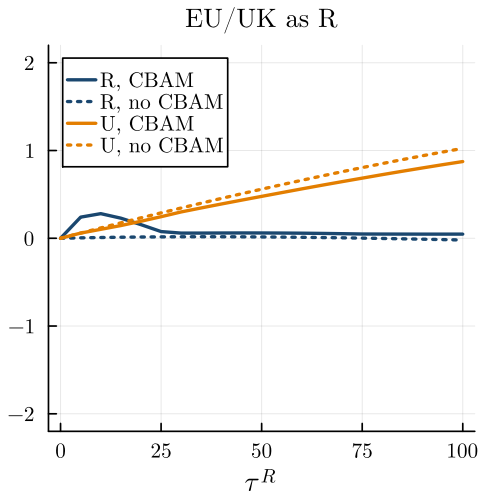
EU/UK as R



EU/UK/China as R



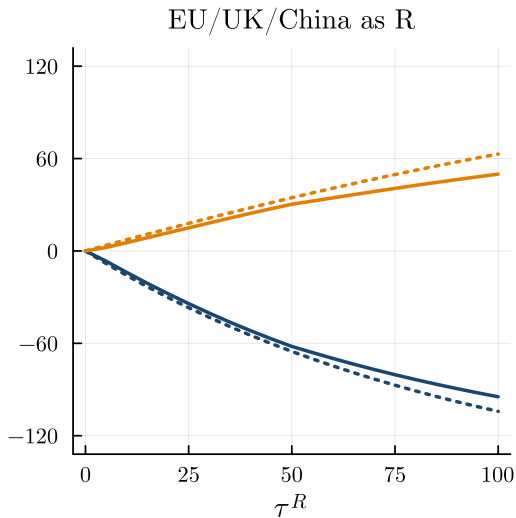
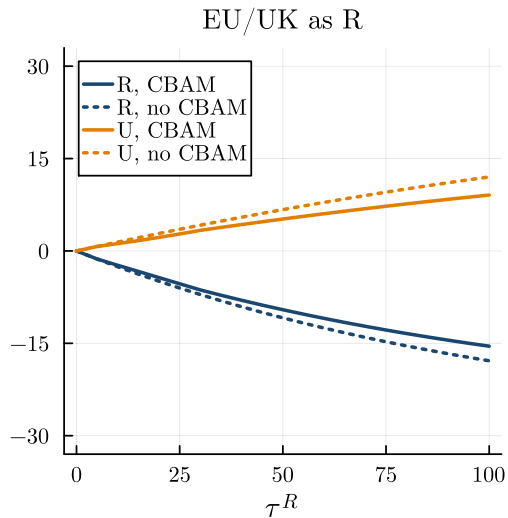
## Welfare effects (1B USD)



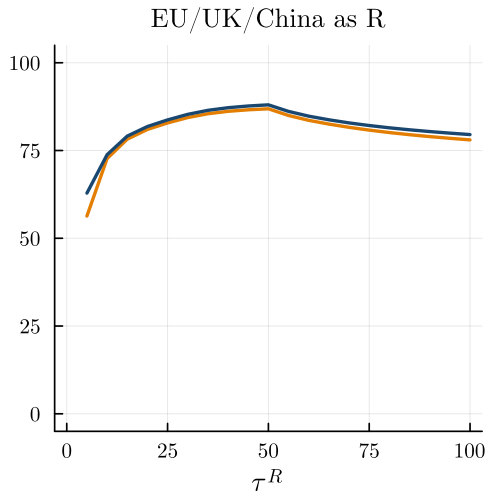
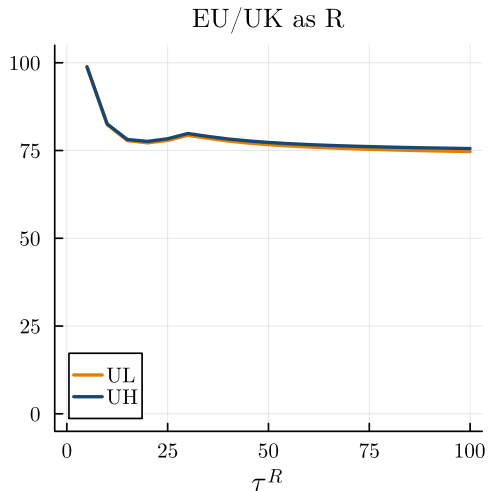
### 3. CBAMs boost competitiveness

