Trade, Outsourcing and the Environment

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Trade and the environment

Important interactions between trade and the environment:

- International trade policy affects:
  - scale and distribution of output (=income)
  - scale and distribution of environmental impact
  - emissions through transportation
- Environmental policy affects international trade
  - relocation and structure of production
- Both have distributional impacts → political economy

→ We study the topics above in a quantitative trade model

The idea of a carbon border adjustment (CBAM)

Some problems with unilateral carbon pricing

- Lower domestic competitiveness
- Relocation of production (aka leakage)

→ CBAM tries to prevent these

Current EU proposal

- Price the carbon content (scope 1 or 2) of (certain) imports into EU
- Try to "level the playing field"
- So far only for only some sectors/products

Considerations

Effectiveness

- Can it prevent leakage?
- What are the implications of an incomplete CBAM design?
- How does it effect other environmental aspects? E.g. efficiency in production and emissions from transportation.

Equity concerns

- Concerns in developing and middle income countries
- Impact is unclear, both across and within countries

Transport Emissions

Approach of this study

This paper studies the effects of:

- Unilateral carbon taxation
- Carbon border adjustments

In a setting with:

- Global trade → potential for leakage
- Outsource parts of production → allows for additional leakage
- Emissions from transportation → more complete picture
- Labor market frictions → reallocation to green production
- Focus on developing countries → important for equity

Literature

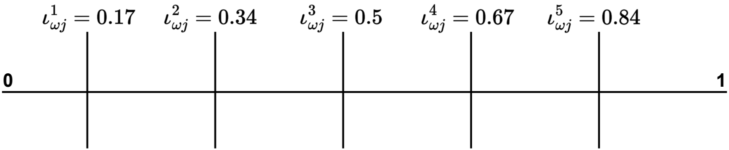
Overview

- General equilibrium international trade model
- Multiple countries and detailed sectors
- Perfectly competitive many producers
- Emissions from production and international transportation of goods
- Endogenous discrete-choice production structure:
  - Use “green labor”
  - Or use carbon-emitting input
  - Or use outsourced components instead
- Labor market frictions

Model details

Production stages

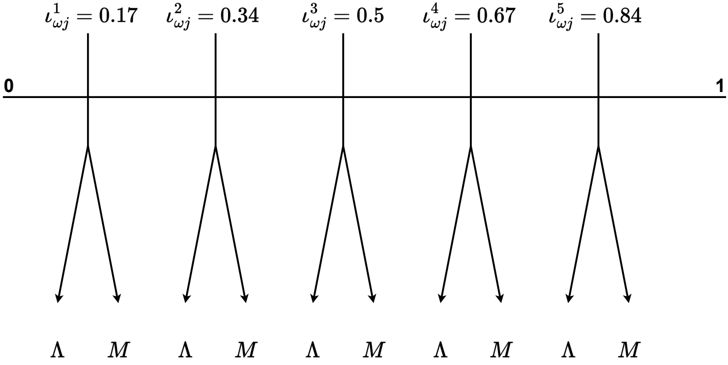
Internationally traded varieties, ω_j, are produced by completing a continuum of independent stages, $\iota_{\omega j} \in (0, 1)$.



After performing each stage once, $1/x^m(\omega_j)$ units of ω_j are produced

Choice between in-house and outsourcing

Stages can be implemented using local input, Λ, or outsourced parts and components, M



Abatement and outsourcing

- Composite local input

$$\Lambda \rightarrow \begin{cases} \text{Clean labor } \; L(\iota_{\omega j}), \;\; \text{Cost: } \; w_j^m \\ \text{Carbon input } \; E(\iota_{\omega j}), \;\; \text{Cost: } \; c_{jE}^{nm} = p_E + \epsilon(\psi_j^m + \kappa_j^{nm}) \end{cases}$$

