Can Trade Policy Mitigate Climate Change?

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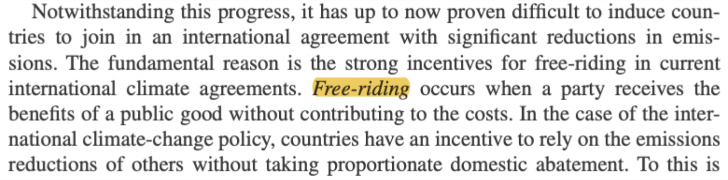
Background

Existing Climate Agreements Have Failed to Deliver!

Cause of Failure: *The Free-Riding Problem*

Nordhaus (2015, *AER*)



Notwithstanding this progress, it has up to now proven difficult to induce countries to join in an international agreement with significant reductions in emissions. The fundamental reason is the strong incentives for free-riding in current international climate agreements. *Free-riding* occurs when a party receives the benefits of a public good without contributing to the costs. In the case of the international climate-change policy, countries have an incentive to rely on the emissions reductions of others without taking proportionate domestic abatement. To this is

Two Trade Policy Proposals to Overcome the *Free-Riding* Problem

Proposal #1: **Carbon Border Taxes**

- Carbon border taxes can serve as a *2nd-best* policy to curb (untaxed) CO_2 emissions in the rest of the world.
- Example: EU's carbon border taxes can cut CO_2 emissions in Asia.

Proposal #2: **Climate Club**

- Climate-conscious governments can use collective trade penalties to deter free-riding.
- Has the potential to achieve *1st-best* carbon-pricing.

Existing Assessments of Climate-Oriented Trade Policy

- We have a limited understanding of the efficacy of Proposals #1 & #2
- Determining the full efficacy of theses proposals is practically infeasible without theoretical formulas for optimal trade & carbon taxes:
  - Theories of optimal policy limited to simple models ⟶ cannot guide quantitative work
  - Quantitative analyses, thus, rely on *easy-to-implement-but-sub-optimal* policies ⟶ cannot uncover the full potential of Proposals #1 and #2.

Related Literature

This Paper: *Roadmap*

1. Develop a rich model of trade with climate externalities
    - general equilibrium + multi-industry + multi-country
    - flexible abatement structure
    - firm relocation + scale economies
2. Derive analytical formulas for optimal *carbon border taxes & climate club penalties*
3. Map model and analytical formulas to data to uncover the full-effectiveness of
    - (Proposals 1) carbon border taxes
    - (Proposals 2) climate club

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Theoritical Framework

The Economic Environment

- Generalized Krugman (1980) **+** Copeland & Taylor's abatement model
- Many countries: $i, j, n = 1, ..., \mathcal{N}$
- Many industries: $k, g = 1, ..., \mathcal{K}$

Preferences and Demand

Three-tier utility function:

1. *Cross-industry:* Non-parametric
2. *Cross-national*: CES with elasticity σ_k
3. *Sub-national*: CES with elasticity γ_k

Demand facing firm ω from nest ji, k (origin j–destination i–industry k):

$$q_{ji,k}(\omega) = \underbrace{\left(\frac{p_{ji,k}(\omega)}{P_{ji,k}}\right)^{-\gamma_k}}_{\text{sub-national}} \underbrace{\left(\frac{P_{ji,k}}{P_{i,k}}\right)^{-\sigma_k}}_{\text{cross-national}} \underbrace{\mathcal{D}_{i,k}\left(\mathbf{P}_i, Y_i\right)}_{\text{cross-industry}}$$

Production and Firms

- Firms compete under monopolistic competition and free entry *à la* Krugman
- Production combines labor and carbon inputs with elasticity of substitution ς

Equivalent formulation:

- a fraction $a_{i,k}$ of labor inputs are allocated to abatement
- abatement raises marginal cost (c) but lowers CO_2 emissions per unit of output (z)

$$c_{ij,k} = \frac{d_{ij,k} w_i}{\varphi_{i,k}} \left(1 - a_{i,k}\right)^{-\frac{1}{\varsigma}} ; \qquad z_{i,k} = \left[\frac{1}{\bar{\kappa}_{i,k}} + \left(1 - \frac{1}{\bar{\kappa}_{i,k}}\right) \left(1 - a_{i,k}\right)^{-\frac{\varsigma-1}{\varsigma}}\right]^{\frac{\varsigma}{\varsigma-1}}$$

