Subglobal Climate Agreements and the Copper Mining Industry

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Introduction

Motivation

- Subglobal carbon policies would induce a change in the relative production costs
- For globalized industries, this might induce a shift of economic activities towards unconstrained countries
- A change in the value of productive assets could have important distributional issues
- Reduction of emissions in committed countries could be compensated by an increase in non-committed countries: carbon 'leakage'

Motivation continued

- The copper mining industry could a priori be significantly affected by subglobal climate policies:
  - Involves several is energy intensive production stages
  - Low transportation costs relative to the value of copper
  - Active international trade in intermediate and refined commodities
  - Homogeneous commodities
  - Competitive industry
- Activities locate according to economic incentives

Relation Economy-Wide Perspective

- Energy-intensive sectors are only crudely represented in economy wide models, e.g. Babiker and Rutherford (2005)
- Multisectors models may either *over*- or *under*-estimate leakage
  - i Multisectoral models may omit sector-specific inputs and assume economy-wide capital stocks, leading to an overestimate of responsiveness.
  - ii Two-way trade in generally portrayed as trade in differentiated goods distinguished by region of origin, providing a tendency to *underestimate* leakage.

Aims of the paper:

- Provide a framework to assess the implications of carbon policies in the copper mining industry
- Quantify the potential for and determinants of carbon leakage
- Assess regional distribution of costs and benefits
- Question: Existence of a compensation scheme to increase participation within the industry?
- Alternative: Implement trade policies to mitigate carbon leakage

- Plant-level neoclassical model of the copper industry
- Spatial representation of trade through geographical information (longitude/latitude)
- Calibration of the model:
  - Benchmark equilibrium: 2007 production and consumption data
  - Supply and demand response: panel data estimates of price elasticities

Presentation outline

- Background on refined copper production
- Description of the model and calibration procedure
- Policy simulations and sensitivity analysis
- Conclusion

Background

Copper production: key facts

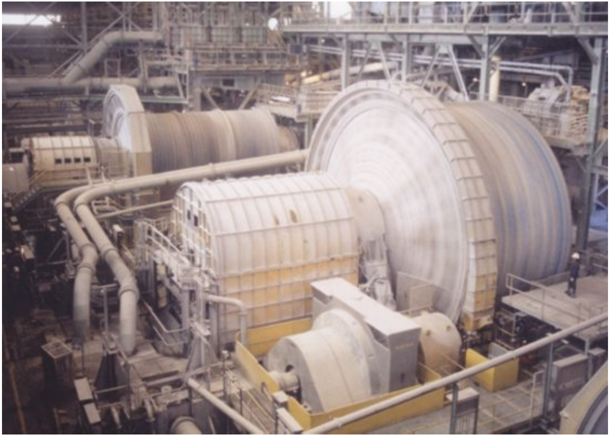
- Copper deposits typically contain 0.5 to 1 percent pure copper
- Retrieving pure copper is energy intensive both in terms of fossil fuels and electricity
- Two main routes to refine copper from deposits:
  - Thermal treatments (Pyrometallurgical processing)
  - Sequential dissolution and precipitation (Hydrometallurgical processing - SXEW)

Pyrometallurgical production process: step 1 of 3

Extraction

Pyrometallurgical production process: step 1 of 3

Grinding



Pyrometallurgical production process: step 1 of 3

Concentrate shipping

Pyrometallurgical production process: step 2 of 3

Smelter

Pyrometallurgical production process: step 2 of 3

Blister

Pyrometallurgical production process: step 3 of 3

Refinery

Refined copper

Refined copper

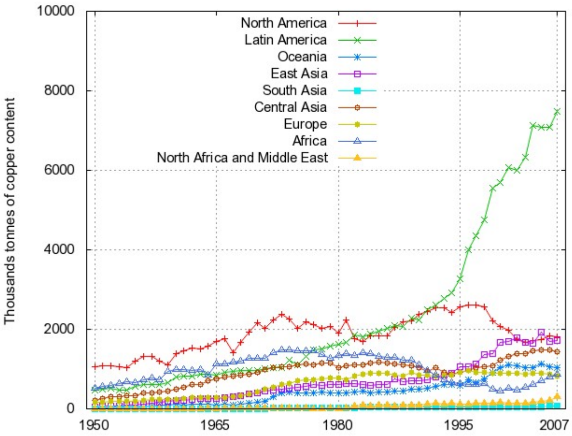
Hydrometallurgical production process (SXEW)