- Outsourced input

$$M \rightarrow \text{Use internationally traded varieties } \; \omega_j$$

Share of carbon emitting processes

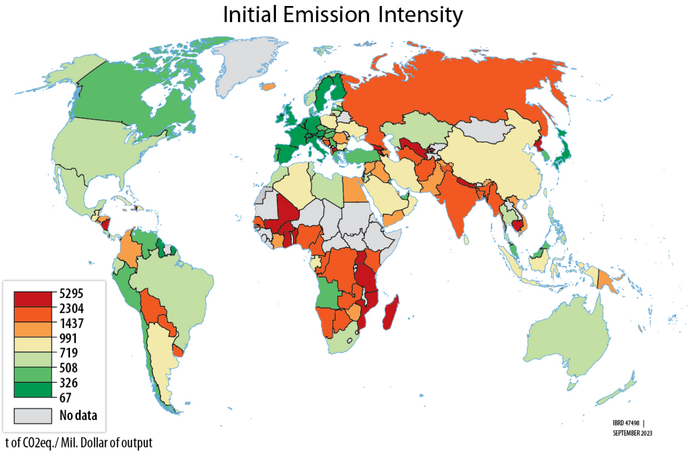
- Cost minimizing share of carbon input in output thus depends on:
  - Labor costs relative to emission costs
  - The relative costs of in-house to outsourcing
  - Variance of productivity draws (i.e. elasticity)
  - Labor market frictions
  - Geography
  - Comparative advantage patterns

→ When trying to reduce emissions, producers can:
  - abate, i.e. move from E to L, or
  - outsource parts of the production, i.e. move from Λ to M

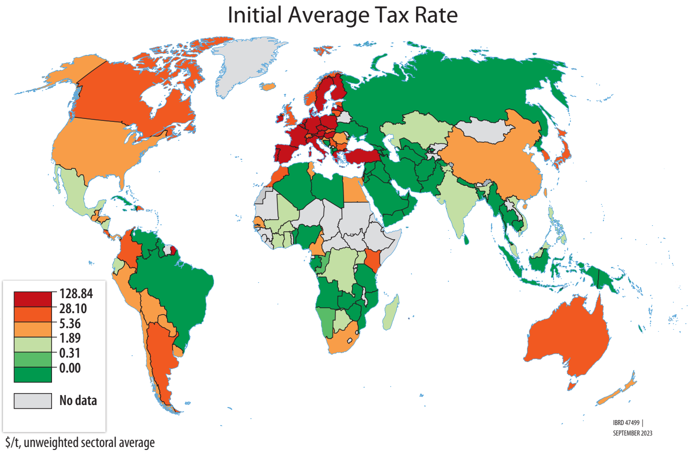
Data sources

- IO and trade (β, γ, π ...): WIOD and EORA Details
- Production emissions: CO_2, CH_4, NO_2 (converted into CO_2 equivalents) from WIOD (2009)
- α_E, carbon emitting input: convert emissions into costs using energy inputs and IEA data Details
- Carbon tax: OECD environmental tax revenues, made granular with Eurostat → Wide definition of carbon taxes Details
- Transport emissions: Based on several sources and methodology from Cristea et al., 2013 and Klotz and Sharma, 2023 Details
- Elasticities all taken from literature Details

Descriptive data 1/2



Descriptive data 2/2



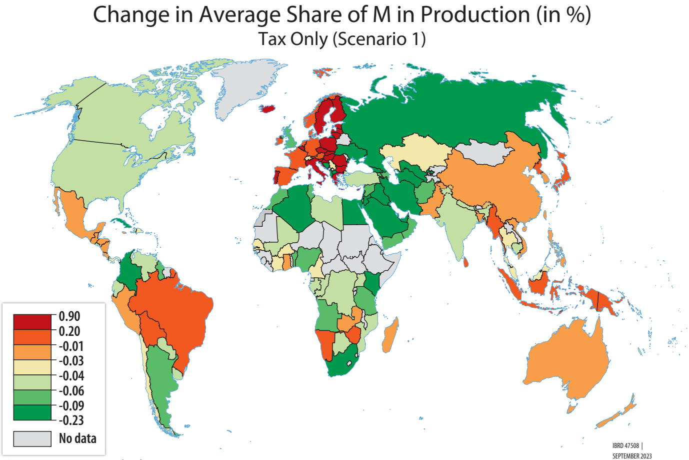
Strategy

Proceed in two steps:

1. Simulate a uniform tax increase in EU/EFTA countries
2. Impose a CBAM in addition to the tax increase

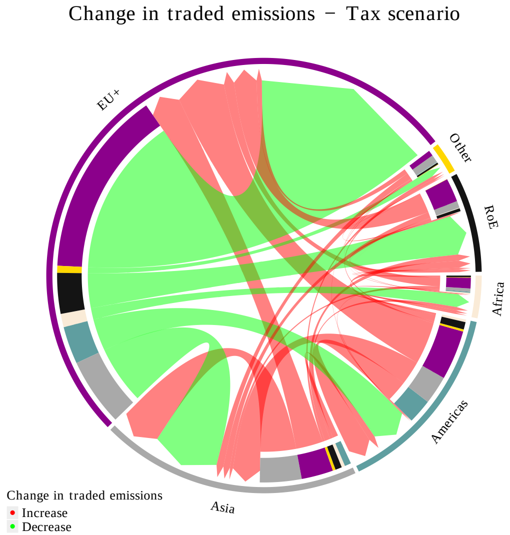
- CBAM is just difference between EU and local tax
- Our simulation is more substantial than the current proposal