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wage rate

iceberg cost

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firm productivity

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Aggregate Production and CO_2 Emissions

- We can summarize prices and emissions in *origin i–industry k* in terms of total output, $Q_{i,k}$, and abatement, $a_{i,k}$:

$$\left[\text{ouput price index}\right] \qquad P_{ij,k} = d_{ij,k}\bar{p}_{ii,k}w_i \left(1 - a_{i,k}\right)^{\frac{1}{\varsigma\gamma_k} - \frac{1}{\varsigma}} Q_{i,k}^{-\frac{1}{\gamma_k}}$$

$$\left[\text{carbon emissions}\right] \qquad Z_{i,k} = \bar{z}_{i,k} \left(1 - a_{i,k}\right)^{\frac{1}{\varsigma\gamma_k} - 1} Q_{i,k}^{1 - \frac{1}{\gamma_k}}$$

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scale effects in abatement

- The special case w/ constant-returns to scale: $\frac{1}{\gamma_k} \to 0$

Policy Objectives & Free-Riding

Social Welfare and Optimal Carbon Taxes

- Welfare in country *i* is the sum of indirect utility from consumption and disutility from global CO_2 emissions: optimal policy definition

$$W_i \equiv \underbrace{V_i(Y_i, \tilde{\mathbf{P}}_i)}_{\text{consumption utility}} - \overbrace{\delta_i \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} Z_{n,k}}^{\text{disutility from CO}_2}$$

- *Unilaterally* vs. *Globally* optimal carbon tax

$$\underbrace{\tau_i^\star = \tilde{\delta}_i}_{\text{unilaterally optimal}} \qquad \overbrace{\tau^\star = \sum_n \tilde{\delta}_n}^{\text{globally optimal}}$$

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disutility per tonne of CO_2

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CO_2 emissions from origin *n*–industry *k*

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The Free-Riding Problem

- Governments have an incentive to lower their carbon tax from the globally optimal rate, $\tau^\star = \sum_n \tilde{\delta}_n$, to the unilaterally optimal rate, $\tau_i^\star = \tilde{\delta}_i \longrightarrow$ race to the bottom

- Two remedies for the free-riding problem:

  1. using carbon border taxes as a 2nd-best policy to curb untaxed CO_2 emissions
  2. forging a climate club and using collective trade penalties to deter free-riding

- What is the optimal design of these border policy remedies?

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Unilaterally Optimal Border Policies under Climate Externalities

[import tariff]
$$1 + t^{\star}_{ji,k} = \left(1 + \omega_{ji,k}\right) \quad + \quad \frac{\gamma_k - 1}{\gamma_k}\, \tilde{\delta}_i \; v_{j,k}$$

[export subsidy]
$$1 + x^{\star}_{ij,k} = \left(1 + \frac{1}{\varepsilon_{ij,k}}\right) \left[1 + \sum_{n \neq i} t^{\star}_{ni,k} \frac{\lambda_{nj,k}}{1 - \lambda_{ij,k}}\right]$$

– Optimal *carbon border tax/subsidies* yield the 2nd-best CO_2 reduction via border measures.

– The sum of carbon & ToT border taxes constitute the optimal trade penalty on free-riders.

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inverse export supply elasticity

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unilateraly optimal production & carbon taxes
small open economy
globally optimal policy
cooperative carbon border taxes

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CO$_2$ per dollar vlaue

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correction for scale effects

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Mapping Theory to Data

Sketch of Optimization-Free Quantitative Strategy

- Our goal is to simulate the counterfactual equilibrium under optimal policy.
- Summary of quantitative strategy:
  1. write **optimal taxes** as a function of the change in equilibrium variables: $\mathbf{T}^\star = f\left(\hat{\boldsymbol{x}}\right)$
  2. write the change in equilibrium variables as a function of optimal taxes: $\hat{\boldsymbol{x}} = g\left(\mathbf{T}^\star\right)$
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- Our quantitative strategy determines the change in *welfare* and *CO$_2$ emissions* in response to optimal policy as a function of the following *sufficient statistics*:

$$\mathcal{B}_v \equiv \{\lambda_{ni,k}, e_{n,k}, r_{ni,k}, \rho_{i,k}, \alpha_{i,k}, \tilde{\delta}_i, w_n\bar{L}_n, Y_n\}_{ni,k} \qquad \mathcal{B}_e = \{\sigma_k, \gamma_k, \varsigma\}_k$$

