A Framework for Integrating Climate Goals into Trade Agreements

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The Core Policy Problem

Trade Agreements (WTO/GATT)

- market access and tariff concessions
- **Silent** on climate externalities

Climate Agreements (Paris Accord)

- carbon tax + emissions targets
- **Silent** on trade externalities

The Cross-Externality Problem

↪ Trade agreements influence emissions

↪ Carbon taxes have distributive externalities

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The Cross-Externality Problem

↪ Trade agreements influence emissions

↪ Carbon taxes have distributive externalities

Research Questions

1. How large are the cross-externalities between trade and climate?
2. What institutional framework can feasibly incorporate carbon pricing into existing trade agreements?

Overview of Paper

Theory

- Quantitative trade model with I-O linkages and fossil-fuel supply chains
- Theoretical characterization of cross-externalities between trade & climate

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2. Local carbon taxes create global distributive externalities

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   $\longrightarrow$ Tying membership to carbon commitments is effective

2. Local carbon taxes create global distributive externalities
   $\longrightarrow$ redistribution mechanism needed to equalize tax burden internationally.

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1. Gains from WTO access are positively linked to emissions from trade
   $\longrightarrow$ Tying membership to carbon commitments is effective
2. Local carbon taxes create global distributive externalities
   $\longrightarrow$ redistribution mechanism needed to equalize tax burden internationally.
3. Leveraging findings 1 and 2, we propose a framework to incorporate carbon pricing into existing trade agreements. Literature

1. Theoretical Framework

Economic Environment

Industries $k, g \in \mathbb{G} \equiv \mathbb{E}_1 \cup \mathbb{E}_2 \cup \mathbb{F}$

- $\mathbb{E}_1$ *primary energy* – coal, oil, gas
- $\mathbb{E}_2$ *secondary energy* – electricity
- $\mathbb{F}$ *non-energy* goods
- All industries are internationally traded and competitive

Countries: $i, j = 1, \ldots, N$

- Labor endowed L_i
- Primary energy reserves $R_{i,k}$

CO_2 Emissions from:

1. Industrial energy use
2. Household energy consumption

Households Preferences and Emissions

Utility of the representative household in country i

$$U_i = C_i - \underbrace{\Delta_i(Z)}_{\text{carbon disutility}}$$

- $C_i = \prod_{k \in \mathbb{G}} \left(\frac{C_{i,k}^{(H)}}{\beta_{i,k}} \right)^{\beta_{i,k}}$ is real consumption aggregated over industry bundles
- $C_{i,k}^{(H)}$ is a CES composite over national varieties with elasticity σ_k
- Z = global CO_2 emissions

Household Emissions. Energy consumption generates CO_2

$$Z_{i,k}^{(H)} = v_{i,k}^{(H)} C_{i,k}^{(H)}, \qquad k \in \mathbb{E}_1 \cup \mathbb{E}_2$$

Production Technologies

Production function for good k in country i

$$Q_{i,k} = \varphi_{i,k} \underbrace{\left(\frac{L_{i,k}}{\alpha^L_{i,k}}\right)^{\alpha^L_{i,k}}}_{\text{labor}} \underbrace{\left(\frac{R_{i,k}}{\alpha^R_{i,k}}\right)^{\alpha^R_{i,k}}}_{\text{reserves}} \underbrace{\prod_{g\in\mathbb{G}} \left(\frac{C^{(I)}_{i,gk}}{\alpha^I_{i,gk}}\right)^{\alpha^I_{i,gk}}}_{\text{intermediates}}$$

- $\alpha^R_{i,k} > 0$ only for primary energy
- $C^{(I)}_{i,gk}$: CES composite of national varieties of good g

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Unit cost of producing good k

$$c_{i,k} = {w_i}^{\alpha^L_{i,k}} \times {r_{i,k}}^{\alpha^R_{i,k}} \times \prod_{g\in\mathbb{G}} {\tilde{P}_{i,g}}^{\alpha^I_{i,gk}}$$

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wage rate

rental rate of reserves

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Prices and Emissions

- Iceberg trade costs $d_{ij,k}$ (technical and policy barriers)
- **Price** of good k supplied by origin i to destination j is

$$P_{ij,k} = d_{ij,k} \frac{c_{i,k}}{\varphi_{i,k}}$$

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- **Industrial Emissions.** fossil fuel energy g used by industry k

$$Z^{(I)}_{i,gk} = v^{(I)}_{i,gk} C^{(I)}_{i,gk}, \qquad g \in \mathbb{E}_1 \cup \mathbb{E}_2$$

- **Total emissions** are the sum of industrial and household emissions

$$Z_i = \sum_{g \in \mathbb{E}_1 \cup \mathbb{E}_2} \left[Z^{(H)}_{i,g} + \sum_{k \in \mathbb{G}} Z^{(I)}_{i,gk} \right]$$