Tax increases outsourcing

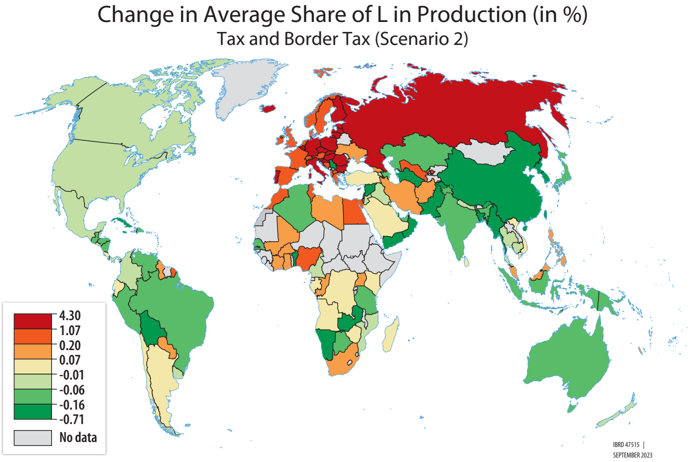


Averages are output weighted, keeping output fixed

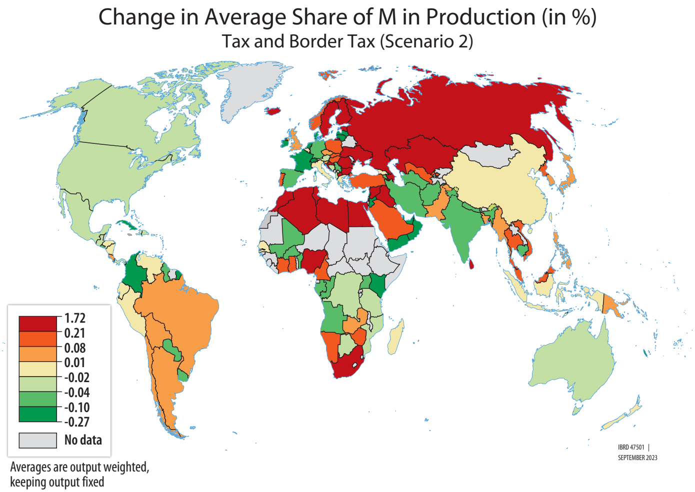
Increase in emission (net)imports into Europe



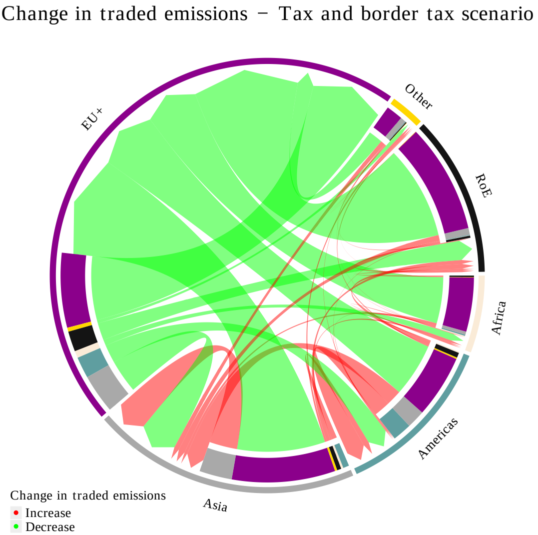
CBAM can induce abatement elsewhere



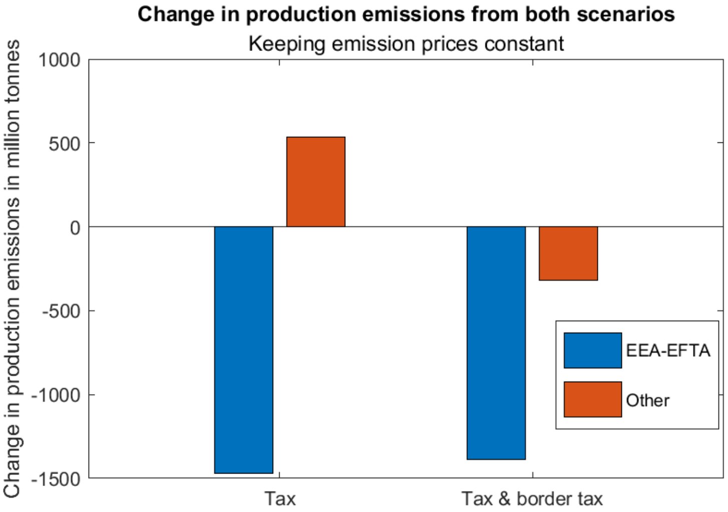
CBAM can also cause additional leakage



Emission imports Europe decrease (increase elsewhere?)