Solvent extraction

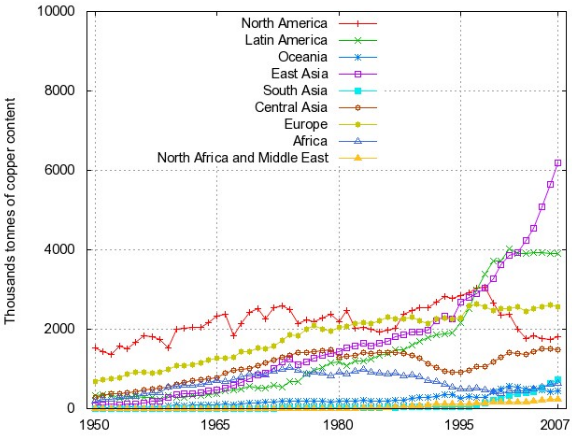
Hydrometallurgical process (SXEW)

Electrowinning

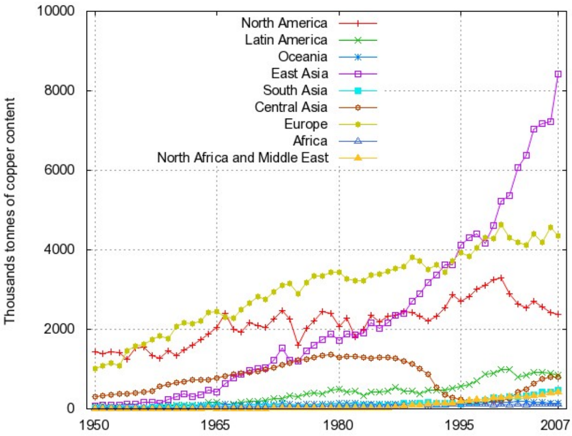
Copper mining output



Refined copper production



Refined copper use

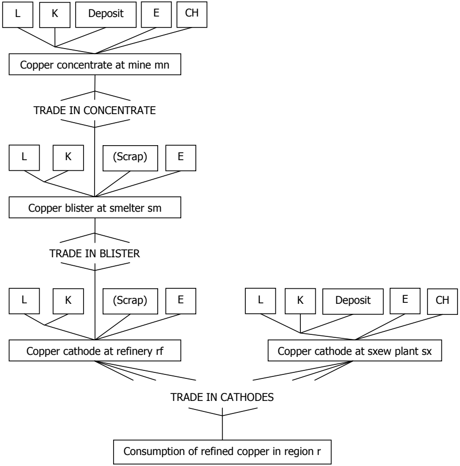


Model for the copper mining industry

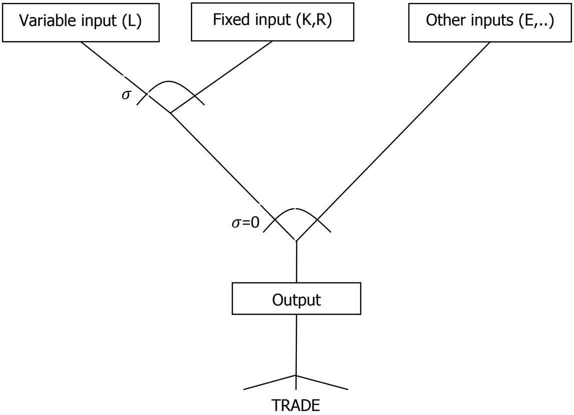
Main assumptions of the model

- Partial equilibrium model – The copper industry is price taker on input markets
- Copper commodities are homogeneous and traded on perfectly competitive markets
- The capital and resource stocks are fixed
- Calibration assumption: observed output and (average) price in a given year represent result of cost minimizing choices in a competitive environment