Carbon Taxes and Energy Prices

Carbon taxes

- $\tau_{i,k}^{(p)}$ *supply-side* paid at the location of extraction
- $\tau_{i,k}^{(c)}$ *demand-side* paid at the location of combustion

Energy prices after taxes

$$\tilde{P}_{i,k} = \tau_{i,k}^{(c)} P_{i,k}, \qquad P_{i,k} = \left[\sum_{n=1}^{N} [\tau_{i,k}^{(p)} d_{ji,k} \frac{c_{j,k}}{\varphi_{j,k}}]^{1-\sigma_k} \right]^{\frac{1}{1-\sigma_k}}$$

- Tax revenues are rebated to the households of the country applying the tax

Three Theoretical Insights

(1) **Emissions from trade** are positively linked to the gains from trade

- consumption gains from trade $\hat{C}_i \propto \prod_{k,k'} \lambda_{ii,k'}^{\omega_{k'k}}, \qquad \omega_{k'k} \equiv \frac{a_{i,k'k}}{1-\sigma_{k'}}\beta_{i,k}$
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(3) **Efficient carbon taxation** requires transfers in *opposite* directions for supply vs. demand-side taxes

$$T_i^* = (\omega_i - y_i^*) Y^*$$

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after-tax global income share

2. Taking the Model to Data

Data and Calibration

Data: GTAP 2014

- Trade, expenditure, production, CO_2 emissions
- 56 countries list
  (50 largest + 6 aggregate regions)

Industries:

- 3 primary energy:
  Coal, Crude oil, Natural gas
- 3 secondary energy:
  Petroleum, Electricity, Gas mfg
- 17 non-energy: Agriculture/Mining, 11 Manufacturing, 4 Services list

Calibration:

- Production and consumption share parameters ← IO table
- Trade elasticities ← local projection IV (Boehm et al. 2023)

Key feature:
Explicit fossil-fuel supply chains linked through the Leontief inverse

Constrained-Optimal Linkage Problem

Objective: find max carbon price (τ) with transfers (T)

subject to

(a) Single Undertaking: The agreement is strictly all-or-nothing.

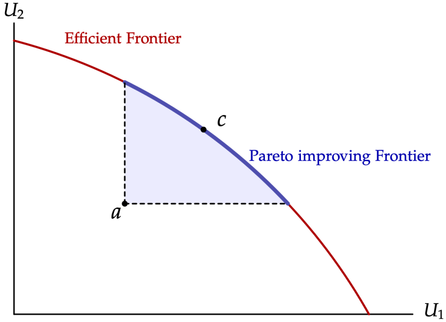
(b) Consensus: The reform (τ, T) must Pareto-dominate the disagreement point.

(c) Fiscal Feasibility: Transfers funded by only border-related tax revenues.

(d) Minimal Information: Requires uniform pricing and easily computable transfers based on verifiable public data.

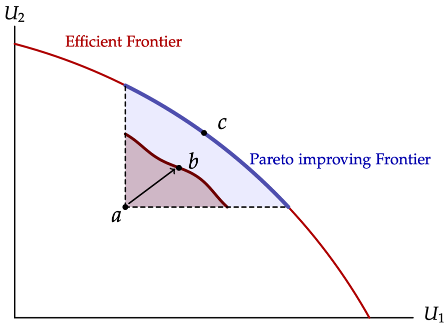
Single Undertaking and Consensus

- Point a Breaking point WTO dissolves
- Red line: Potential outcomes under an efficient agreement
- Only point blue areas satisfies the **Consensus** principle



Fiscal Feasibility

- Fiscal constraints may prevent sufficiently large transfers
- If so, we end up at point b instead of c
- The reform is restricted to operate within this budget



Research Design

Step 1: estimate the loss from WTO dissolution

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Core Task: Find the highest carbon price τ that Pareto dominates the disagreement point

Estimating the Effects of WTO Membership

Data: International Trade & Production Database + Dynamic Gravity Dataset

Estimating equation:

$$\ln X_{ij,k,t} = \underbrace{\delta_k^{\text{WTO}}\,\text{WTO}_{ij,t} + \delta_{ij,k} + \delta_{i,k,t} + \delta_{j,k,t} + \delta_k^{C}\cdot \text{Controls}_{ij,t}}_{(1-\sigma_k)\ln d_{ij,kt}} + \varepsilon_{ij,k,t}$$

- Controls: PTA, FTA, sanctions
- WTO variable: staggered GATT/WTO membership
- Identification: Staggered DiD (Wooldridge 2021)

Implied change in trade costs from WTO dissolution:

$$\Delta \ln d_{ij,kt} = \frac{1}{1-\sigma_k} \times \hat{\delta}_k^{(\text{WTO})}\,\text{WTO}_{ij,t}$$