Global emissions decrease (when allowed to change)



Conclusions

- We develope a quantitative trade model that:
  - includes emissions and emission (border) taxes
  - incorporates input-output linkages (between countries)
  - incorporate emissions from transportation
- We find that:
  - an imperfect CBAM can trigger a second form of leakage
  - countries most affected by an EU CBAM will be countries in close proximity

Thank you!

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The importance of transport emissions in trade

- International transport responsible for 33% of trade related emissions (Cristea et al., 2013)
- Literature has largely ignored transport emissions and focused on production relocation
- More trade can imply increases in production efficiency, but can also increase emissions from transportation
- Carbon taxes and CBAM do not account for these emissions

CBAM

Literature

Trade and environment

Antweiler et al., 2001; Frankel and Rose, 2005; Levinson and Taylor, 2008; Shapiro and Walker, 2018; Duan et al., 2021; ... among many others

CBAM

CGE: Fischer and Fox, 2012; Chepeliev et al., 2022
GE trade: Larch and Wanner, 2017; Farrokhi and Lashkaripour, 2021

Transportation emissions from trade

Shapiro, 2016; Cristea et al., 2013

Trade foundation

Eaton and Kortum, 2002; Caliendo and Parro, 2015; Grossman and Rossi-Hansberg, 2008; Artuç and McLaren, 2015

Main

Disutility from emissions

$$Q_j^n \equiv \left[\int \left(Q^n(\omega_j) \right)^{\frac{\sigma-1}{\sigma}} d\omega_j \right]^{\frac{\sigma}{\sigma-1}}$$

$$U^n = \left[1 + \left(\frac{\widetilde{E}}{\gamma_E^n} \right)^2 \right]^{-1} \prod \left(Q_j^n \right)^{\gamma_j^n}$$

Main

Leads a CES cost structure for ω_j

- For one unit of ω_j, minimized cost

$$c^{nm}(\omega_j) = x^m(\omega_j)\left[\left(a_{j\Lambda}c_{j\Lambda}^{nM}\right)^{-\varsigma} + \left(a_{jM}c_{jM}^{n}\right)^{-\varsigma}\right]^{-\frac{1}{\varsigma}}$$

- Cost index

$$c_j^{nm} = c^{nm}(\omega_j)\frac{1}{x^m(\omega_j)} \qquad \text{for any variety of } \omega_j$$

Main

In-house production

- In-house production has a CES technology

$$\Lambda_j = \left[\left(\frac{1}{a_{jL}} L_j^m(\iota) \right)^{\frac{\varphi}{\varphi+1}} + \left(\frac{1}{a_{jE}} E_j^m(\iota) \right)^{\frac{\varphi}{\varphi+1}} \right]^{\frac{\varphi+1}{\varphi}}$$

  - L: Labor input
  - E: Emission input
  - $\varphi + 1$: Elasticity of substitution

- Labor is perfectly mobile across processes and stages within a sector

Main

Details on in-house production costs

- Minimized cost of in-house production

$$c_{j\Lambda}^{nm} = \left(\left(a_{jL} w_j^m \right)^{-\varphi} + \left(a_{jE} c_{jE}^{nm} \right)^{-\varphi} \right)^{-\frac{1}{\varphi}}$$

Main

Parts and components: Details

- Input M_j^n for sector j is produced using varieties ω_k

$$M_j^m = \prod_k \left(\left[\int \left(Q_M^m(\omega_k) \right)^{\frac{\widetilde{\sigma}-1}{\widetilde{\sigma}}} d\omega_k \right]^{\frac{\widetilde{\sigma}}{\widetilde{\sigma}-1}} \right)^{\beta_{jk}^m}$$

  - $Q_M^m(\omega_k)$: Quantity of ω_k used in M_k^m
  - β_{jk}^m Share of sector k in M_j in country m
  - $\widetilde{\sigma}$ Elasticity of subst. between varieties within j