Model structure



Production technologies: Nested CES representation



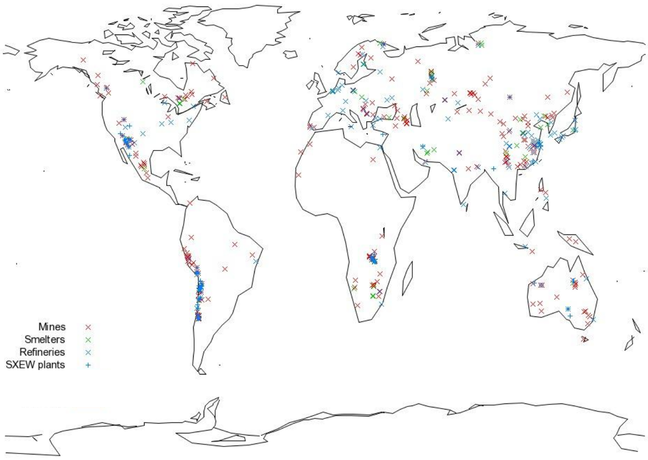
Data sources

- Production, consumption and prices for 2007: ICSG (2008)
- Location of facilities: ICSG (2008), USGS (2003) and online resources
- Rail freight rates: World Bank (2007)
- Ports and sea distances: Lloyd's Maritime Atlas (2005)
- Sea freight rates: UNCTAD (2008)
- Tariffs levied on concentrate, blister and refined copper imports WTO (2008)
- Cost shares and CO_2 emissions: engineering study by Kuckshinrichs et al. (2007)

Average cost shares and emission coefficient

	Mining	Smelting	Refining	SXEW
Top nest				
Value share of copper input (%)	-	69.1	70.4	-
Value share of scrap copper (%)	-	10.4	16.0	-
Value share of energy (%)	24.1	5.0	3.9	22.8
Bottom nest				
Value share of labor (%)	20.8	5.0	2.4	18.5
Carbon emissions				
Tonnes CO_2 per tonnes of copper	2.66	0.80	0.23	1.68

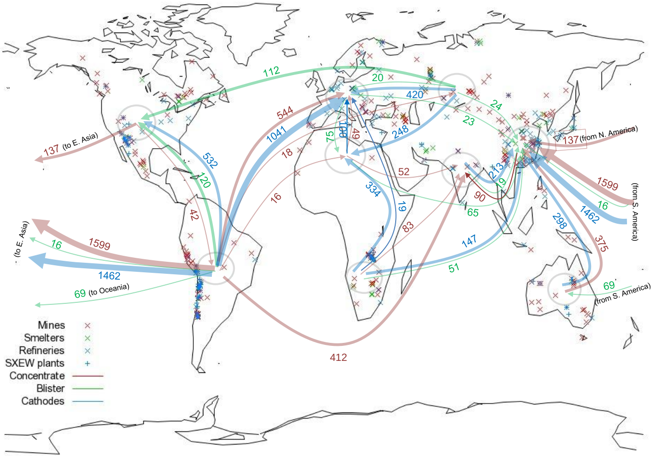
Spatial representation



Auxiliary trade model

- The benchmark equilibrium data only describe plant-level output and consumption of refined copper
- Need to estimate trade flows in the benchmark
- Solve a LP problem minimizing overall transportation costs subject to supply and demand constraints

Simulated trade flows



Supply response of individual plants

- The fixed production factors (residual) constrains the output response to a price increase
- Analytical link between the elasticity of substitution (σ), the cost shares of inputs (θ) and the supply price elasticity (η):

$$\sigma = \theta_{VA} \eta_y^{st} \frac{1 - \theta_L}{\theta_L}$$

$$\theta_R = 1 - \frac{\theta_{VA} \eta_y^{lt}}{\sigma + \theta_{VA} \eta_y^{lt}}$$

- Given data on cost shares we use estimated price elasticities to calibrate the elasticity of substitution

Estimation of market price elasticities (overview)

- Data on mining output, refined copper production and consumption 1950 - 2007
- Data on smelters output 1994 - 2007
- Country level data aggregated into 9 regions
- Panel data – random parameter model
- Constant elasticity (log-log) specification with time fixed effects
- Long run price elasticity for mines estimated by including lags

Random parameter regression results.

Variable	Mines	Smelters	Refineries	Demand
$Price_t$	0.355***	0.376***	1.596***	-0.491***
	(0.110)	(0.010)	(0.078)	(0.109)
P_{t-1}	0.085	-	-	-
	(0.169)			
P_{t-2}	0.159	-	-	-
	(0.177)			
P_{t-3}	0.365**	-	-	-
	(0.178)			
P_{t-4}	0.061	-	-	-
	(0.175)			
P_{t-5}	0.607***	-	-	-
	(0.126)			
GDP_t	-	-	-	1.165***
				(0.058)
Time	0.022***	0.074***	0.029***	0.005**
	(0.002)	(0.010)	(0.002)	(0.002)
$SD(P_{t,t-1,...})$	0.076***	0.136***	0.231***	0.105***
	(0.016)	(0.323)	(0.055)	(0.025)
$SD(GDP_t)$	-	-	-	5.6e-5
				(3.9e-4)
Observations (n/t)	9/52	9/13	9/57	9/57
Pseudo adj. R^2	62.4	51.9	41.9	47.0

Regional elasticity estimates from the random parameter model.