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expenditure share

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sales share

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CO_2 input share

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$\tilde{\delta}_i \rightarrow$ $\boxed{\text{precieved cost of CO}_2}$

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national accounts data

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structural parameters

Data Sources

Trade, Production, and Emissions

- 2009 WORLD INPUT-OUTPUT DATABASE & WIOD ENVIRONMENTAL ACCOUNTS.
- 34 Countries + 19 broadly-defined Industries country list industry list

Applied Taxes

- Import Tariffs from UNCTAD-TRAINS
- Environmentally-related Taxes from EUROSTAT & OECD-PINE

Calibration and Estimation of Parameters

Demand Parameters

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- σ_k is estimated via Caliendo & Parro's (2014) technique (Wiod + Trains).

Carbon Input Demand Elasticity (ς)

- estimate the input demand function w/ national energy reserves as IV ($\varsigma = 0.62$)

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Quantitative Analysis of Proposals 1-2

Proposal #1: Brief Summary

- **Proposal 1:** governments appeal to carbon border taxes to correct transboundary CO_2 externalities on their residents.

- We simulate a non-cooperative equilibrium where all countries adopt their unilaterally optimal carbon and border taxes
  - governments with little care for climate damage, apply little-to-no carbon border taxes

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Proposal #1: Impact of Non-Cooperative Border Taxes

	Non-Cooperative Carbon/Border Taxes			Globally Optimal Carbon Taxes (1st best)		
Country	Δ CO_2	ΔV	ΔW	Δ CO_2	ΔV	ΔW
EU	0.7%	-1.2%	-1.3%	-9.2%	0.0%	2.0%
BRA	-6.0%	-1.3%	-1.3%	-70.7%	-1.3%	-0.8%
CHN	3.0%	-1.0%	-1.0%	-69.3%	-1.3%	-0.9%
IND	1.1%	-4.4%	-4.4%	-76.0%	-2.6%	-2.1%
JPN	3.4%	-0.9%	-0.9%	-23.1%	-0.2%	1.5%
MEX	-1.6%	-3.2%	-3.2%	-79.5%	-0.6%	-0.4%
USA	1.3%	-1.7%	-1.7%	-48.2%	-0.3%	0.3%
Global	-0.6%	-1.7%	-1.7%	-61.0%	-0.6%	0.4%

– Border taxes can replicate 1% of the globally 1st-best CO_2 reduction. EU carbon border taxes

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Inefficacy of Carbon Border Taxes: *Intuition*

Why are carbon border taxes ineffective at reducing global CO_2 emissions? robustness

1. border taxes cannot target non-traded but high-carbon goods/services:
   - $^2/_3$ of CO_2 emissions are generated by industries with $\frac{\text{Trade}}{\text{GDP}} < 0.1$
2. border taxes are not granular enough to induce firm-level abatement:
   - carbon border taxes are applied based on *origin*×*industry*-level CO_2 intensity
   - individual firms take *origin*×*industry*-level CO_2 intensity as given ⟶ carbon border taxes have limited ability to induce firm-level abatement abroad.

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   - individual firms take *origin*×*industry*-level CO_2 intensity as given $\longrightarrow$ carbon border taxes have limited ability to induce firm-level abatement abroad.

Proposal #2: Brief Summary

- **Proposal 2:** Climate-conscious governments form a **climate club** and use collective trade penalties to induce global climate cooperation (Nordhaus, 2015).

Proposal #2: The Climate Club Game

- Core members commit to rules of membership. Other countries play strategically:

Trade taxes set by

	Members	*Non-members*
Against Members	zero	unilaterally optimal
Against Non-members	unilaterally optimal	status quo (i.e., applied tariffs)

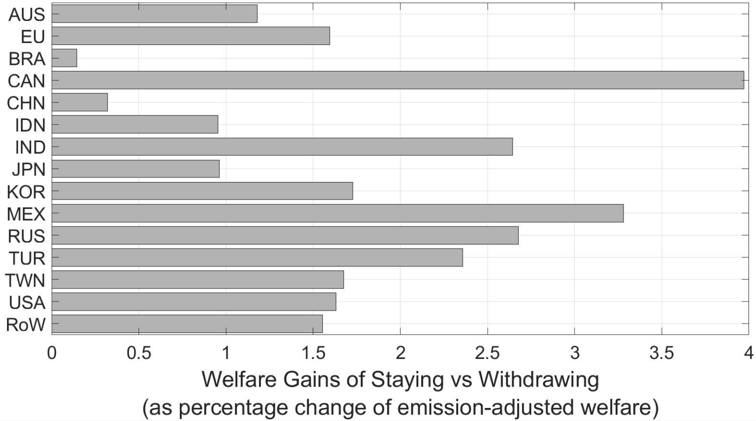
Carbon taxes set by

Members	*Non-members*
globally optimal	status quo (i.e., unilaterally optimal)