Impact of WTO Membership on Trade Costs

	Agriculture	Mining	Manfacturing		Energy	
	(1)	(2)	(3)	(4)	(5)	(6)
$\hat{\delta}_k^{WTO}$	0.534	0.399	0.795	0.792	0.239	0.150
	(0.131)	(0.132)	(0.140)	(0.148)	(0.179)	(0.184)
On-set year	$t = 0$	$t = -2$	$t = 0$	$t = -2$	$t = 0$	$t = -2$
Exporters	148	148	147	147	147	147
Importers	148	148	147	147	147	147
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Implied trade cost increase from WTO dissolution

- Agriculture: $\Delta \ln d_{ij,k} \simeq 24\%$
- Manufacturing: $\Delta \ln d_{ij,k} \simeq 56\%$
- Energy: $\Delta \ln d_{ij,k} \simeq 10\%$

Trade Elasticity Estimation

Method: Local projection IV (Boehm-Levchenko-Pandalai-Nayar, 2023)

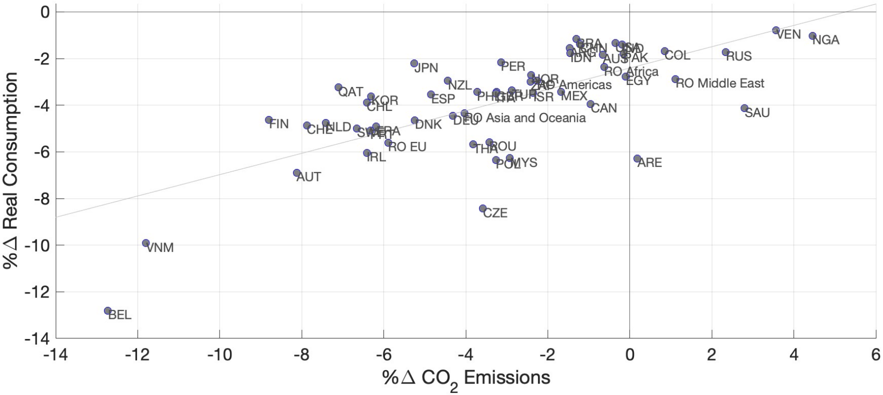
- Identification: changes in MFN rates for non-major partners

Industry	OLS	LP-IV
Agriculture and Mining	4.25	7.02
	(0.25)	(2.59)
Manufactruing	2.35	3.95
	(0.17)	(1.90)
Primary and Secondary Energy	7.81	12.25
	(0.56)	(4.25)

Result (1)

Gains from Trade vs. Emissions from Trade

The Impacts of Dissolving the WTO



Δ real consumption $(avg) = -4.1\%$ $\quad \Delta$ global CO_2 emissions $= -4.2\%$ $\quad$ Correlation $= 0.76$.

- Emissions due to WTO membership are positively related to the consumption gains from WTO membership

Takeaway: Trade and Emissions are Intertwined

Countries benefiting the most from the WTO also generate the most trade-related emissions.

- Trade-related emissions driven by scale and technique effects details
- Pattern holds under unilateral withdrawal and autarky details

⟶ WTO reforms linking market access to carbon pricing offer a credible and effective pathway to reducing global emissions.

The **biggest winners** from the WTO have the most to lose by refusing carbon-pricing concessions -- this is the leverage point for institutional design.

Result 2

Carbon Pricing Incidence: Supply-side *vs.* Demand-Sided Taxes

Carbon Pricing Incidence

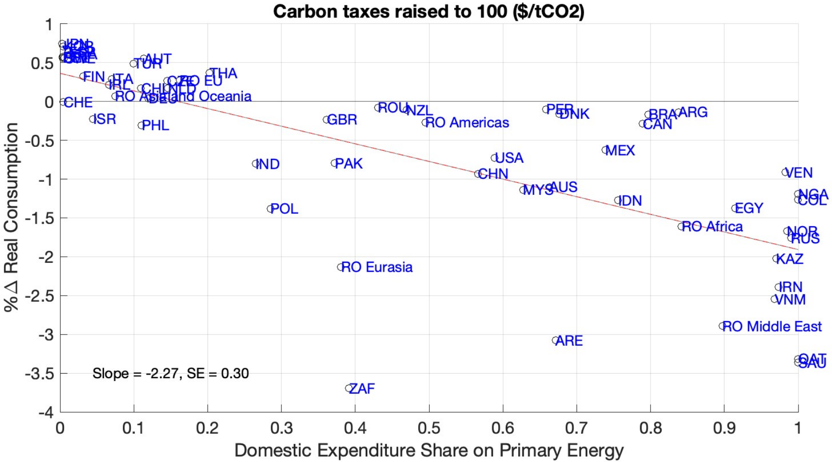
International incidence of carbon taxes

- **Demand-side tax** $\tau^{(c)}$: redistributes from energy exporters to importers
- **Supply-side tax** $\tau^{(p)}$: redistributes from energy importers to exporters

Comparison: **demand-side vs. supply-side**

- No difference in aggregate carbon reduction
- Highly asymmetric distributional consequences