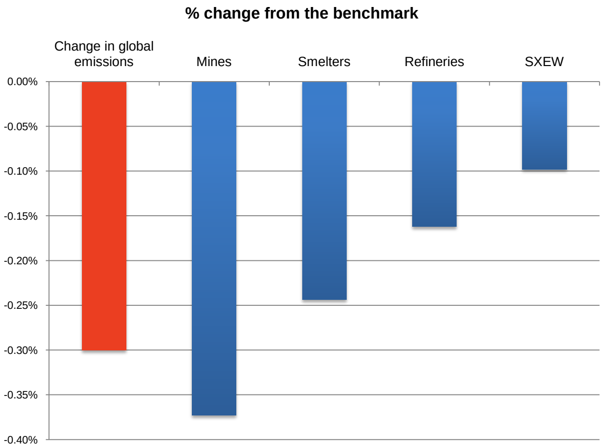
Region	Mines		Smelters	Refineries	Demand
	s.t.	l.t.			
Africa	0.358	1.652	0.294	1.664	-0.440
Central Asia	0.371	1.726	0.428	1.726	-0.363
East Asia	0.365	1.693	0.558	1.731	-0.479
Europe	0.349	1.597	0.498	1.800	-0.435
Latin America	0.401	1.910	0.510	1.723	-0.535
North Africa and Middle East	0.332	1.491	0.190	1.160	-0.711
North America	0.377	1.765	0.452	1.832	-0.450
Oceania	0.346	1.575	0.267	1.484	-0.395
South Asia	0.298	1.287	0.186	1.246	-0.614

Policy simulations

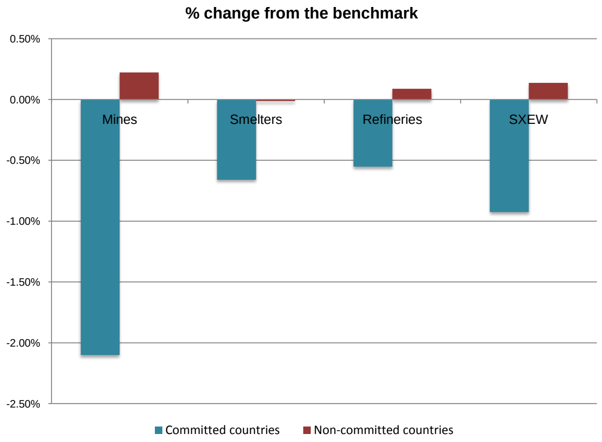
Policy scenarios

- Counterfactual analysis: comparative statics
- First instrument: carbon tax of 100\$/tCO_2 levied in Annex-B countries plus the US and Australia
- Industry specific emission trading scheme (efficient abatement outcome)
- Trade policy measures: border tax adjustments

Change in emission with subglobal carbon tax



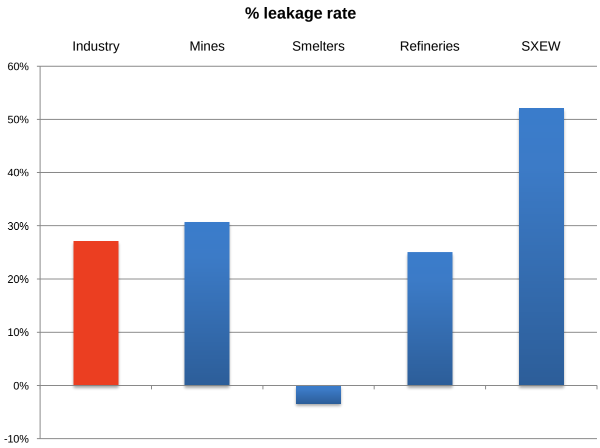
Change in emission with subglobal carbon tax