- By joining the club, a country
  - ... incurs a production loss by adopting a higher carbon tax,
  - ... but, it escapes the climate club's trade penalties.

Proposal #2: The Club of All Nations is a Nash Equilibrium

- The club-of-all-nations is a Nash equilibrium, no matter who core members are.
- Why? Because abandoning the club-of-all-nations is too costly.



Proposal #2: Determining all Nash Equilibria is Challenging

Characterizing all Nash equilibria faces two major challenges:

1. Computing optimal trade penalties is strenuous w/ numerical optimization
    - Our analytical formulas for optimal trade penalties help us overcome this challenge.
2. Nash outcomes must be identified over 2^N possible outcomes.[1]
    - To overcome the *curse of dimensionality*, we note that net benefits from joining the climate club rise with the number of existing members.
    - We use iterative elimination of dominated strategies to shrink the outcome space

---

[1] N denotes the number of countries that are not core members.

Proposal #2: The Efficacy of the Climate Club

- The makeup of core members is pivotal to the efficacy of the climate club.

- If EU is the only core member ⟶ the club-of-only-EU is also a Nash eq.

- If EU + USA are core members ⟶ the club-of-all-nations is the unique Nash eq.
  - Core members: EU, USA
  - 2nd round: CAN, ROW
  - 3rd round: AUS, IND, JPN, KOR, MEX, RUS, TUR, TWN
  - 4th & 5th round: CHN & BRA, IDN

- CO_2 reduction under a US-EU climate club:

$$\%\Delta CO2_{\text{global}} = \underbrace{-8.3\%}_{\text{EU \& US}} + \underbrace{-52.7\%}_{\text{Other members}} = -61.0\%$$

contant-returns to scale
alternative carbon demand elast.
trade-off: participation vs. tax target

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Summary of Findings

- Carbon border taxes have limited efficacy at curbing CO_2 emissions, because
  - most high-carbon goods/services never cross international borders
  - border taxes have a limited influence on firm-level abatement.
- The climate club can be highly effective at curbing CO_2 emissions, but its efficacy hinges critically on the make-up of core members.

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Thank You.

Related Literature

Optimal climate/environmental policy in open economies

- 2×2 or partial equilibrium: Markusen (1975), Copeland (1996), Hoel (1996)
- Kortum and Weisbach (2021): DFS with carbon externalities and energy markets

Quantitative general equilibrium models of climate/environmental policy

- Babiker (2005), Elliott et al. (2010), Nordhaus (2015,2021), Bohringer et al. (2016), Larch and Wanner (2017), Cherniwchan et al. (2017), Shapiro and Walker (2018), Shapiro (2020)

Optimal policy in quantitative trade models

- Costinot et al. (2015), Costinot et al. (2016), Lashkaripour and Lugovskyy (2021), Bartelme et al. (2019), Lashkaripour (2021); Beshkar and Lashkaripour (2020), Caliendo and Parro (2021)

Linkage in international cooperation

- Barrett (1997), Maggi (2016), Nordhaus (2015, 2021), Barrett and Dannenberg (2022)

Return

Definitions of Unilaterally vs. Globally Optimal Policy

- *Unilaterally* optimal border, production, and carbon taxes solve

$$\max\ W_i \qquad s.t. \qquad \text{equibrium constraints}$$

- *Globally* optimal border, production, and carbon taxes solve

$$\max\ \sum_n W_n \qquad s.t. \qquad equibrium\ constraints$$

Return

Country i's Unilaterally Optimal Policy Schedule

[carbon tax] $\tau^{\star}_{i,k} = \tilde{\delta}_i$

[industrial subsidy] $1 + s^{\star}_{i,k} = \dfrac{\gamma_k}{\gamma_k - 1}$

[import tariff] $1 + t^{\star}_{ji,k} = 1 + \omega_{ji,k} + \dfrac{\gamma_k - 1}{\gamma_k}\tilde{\delta}_i v_{j,k}$