Global Carbon Pricing: Demand-Side Tax



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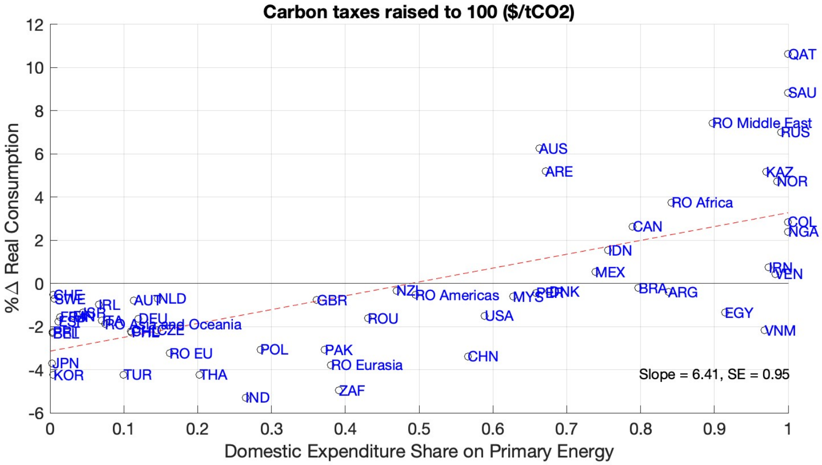
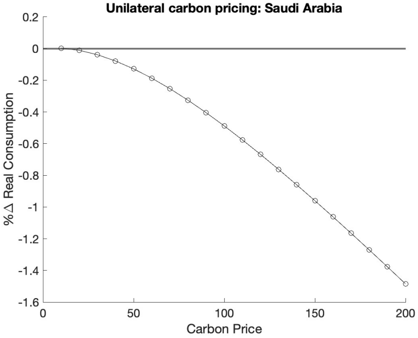


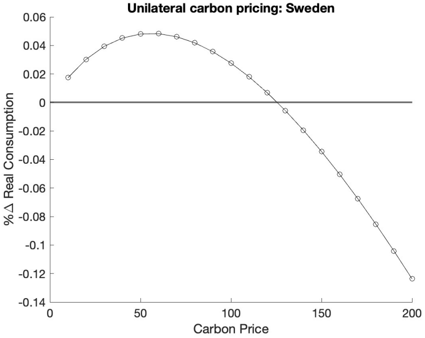
Unilateral Carbon Pricing (Demand-side)

Energy importers may benefit from unilateral *demand-side* carbon taxes

- If all energy is imported demand-side carbon tax = import tariff on energy
- if all industrial production is exported demand-side carbon tax = export tax
- The unilaterally-optimal import tariff and export tax is positive in both cases



a Saudi Arabia

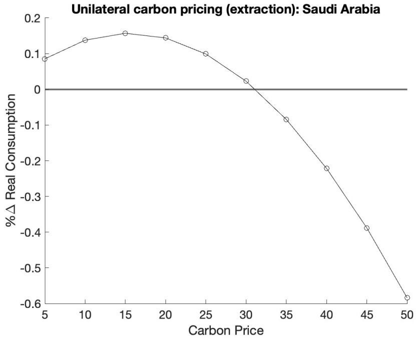


b Sweden

Unilateral Carbon Pricing (Supply-side)

Energy exporter may benefit from unilateral *supply-side* carbon pricing.

- If all energy supply is exported supply-side carbon tax = export tax
- Unilaterally-optimal export tax is positive for energy exporters



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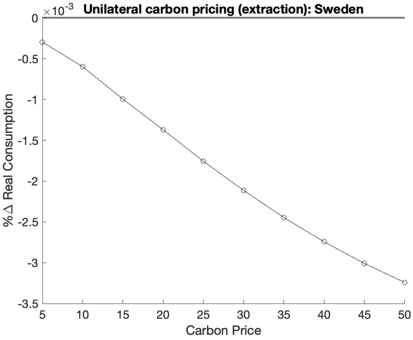

d Sweden

Takeaway: Distributive Externalities Are Large

- Carbon taxes generate distributive externalities, transferring surplus from energy exporters to importers or vice versa.
- The direction of these transfers depends on whether taxes target emissions at the point of supply or demand.
- **Bottomline**: A global carbon pricing agreement must address distributive externalities to ensure political feasibility.

Result 3

Effectiveness of Integrating Carbon Pricing into the WTO

Overview

Goal solve the constrained optimal linkage problem

Overview

Goal solve the constrained optimal linkage problem

We explore two complementary mechanisms

1. **Centralized** with feasible side payments

Harmonize carbon taxes and establish a Global Climate Fund to redistribute the tax burden internationally.

2. **Decentralized** no side payments

Allow countries to strategically choose their own mix of demand-side and supply-side carbon taxes.