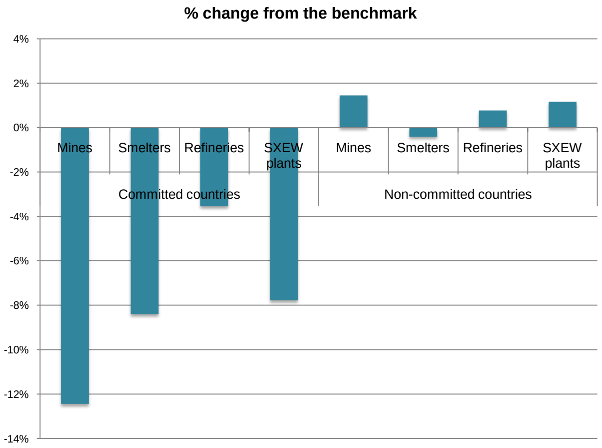
Leakage rate

$$\text{Leakage rate} = \frac{\text{Increase of emissions in non-committed countries}}{\text{Decrease of emissions in committed countries}}$$

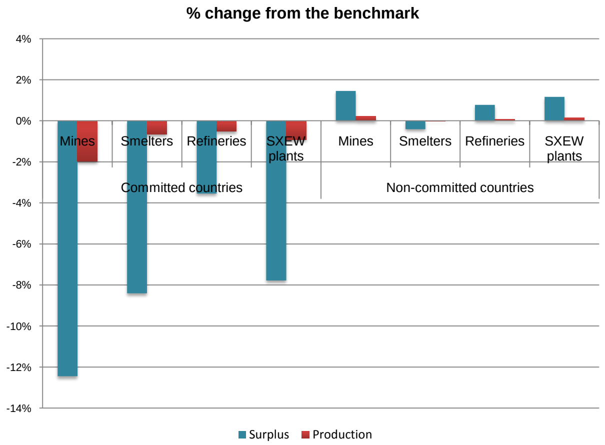
Leakage rate



Change in rents, US$100 tax

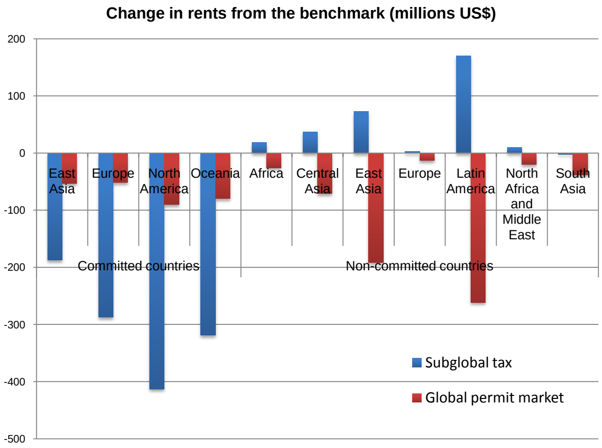


Change in rents and output, US$100 tax



- Relatively high leakage rate
- Limited by changes in the value of fixed productive assets
- Traditional mines would be the most affected units
- Substitution towards SXEW process

Comparison with an industry-specific permit markets



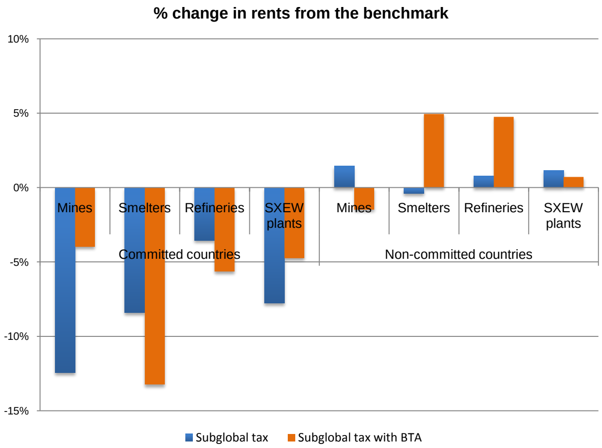
Comparison with an industry-specific permit markets

- For a given emission reduction target, the carbon price resulting from the carbon market is about a third of that imposed by the subglobal tax
- Increasing participation to the entire industry could provide significant efficiency gains
- The loss of rents to the owners of the fixed factors in non-committed countries is larger than the revenue that would be generated by the tax
- Increasing participation appears difficult to achieve