- 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, %)

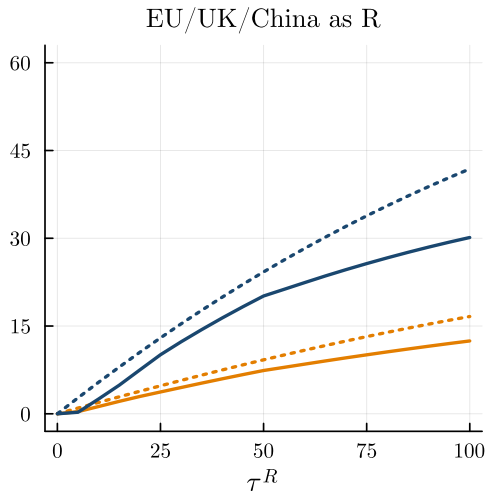
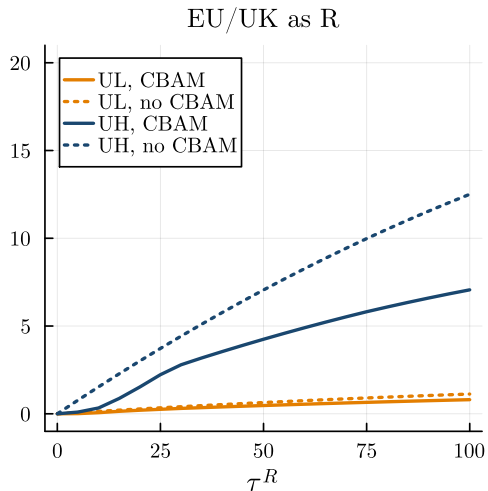


## 4. CBAMs curb leakage

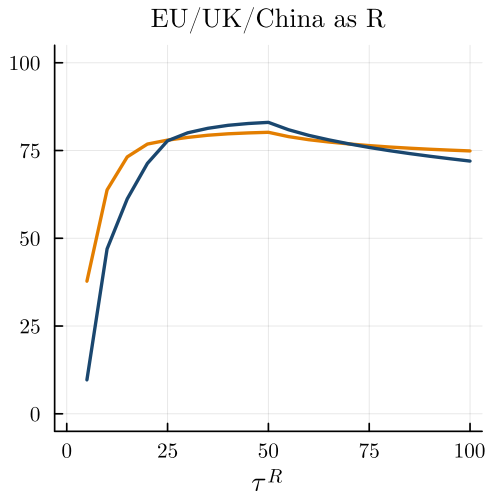
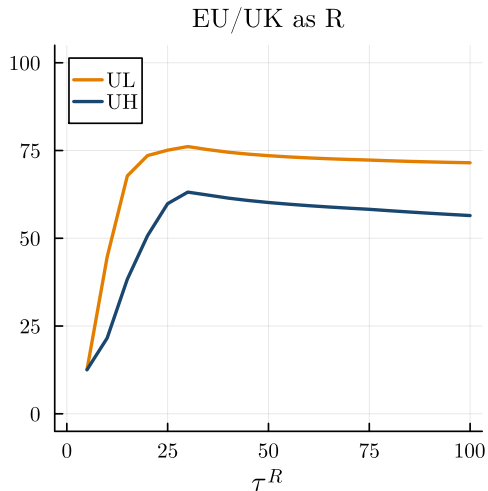
- Regulation in  $R$  lowers emissions in  $R$ , raises emissions in  $U$ 
  - Because of higher world price  $P$
- CBAM reduces emissions increases in  $R$  by 25-50%
  - With similar pressure on lower- and higher-income countries
- Despite leakage, total emissions reductions are large
  - Up to 1 Gt when  $R$  includes China and  $\tau^R = 100$  per ton of  $\text{CO}_2$
  - Relative to 3.9 Gt in our baseline data