Centralized Reform Details

Key design elements

1. **Harmonize** demand-side carbon prices among WTO members

Centralized Reform Details

Key design elements

1. **Harmonize** demand-side carbon prices among WTO members
2. Establish a **Global Climate Fund** to balance the burden
   - Collects the border-related portion of tax revenues
   - Allocates revenues to countries bearing a disproportionately large burden
     details

Centralized Reform: Fund Allocation Rules

The allocation rule should favor countries that

(i) **Gain less** from trade agreements
(ii) **Suffer more** from carbon pricing

Four minimal information rules

(a) Share of global primary energy exports
(b) Proportional to λ_{ii} aggregate domestic share
(c) Proportional to λ_{ii} in all energy
(d) Proportional to λ_{ii} in primary energy

For each rule identify the highest carbon price consistent with Pareto improvement.

Centralized Reform: Results

	Max Carbon Price $/tCO2	Reduction in Global Emission
No Side Payments	61	36.2
Side Payments Allocations from the Fund		
(a) *Share of Global Primary Energy Exports*	67	37.9
(b) *Prop to* λ_{ii}	72	39.1
(c) *Prop to* λ_{ii} *in All Energy*	81	41.1
(d) *Prop to* λ_{ii} *in Primary Energy*	106	46.0

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Decentralized Reform: Strategic Tax Mix

Mechanism: For a given harmonized carbon price, each country chooses its own mix of demand-side and supply-side carbon taxes.

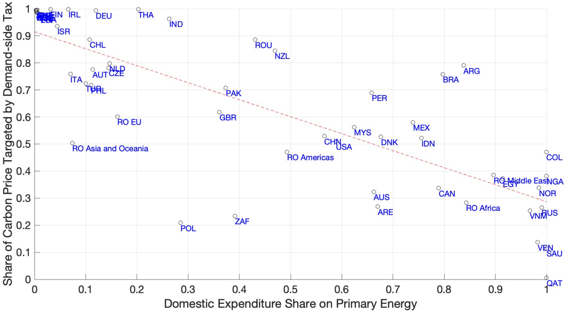
- Each country meets a revenue target implied by the carbon price
- Any mix of demand- and supply-side taxes achieving this revenue is admissible
- Countries optimize their mix given others' choices
- **Nash equilibrium**: each country's mix is optimal given other's choices

Key insight: distributive externalities from importers' demand-side taxes are offset by exporters' supply-side taxes, thereby lifting the need for explicit transfers.

Decentralized Reform: Results

Key results:

- Maximum carbon price: **$105/tCO₂**
- As effective as centralized reform
- Energy importers lean toward *demand-side* taxes



Takeaway: Decentralized mechanism yields comparable emission reductions without explicit transfers.

Concluding Remarks

We proposed mechanisms to harmonize carbon prices within the WTO

- Our harmonization mechanisms achieve over 80% of the CO_2 reductions attainable under the first-best SSC = 156.
- A centralized Global Climate Fund is essential to equalize tax burdens internationally when only one type of carbon tax is enforced.
- Comparable emission reductions is achieved when countries strategically choose their own mix of demand- and supply-side taxes.

Robustness

- Climate adjusted welfare details, Alternative trade elasticities details, Alternative energy demand elasticities details, Alternative energy supply elasticity details

Thank you.

Related Literature

Trade agreements contingent on environmental action

- Barrett 1997, Nordhaus 2015, Maggi 2016, Harstad 2024, Farrokhi-Lashkaripour 2025, Iverson 2024, Bourany 2025

→ We embed carbon policy into existing trade agreements and introduce mechanisms that balance the tax burden

Interplay between trade and the environment

- Antweiler-Copeland-Taylor 2001, Cristea-Hummels-Puzzello-Avetisyan 2013, Shapiro 2016, 2021, Copeland-Taylor-Shapiro 2022, Farrokhi-Kang-Pellegrina-Sotelo 2024, Carleton-Crews-Nath 2024
- Markusen 1975, Copeland 1996, Cruz-Rossi-Hansberg 2024, Kortum-Weisbach 2024, Dominguez-Iino 2025, Conte-Desmet-Rossi-Hansberg 2025

→ Cross-externalities b w trade and climate designs for international agreements to address them