Trade policies: border tax adjustments

- Unilateral carbon tax in committed countries and a tax on imports according to carbon content
- Tax rate determined endogenously to keep emission reduction constant
- Prevents leakage at the cost of further distributional consequences

Welfare effects of border tax adjustments

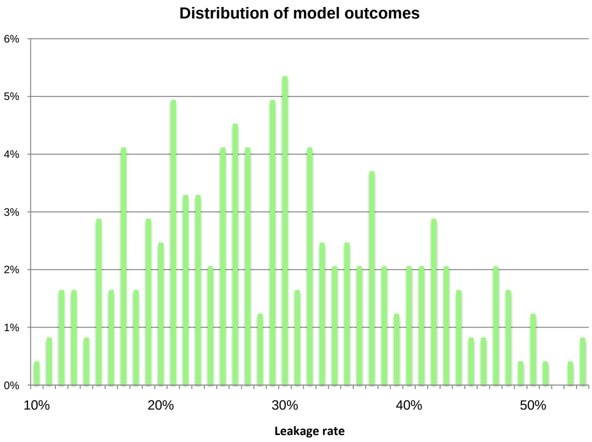


Sensitivity analysis

Sensitivity analysis: elasticity estimates

- Given the calibration procedure, the elasticity estimates determines the supply response
- Unconditional sensitivity analysis: mean, upper and lower bounds of 95% confidence intervals
- Leakage:
  - mean 29%
  - min 10%
  - max 54%

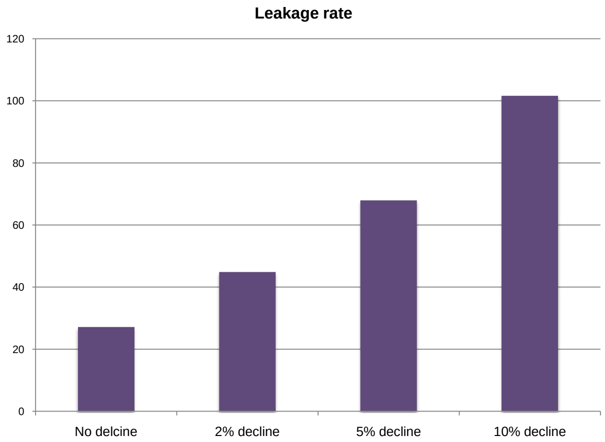
Sensitivity analysis: elasticity estimates



Sensitivity analysis: global energy market

- Carbon policies are likely to reduce the demand for fossil fuels and hence a decline in the price of energy
- Non-committed countries could therefore also benefit through a decline in the cost of the energy input
- Assume carbon policy decrease energy prices in non-committed countries by 2%, 5% and 10%
- For a subglobal carbon tax of US$100, the leakage rate would increase significantly

Sensitivity analysis: global energy market



Sensitivity analysis: benchmark year for calibration

- Calibrating the model with 2007 data imposes the cost structure to match a price of US$7000 per tonne of refined copper
- Historically this is a relatively high price
- We calibrated the model to production and consumption data for 2002, with average price of copper US$1500 per tonne
- Two countervailing effects: trade costs are relatively higher and the carbon price has a larger impact on production costs
- We find the tax to have a greater incidence on emissions in committed countries and a relatively lower leakage effect (18%)

Conclusion

Summary

- At the current price levels, a subglobal carbon tax would have a relatively small impact on emissions from the copper industry
- Production is price inelastic, and most of the change would be ‘buffered’ by a change in the value of productive assets
- This limits the short run carbon leakage effect
- However, this implies significant incentives to invest in capacity expansion in non-committed countries
- Over time, as the fixed input is allowed to expand or depreciate, the carbon leakage effect might increase

Summary

- The winners of subglobal carbon policies would thus be the owners of capital and resource stocks in non-committed countries
- The formation of a larger coalition seems unlikely
- Trade policy tools can mitigate carbon leakage but have distributional consequences among the committed countries
- Outcome on global energy markets is likely to be of first order importance for the copper industry

Implications

- We conclude that economy-wide analyses tend to *overestimate* the response of copper mining and production to subglobal carbon emission restrictions.
- Sunk costs imply low short-run elasticities. That is, abatement costs are capitalized and there is limited short-run impact on the location of production.

Good News: We do not need for complex border measures to prevent leakage.

Bad News: It is unlikely the copper industry can provide low-cost abatement over the next decade or two.

Thank you for your attention.