[export subsidy] $1 + x^{\star}_{ij,k} = \left(1 + \dfrac{1}{\varepsilon_{ij,k}}\right)\left[1 + \sum_{n \neq i}\left[t^{\star}_{ni,k}\dfrac{\lambda_{nj,k}}{1 - \lambda_{ij,k}}\right]\right]$

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Theorem: *Country i's Unilaterally Optimal Policy*

Special Case: Small Open Economy

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Cooperative *2nd-Best* Carbon Border Taxes

- Suppose governments are cooperative but cannot raise their carbon tax beyond its unilaterally optimal level, $\tau_{i,k} = \tilde{\delta}_i$.
- **Cooperative carbon border taxes** that maximize global welfare, in that case, are

$$1 + t^{*}_{ji,k} = \left(1 + \tilde{\delta}_{-j}\ \nu_{j,k}\right) \frac{1 + (\sigma_k - 1)\lambda_{ii,k}}{1 + \left[1 + \tilde{\delta}_{-i}\nu_{i,k}\right](\sigma_k - 1)\lambda_{ii,k}}$$

Cooperative carbon border taxes have two components:

1. 1st component taxes origin *j*'s *total* CO_2 externality on RoW: $\tilde{\delta}_{-j} = \sum_{n \neq j} \tilde{\delta}_n$
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Globally Optimal Policy Schedule

- Suppose governments act *cooperatively* to maximize global welfare $\sum_n W_n$.
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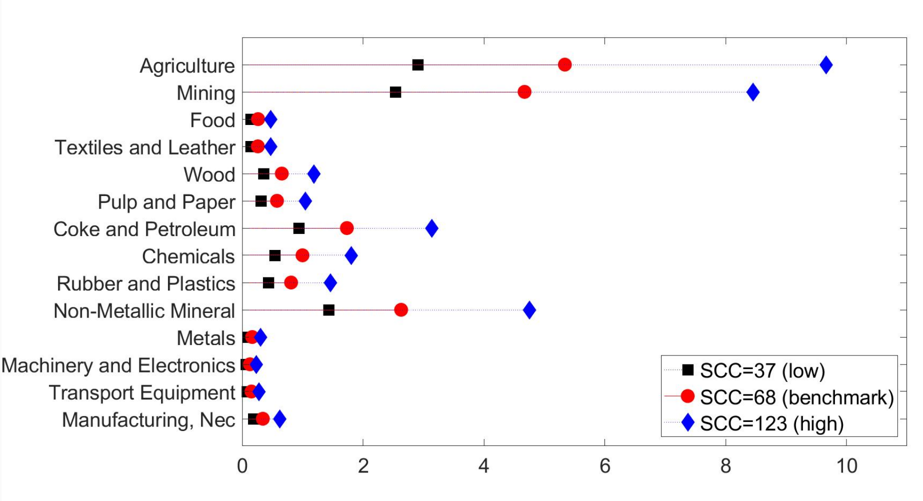
Country	Share of World GDP	Share of World CO2	Carbon Intensity ($\bar{v}_i$)	Emission Tax Rate ($\bar{\tau}_i$)	CO2 Disutility ($\tilde{\phi}_i$)	Normalized $\tilde{\phi}_i$
AUS	1.7%	1.4%	100.00	32.51	0.49	40.43
EU	27.2%	12.1%	53.57	80.41	19.12	100.00
BRA	2.4%	2.4%	121.33	13.43	0.28	16.70
CAN	2.0%	1.7%	102.68	20.83	0.37	25.90
CHN	13.6%	23.1%	204.31	6.93	0.82	8.61
IDN	1.0%	1.8%	218.95	8.43	0.07	10.48
IND	2.2%	6.5%	359.48	5.25	0.10	6.53
JPN	8.4%	2.9%	40.99	69.13	5.08	85.97
KOR	1.9%	1.6%	99.68	26.80	0.44	33.33
MEX	1.2%	1.4%	137.31	3.76	0.04	4.67
RUS	2.0%	5.8%	344.11	3.69	0.07	4.59
TUR	1.0%	0.9%	116.09	48.45	0.41	60.25
TWN	0.7%	0.8%	139.84	13.69	0.09	17.03
USA	21.1%	15.3%	87.32	18.18	3.35	22.61
RoW	13.5%	22.1%	197.23	2.21	0.26	2.75