return

Industry	Share from World: CO_2 Emission	Share from World: Output	Share from World: Exports	Exports to Output Ratio	Energy Cost Share	CO_2 Emiss per Outp
Coal	0.6	0.3	0.9	0.27	0.05	0.29
Crude Oil	1.1	1.6	8.5	0.51	0.02	0.11
Natural Gas	0.7	0.4	2.1	0.46	0.05	0.29
Refined Petroleum	3.9	2.6	4.8	0.19	0.84	0.26
Electricity	48.3	1.9	0.3	0.02	0.38	4.35
Gas Mfg and Dist	1.1	0.2	0.2	0.08	0.14	0.98
Agriculture	1.5	2.9	3.5	0.11	0.04	0.09
Other Mining	0.6	0.7	1.0	0.28	0.07	0.14
Food	1.3	4.8	6.3	0.12	0.02	0.04
Textile	0.4	2.1	5.9	0.27	0.02	0.03
Wood	0.1	0.6	0.4	0.14	0.02	0.03
Paper	0.7	1.2	1.8	0.15	0.05	0.10
Chemicals	3.4	3.6	11.1	0.33	0.12	0.16
Plastics	0.5	1.3	2.3	0.22	0.04	0.06
Nonmetallic Minerals	5.2	1.3	0.6	0.12	0.10	0.70
Metals	5.3	5.0	5.9	0.23	0.06	0.18
Electronics and Machinery	0.6	6.9	13.4	0.40	0.01	0.01
Motor Vehicles	0.2	3.5	7.0	0.36	0.01	0.01
Other Manufacturing	0.2	1.2	2.4	0.29	0.01	0.03
Construction	0.7	7.7	0.1	0.01	0.01	0.01
Wholesale and Retail	0.6	7.7	2.1	0.03	0.02	0.01
Transportation	19.5	4.2	4.6	0.13	0.22	0.78
Other Services	3.5	38.3	14.9	0.04	0.01	0.02

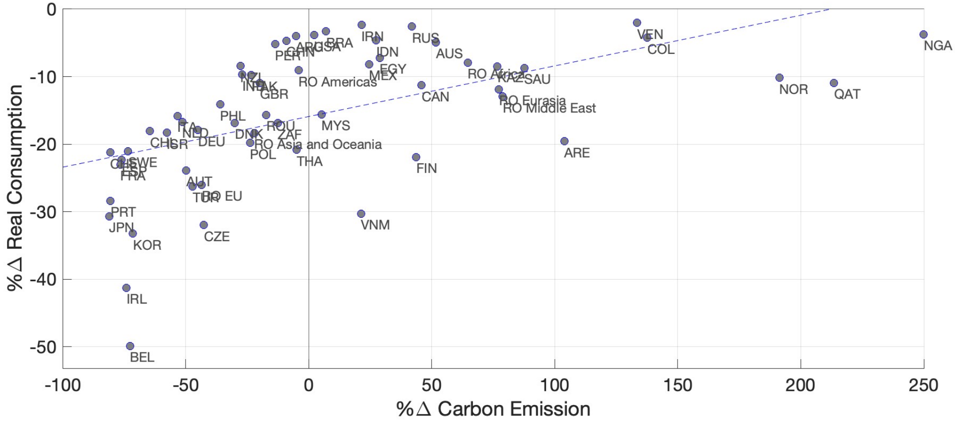
return

Country	Share from World			CO_2 Emission		Energy Cost
	CO_2 Emission	Output	Population	per Output	per Capita	Share
United Arab Emirates	0.5	0.4	0.1	146.1	106.9	0.07
Argentina	0.7	0.6	0.6	134.5	28.2	0.09
Australia	1.2	1.8	0.3	82.6	98.1	0.04
Austria	0.2	0.5	0.1	40.1	40.4	0.03
Belgium	0.3	0.8	0.2	45.7	54.5	0.05
Brazil	1.6	2.7	2.8	67.6	14.3	0.06
Canada	1.9	2.0	0.5	108.5	99.6	0.06
Switzerland	0.1	0.9	0.1	17.2	30.4	0.01
Chile	0.3	0.3	0.2	99.3	27.8	0.06
China	26.5	17.9	18.9	172.1	35.9	0.05
Colombia	0.2	0.4	0.6	73.3	9.8	0.04
Czech Republic	0.3	0.3	0.1	100.4	50.2	0.05
Germany	2.3	4.8	1.1	55.5	52.0	0.04
Denmark	0.2	0.4	0.1	52.1	56.7	0.03
Egypt, Arab Rep.	0.6	0.3	1.3	192.0	11.7	0.07
Spain	0.8	1.7	0.6	54.6	31.9	0.05
Finland	0.2	0.3	0.1	56.9	54.7	0.06
France	1.1	3.2	0.9	38.6	29.9	0.03
United Kingdom	1.4	3.6	0.9	46.7	41.0	0.03
Indonesia	1.5	1.1	3.5	156.7	10.7	0.06
India	6.4	2.7	17.9	274.4	9.1	0.13
Ireland	0.1	0.3	0.1	52.6	58.7	0.03
Iran, Islamic Rep.	1.8	0.5	1.1	433.4	42.5	0.17
Israel	0.2	0.3	0.1	73.6	48.3	0.05
Italy	1.1	2.6	0.8	47.0	32.6	0.04
Japan	3.4	5.9	1.8	67.5	50.1	0.06
Kazakhstan	0.8	0.2	0.2	364.8	82.8	0.09
Korea, Rep.	1.7	2.2	0.7	88.3	60.2	0.09
Mexico	1.4	1.4	1.7	115.1	21.6	0.06