Main

Composite material input: costs

- Price of M_j^n can be expressed using final good prices
- Cost of composite input

$$c_{jM}^n = \prod_k \left(\frac{\Phi_k^n}{\beta_{jk}^n} \right)^{\beta_{jk}^n}$$

- $\Phi_j^n \equiv \left[\sum_m \left(c_j^{nm} \tau_j^{nm} \right)^{-\theta} \right]^{-\frac{1}{\theta}}$ is a price index; with τ_j^{nm} trade costs

Main

International Trade

- Share of imports from country m for sector j

$$\pi_j^{nm} = \left(\frac{c_j^{nm} \tau_j^{nm}}{\Phi_j^n} \right)^{-\theta}$$

  - θ: Productivity dispersion/trade elasticity
  - $\Phi_j^n \equiv \left[\sum_m \left(c_j^{nm} \tau_j^{nm} \right)^{-\theta} \right]^{-\frac{1}{\theta}}$ is a price index; with τ_j^{nm} trade costs

Main

Labor markets

- Workers can choose a sector subject to frictions; total measure of $\widetilde{L}^m$ workers
- Sector-specific productivity shocks to workers $\rightarrow$ Frechet shape ν
- No factor price (i.e. wage) equalization
- The share of workers allocated to production of j varieties is

$$L_j^m = \left(\frac{w_j^m}{W^m} \right)^{\nu} \widetilde{L}^m$$

- Maximized total labor income

$$W^m = \left[\sum_k \left(w_k^m \right)^{\nu} \right]^{\frac{1}{\nu}}$$

Main

Externality: Emissions

- Production creates emissions (due to carbon input)

$$E_j^{nm} = \frac{\alpha_{jE}^{nm} \alpha_{j\Lambda}^{nm} Y_j^{nm} \epsilon}{c_{jE}^{nm}}$$

- Transportation also creates emissions

$$T_j^{nm} = \frac{Y_j^{nm}}{c_j^{nm} \tau_j^{nm}} \Omega_j^{nm}$$

Main

Emission supply

A few choices:

1. Keeping emissions constant (baseline)
2. Keeping emission prices constant
3. Supply monopolist maximizes profits

Main

Equilibrium

- Given parameters of the model, and the tax rates ψ^m and κ^{nm}
- Wages w_j^m, carbon price c_{jE}^{nm}, material input price c_{jM}^m, and international trade and production matrix Y_j^{nm} satisfy
- Solutions to discrete choice optimization problems:
  - Labor allocations
  - Input shares
  - Import shares
- International market clearing conditions:
  - International demand is equal to local supply

Main

IO and trade data

World Input Output data

Used to calculate:

- β, γ, π ...
- Trade flows and production parameters

Extend the country coverage by using:

EORA

- Split WIOD ROW into countries available in EORA
- Inlucde all countries with GDP higher than 5bn USD in 2009

$\rightarrow$ Will allow to study effects on smaller countries

Main

Production emissions and taxes

Satellite accounts in WIOD

- CO_2, CH_4, NO_2 (converted into CO_2 equivalents)
- Production related emissions, 2009
- Exercise with scope 2 emissions included

Carbon tax, 2 alternative sources

1. Actual carbon taxes - RFF
2. Environmental tax revenue - OECD; convert into \$/ton value by dividing by emissions → Currently chosen

- → Make sector-specific and get rid of household part with Eurostat data

Main

Focus: Carbon emitting input

Current calibration

- Data on **emission-relevant energy consumption** from WIOD
- (Fuel-specific) **Energy prices** from IEA
- Treat this as E costs, add all costs together and take shares

Main

Transport emissions

Data needs

- Trade values (WIOD)
- Weight to value ratios (Cristea et al., 2013)
- Modes of transportation (Cristea et al., 2013)
- Distances (by mode of transportation) (CEPII and Bertoli et al., 2016)
- Emissions by mode of transportation (Shapiro and Walker, 2018)

→ Transport emissions account for about 38% of total emissions (roughly in line with Cristea et al., 2013)

Main

Elasticities

- Frechet shape parameter (related to trade elasticity), θ: 4.6 (Simonovska & Waugh, 2014)
- Two input substitution elasticities:
  - between E and L; currently $\varphi = 1.86$ (Shen & Whalley, 2013) and
  - between Λ and M; currently $\varsigma = 1.34$ (Chan, 2017)
- Labor substitution elasticity: $\nu = 1.44$ (Lee, 2020)

Main