Return

	Industry	CO2 Emissions (% of total)	$\frac{\text{Trade}}{\text{GDP}}$	Carbon Intensity (ν)	Carbon Input Share (α)	Trade Elasticity ($\sigma - 1$)	Markup ($\frac{\gamma}{\gamma-1}$)
1	Agriculture	19.9%	6.8%	100.0	0.020	2.05	1.46
2	Mining	8.0%	27.6%	40.4	0.019	1.80	1.53
3	Food	1.1%	9.0%	4.2	0.004	1.36	1.70
4	Textiles and Leather	0.4%	27.1%	4.2	0.005	0.86	2.11
5	Wood	0.2%	8.4%	5.4	0.010	3.42	1.28
6	Pulp and Paper	0.6%	8.9%	6.8	0.004	3.21	1.30
7	Coke and Petroleum	2.7%	17.9%	23.2	0.006	3.31	1.18
8	Chemicals	3.4%	24.6%	19.5	0.017	0.89	2.06
9	Rubber and Plastics	1.0%	14.0%	15.2	0.006	1.55	1.27
10	Non-Metallic Mineral	9.6%	13.1%	31.5	0.006	1.95	1.49
11	Metals	0.3%	25.9%	2.1	0.001	3.97	1.24
12	Machinery and Electronics	0.4%	37.1%	1.8	0.004	1.90	1.50
13	Transport Equipment	0.3%	23.3%	1.6	0.002	0.59	1.21
14	Manufacturing, Nec	0.4%	32.8%	10.1	0.005	0.59	1.91
15	Electricity, Gas and Water	32.0%	1.0%	205.5	0.018	7.14	1.12
16	Construction	0.9%	0.3%	2.1	0.008	7.14	1.10
17	Retail and Wholesale	1.8%	3.7%	2.6	0.009	6.93	1.14
18	Transportation	8.1%	10.9%	30.2	0.033	7.14	1.01
19	Other Services	9.0%	2.6%	4.1	0.007	1.59	1.60

Return: data Return: parameters

EU's Optimal Carbon Border Taxes



Return

Inefficacy of Carbon Border Taxes: *Alternative Specifications*

	$\Delta CO2$	$\Delta CO2$ as % of 1st-best	ΔV
Main specification (SCC = 31 \$/tC, $\varsigma = 0.62$)	-0.62%	1.02%	-1.71%
SCC = 68 \$/tC	-0.71%	1.01%	-1.72%
$\varsigma = 1$ (Cobb-Douglas)	-2.07%	2.85%	-1.64%
CRS ($\gamma \to \infty$)	-1.29%	2.16%	-1.63%
CRS with SCC = 68 \$/tC	-1.42%	2.04%	-1.64%
CRS with $\varsigma = 1$	-2.70%	3.74%	-1.64%
No ToT border taxes (base: zero tariffs)	-0.87%	1.42%	-0.01%
No ToT border taxes (base: applied tariffs)	-0.31%	0.51%	0.01%
Cooperative border taxes	-0.34%	0.56%	0.03%

Return

Climate Club: Constant-Returns to Scale

$$\text{CRS: } \gamma_k \to \infty$$

Core Members
EU, USA

1st Round
CAN, MEX, ROW

2nd Round
AUS, BRA, IND, JPN, KOR, RUS, TUR, TWN

3rd Round
CHN, IDN

Return

Climate Club: Alternative Carbon Demand Elasticities

SCC= 31, $\varsigma = 0.25$

Core Members	*1st Round*	*2nd Round*	*3rd Round*	*Remain Outside of the Club*
EU, USA	CAN, ROW	AUS, JPN, KOR, RUS, TUR, TWN	MEX	BRA, IND, CHN, IDN

SCC= 31, $\varsigma = 0.99$

Core Members	*1st Round*	*2nd Round*	*3rd Round*
EU, USA	CAN, ROW	AUS, IND, JPN, KOR, MEX, RUS, TUR, TWN	BRA, CHN, IDN

Return

Climate Club: Higher Global Carbon Tax Target

$$\text{SCC}= 68, \quad \varsigma = 0.63$$

Core Members	*1st Round*	*2nd Round*	*3rd-5th Round*	*Remain Outside of the Club*
EU, USA	CAN, ROW	AUS, JPN, TWN	KOR, MEX, RUS, TUR	BRA, IND, CHN, IDN

Return