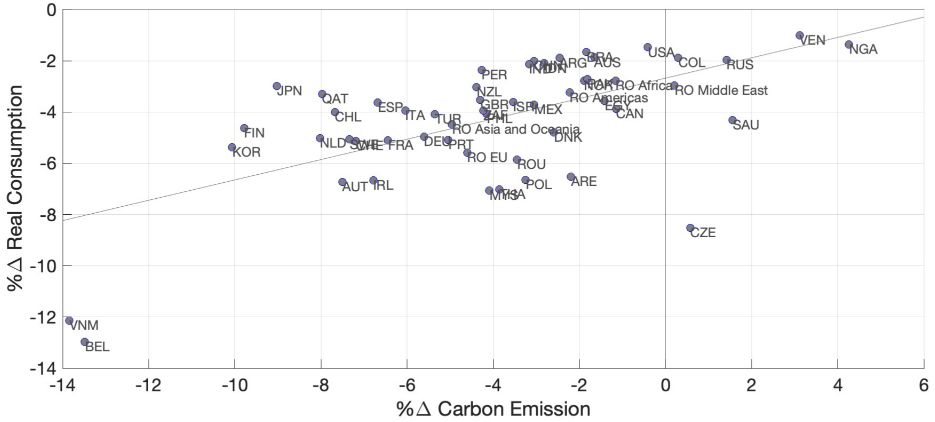
Country	Share from World			CO_2 Emission		Energy Cost
	CO_2 Emission	Output	Population	per Output	per Capita	Share
Malaysia	0.8	0.6	0.4	155.4	49.9	0.07
Nigeria	0.2	0.5	2.4	56.0	2.3	0.02
Netherlands	0.6	1.2	0.2	55.0	61.5	0.06
Norway	0.2	0.6	0.1	45.9	79.0	0.04
New Zealand	0.1	0.3	0.1	53.6	47.6	0.04
Pakistan	0.5	0.3	2.7	179.8	4.4	0.07
Peru	0.2	0.3	0.4	70.4	10.0	0.05
Philippines	0.3	0.3	1.4	113.5	6.1	0.05
Poland	0.9	0.7	0.5	141.3	42.8	0.06
Portugal	0.2	0.3	0.1	67.9	29.8	0.06
Qatar	0.3	0.2	0.0	146.0	194.9	0.06
Romania	0.2	0.2	0.3	102.4	20.2	0.07
Russian Federation	4.7	2.4	2.0	228.7	60.1	0.14
Saudi Arabia	1.6	0.8	0.4	246.3	95.2	0.15
Sweden	0.1	0.7	0.1	24.3	26.5	0.04
Thailand	0.9	0.6	0.9	172.3	24.8	0.12
Turkey	1.0	1.0	1.1	123.4	24.3	0.06
United States	17.2	20.0	4.4	100.0	100.0	0.05
Venezuela, RB	0.5	0.5	0.4	115.8	32.7	0.03
Vietnam	0.5	0.3	1.3	187.2	9.5	0.05
South Africa	1.4	0.5	0.8	317.1	47.7	0.07
RO Africa	1.5	1.5	11.4	115.3	3.3	0.06
RO Americas	0.8	0.9	1.7	110.5	12.4	0.07
RO Asia and Oceania	2.2	2.5	5.0	99.4	11.0	0.07
RO EU	1.5	1.3	1.0	129.8	39.6	0.08
RO Eurasia	1.6	0.6	1.7	336.8	24.9	0.14
RO Middle East	1.4	0.7	1.5	221.9	23.5	0.15

return

Autarky Real Consumption vs. Carbon Emissions



Unilateral Defection from the WTO



%Δ real consumption global avg -8.2, %Δ global emissions -2.0 Correlation 0.55.

return

Sources of emission change

- Copeland-Taylor Decomposition
  - Trade-induced emissions are driven by **Scale** and **Technique** effects, partly offset by **Composition** effect

Scale	Composition	Technique
120%	−43%	23%

- Correlation between C and Z
  - Mechanisms that reduce the relative price of consumption goods to wage (thereby increasing real consumption, C) also lower the relative price of energy inputs to wage (thereby increasing emissions, Z). return

Global Climate Fund

- Inflows and outflows of the Fund

$$\text{Fund} \sim \sum_i (\text{contribution})_i = \sum_i \text{allocation}_i$$

where

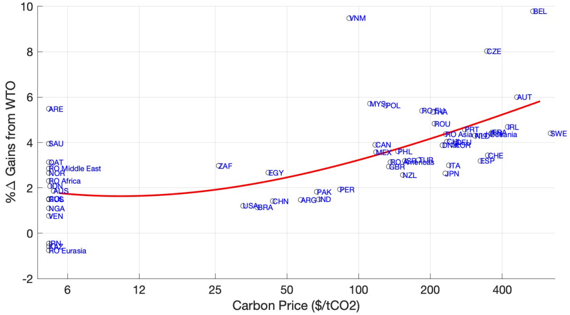
$$(\text{contribution})_i = \text{carbon tax}_i \times \sum_{k \in \mathbb{E}} \left[\left(1 - \lambda_{ii,k}\right) \times Z_{i,k} \right]$$

allocation_i determined by a simple formula that compensates countries experiencing disproportionately large tax burden.

return

Naive Design Heterogenous Carbon Pricing

- Countries raise their local carbon taxes to the point where the cost of carbon pricing matches an equal fraction of their gains from trade agreements.
  - extremely high carbon taxes in some countries politically infeasible.
  - heterogeneous carbon taxes are inefficient.