# Emissions effects (Mt CO<sub>2</sub>)



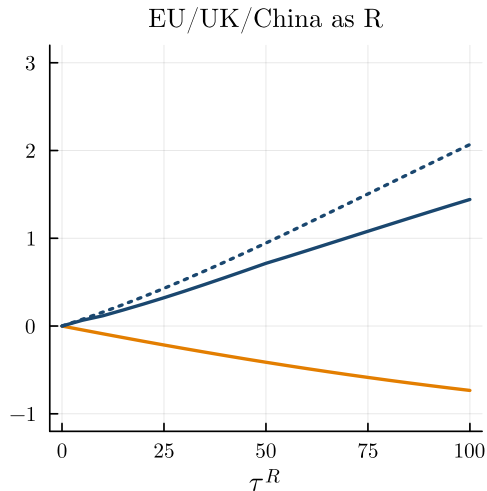
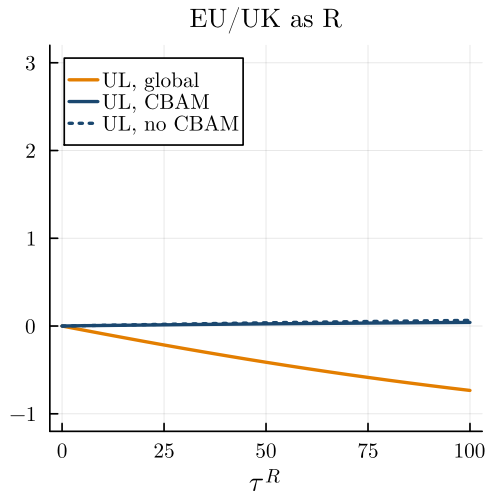
## Emissions effects (CBAM vs. no CBAM, %)



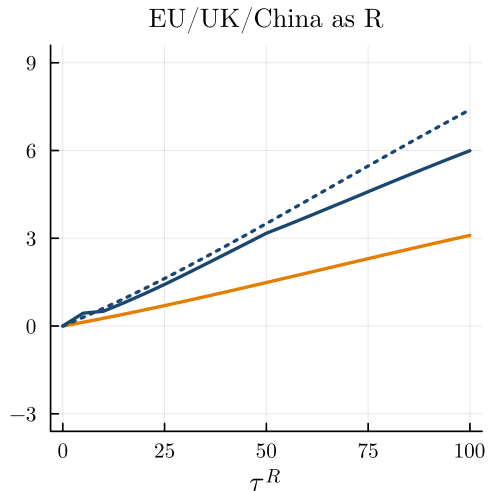
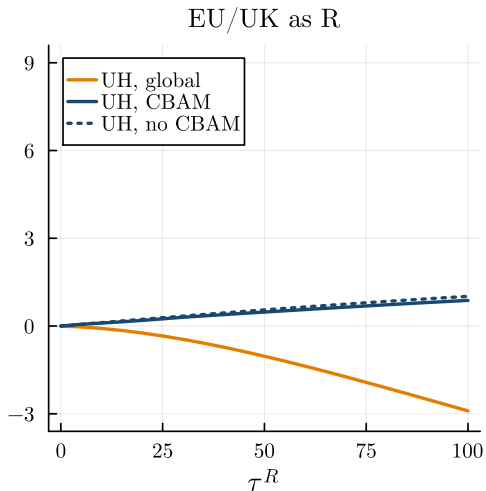
## 5. CBAMs encourage regulation

- 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