Carbon prices that wash away 25 of each countries consumption gains from WTO membership. return

Government's policy objective

- Potential misalignment b w government’s objective and social welfare”
  - Virtually no carbon pricing in most countries, with the EU as the major exception.
- for today Adopt a pessimistic approach no climate damage in the governments’ objective function.
- Run robustness checks. Main takeaways remain in place when
  - No misalignment Climate damage calibrated based on country-level SSC
  - Misalignment only in the objective functions of European countries.

In progress Recover perceived climate damages in the spirit of revealed preferences of governments return

Experimenting with EU's Obj Function

- If the EU had no care toward climate change, then a carbon price of 18 tCO_2 would maximize its objective function.
- Optimization algorithm
  - Example Suppose the EU's carbon price was 50 tCO_2 $\longrightarrow$ EU's perceived climate damage must be equal 39 tCO_2.
- Use similar exercises For each country region, recover their government's attitude toward climate change.

return

Algorithm

- Outer loop Increase the carbon price if the maximum carbon price is not yet reached.
- Inner loop
  - Start with an initial guess of transfers.
  - Check which countries win and which lose.
  - Check whether contributions from winners are sufficient to make losers better off
    - If yes, update transfers by applying proportional reallocation from winners to losers. when binding, set at zero
    - If no, we have exceeded the maximum carbon price.
  - Iterate by re-calculating the GE until convergence.

Best Subset Selection

- Consider K country characteristics
  - GDP, Population, Emission, Sectoral domestic expenditure share Agr, Mfg, Sec. Energy, Pri Energy , Energy cost share in production, Energy expenditure share in final consumption. Historical emissions.
- Among subsets of size $J < K$ explanatory variables, find the one that minimizes the sum-of-squared-errors.
  - Among subsets of size 1 DES in primary energy
  - Among subsets of size 2 DES in primary energy and Energy cost share in production

Return

Climate-adjusted welfare Calibration

- Adopt the functional form Shapiro 2021

$$\Delta_i(Z) = \left[1 + \mu_i \left(Z^{(global)} - Z_0^{(global)}\right)\right]^{-1}$$

  where $Z_0^{(global)}$ is set at the level of baseline global emissions, making $\Delta_i = 1$ at the baseline.

- For each country, calibrate μ_i to match the country-level social cost of carbon estimates from Ricke et al 2018 .

Climate-adjusted welfare

- Proposal 1 achieves a carbon price as high as 208.

	Max Carbon Price tCO2	Reduction in Global Emission
No Side Payments	64	37.0
Side Payments Allocations from the Fund		
a Share of Global Primary Energy Exports	208	57.7
b Prop to DES	77	40.2
c Prop to DES in All Energy	83	41.6
d Prop to DES in Primary Energy	100	44.9

- Proposal 2 achieves a carbon price as high as 305. return

Alternative Trade Elasticity -- OLS Estimates

- Proposal 1 achieves a carbon price as high as 125.

	Max Carbon Price tCO2	Reduction in Global Emission
No Side Payments	67	37.5
Side Payments Allocations from the Fund		
a Share of Global Primary Energy Exports	76	39.8
b Prop to DES	88	42.3
c Prop to DES in All Energy	98	44.2
d Prop to DES in Primary Energy	125	48.6

- Proposal 2 achieves a carbon price as high as 135. return

Alternative Energy Demand Elasticity

- Set energy demand elast at 0.65 FL-2025 using a CES structure.
- Proposal 1 achieves a carbon price as high as 84.

	Max Carbon Price tCO2	Reduction in Global Emission
No Side Payments	58	30.8
Side Payments Allocations from the Fund		
a Share of Global Primary Energy Exports	50	28.6
b Prop to DES	82	36.3
c Prop to DES in All Energy	84	36.7
d Prop to DES in Primary Energy	77	35.3

- Proposal 2 achieves a carbon price as high as 93. return

Alternative Energy Supply Elasticity

- Set inverse primary energy supply elasticity at 0.6 instead of 0.3 .
- Proposal 1 achieves a carbon price as high as 84.

	Max Carbon Price tCO2	Reduction in Global Emission
No Side Payments	45	28.5
Side Payments Allocations from the Fund		
a Share of Global Primary Energy Exports	55	31.7
b Prop to DES	58	32.5
c Prop to DES in All Energy	64	34.1
d Prop to DES in Primary Energy	84	38.7

- Proposal 2 achieves a carbon price as high as 108. return