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: implement border taxes unilaterally as a 2nd best solution

- Climate-conscious governments can use unilateral ***carbon border taxes*** to curb CO_2 emissions in the rest of the world.
- Example: EU's carbon border taxes can scale down production in high-CO_2 industries in Asia.

Proposal #2: Use collective trade penalties to enforce climate cooperation

- Climate-conscious governments can form a ***climate club.***
- Members of the climate club can use collective trade penalties to incentivize climate cooperation by reluctant governments.

Existing Assessments of Proposals #1 and #2

- Multiple studies have analyzed some variation of *Proposals #1* and *#2*.
- Existing studies, however, exhibit some limitations:
  1. Theoretical studies often overlook firm-delocation in response to policy, scale economies in abatement, and multilateral carbon leakage.
  2. Quantitative studies often examine arbitrarily-chosen (*i.e.*, sub-optimal) border taxes or trade penalties $\longrightarrow$ cannot identify the full effectiveness of Proposals 1 and 2.

This Paper: *Contribution to the Literature*

- Develop a multi-industry, multi-country GE model of trade that accommodates
  1. transboundary CO_2 externality
  2. firm relocation + scale economies in production/abatement.
- Analytical formulas for optimal *carbon border taxes* and *climate club penalties*
  - Intermediate step: Envelope result that simplifies optimal policy analysis in GE
- Map model and analytical formulas to data to uncover full-effectiveness of
  1. (Proposals 1) carbon border taxes
  2. (Proposals 2) climate club Related Literature

Theoritical Framework

The Economic Environment

- Many countries: $i, j, n = 1,...,\mathcal{N}$
  - Country i is populated by L_i workers who supply labor inelastically.
- Many industries: $k, g = 1,..., \mathcal{K}$
  - Each industry is served by many firms (index ω)
- Market structure: monopolistic competition + free entry
  - Free entry creates industry-level economies of scale

Preferences and Demand

Three-tier utility structure:

1. Non-parametric utility aggregator across industries
2. *Cross-national*: elasticity of substitution σ_k between national-level varieties
3. *Sub-national*: elasticity of substitution γ_k between firm-level varieties

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

$$q_{ji,k}(\omega) = \underbrace{\left(\frac{\tilde{p}_{ji,k}(\omega)}{\tilde{P}_{ji,k}}\right)^{-\gamma_k}}_{\text{within-national}} \underbrace{\left(\frac{\tilde{P}_{ji,k}}{\tilde{P}_{i,k}}\right)^{-\sigma_k}}_{\text{national-level}} \underbrace{\mathcal{D}_{i,k}\left(\tilde{\mathbf{P}}_i, Y_i\right)}_{\text{industry-level}}$$

Production and Firms

– Firms compete under monopolistic competition and free entry *à la* Krugman

Traditional formulation: firm-level production combines labor and carbon inputs:

- elasticity of substitution b/w labor and carbon input (ς)
- carbon intensity in origin i–industry k ($\bar{\kappa}_{i,k}$)

Equivalent formulation: A fraction $a_{i,k}$ of inputs are allocated to abatement:

$$\text{Marginal cost} = \frac{d_{ij,k} w_i}{\left(1 - a_{i,k}\right) \varphi_{i,k}}$$

$$\text{CO}_2 \text{ per unit of output} = \left[\frac{1}{\bar{\kappa}_{i,k}} + \left(1 - \frac{1}{\bar{\kappa}_{i,k}}\right) \left(1 - a_{i,k}\right)^{-\frac{\varsigma - 1}{\varsigma}} \right]^{\frac{\varsigma}{\varsigma - 1}}$$

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Aggregate Production and CO_2 Emissions

- We can summarize production in *origin i–industry k* in terms of total output, $\mathcal{Q}_{i,k} \equiv \sum_{j \in \mathbb{C}} d_{ij,k} Q_{ij,k}$, and abatement, $a_{i,k}$:

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

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

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

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Policy Objectives and Instruments

Three Cases for Policy Intervention

From country i's perspective, the market equilibrium is inefficient for 3 reasons:

1. Firms do not internalize their CO_2 externality on country i's residents
2. Industries exhibit differential markups $\longrightarrow$ misallocation
3. There is unexploited export/import market power *vis-à-vis* the rest of the world.

Instruments of Policy

– Import tariffs, export subsidies, and industrial subsidies create a wedge b/w *producer prices* (P) and *consumer prices* ($\tilde{P}$):

$$\tilde{P}_{ij,k} = \frac{1 + \boldsymbol{t_{ij,k}}}{(1 + \boldsymbol{x_{ij,k}})(1 + \boldsymbol{s_{i,k}})} P_{ij,k}$$

– Carbon taxes $\tau_{i,k}$ regulate abatement $a_{i,k}$:

$$(1 - a_{i,k}) = (1 - \bar{\kappa}_{i,k})^{-\varsigma} \left[(1 - \bar{\kappa}_{i,k})^{\varsigma} + (\bar{\kappa}_{i,k})^{\varsigma} \left(\frac{\tau_{i,k}}{w_i} \right)^{1-\varsigma} \right]^{\frac{\varsigma}{\varsigma - 1}}.$$

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export subsidy offered by country i

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National Welfare—Adjusted for Climate Change

- $\mathbb{T}_i \equiv (\mathbf{t}_i, \mathbf{x}_i, \mathbf{s}_i, \boldsymbol{\tau}_i)$ denote country i's vector of taxes and $\mathbb{T} \equiv (\mathbb{T}_i, \mathbb{T}_{-i})$ denote the global vector of taxes.

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

$$W_i(\mathbb{T}) \equiv \underbrace{V_i(Y_i(\mathbb{T}), \tilde{\mathbf{P}}_i(\mathbb{T}))}_{\text{utility from consumption}} - \underbrace{\delta_i \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} Z_{n,k}(\mathbb{T})}_{\text{disutility from } CO_2}$$

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CO_2 emissions from origin n–industry k

Country i's Optimal Policy Problem

– A non-cooperative government's optimal policy $\mathbb{T}_i^\star \equiv (\mathbf{t}_i^\star, \mathbf{x}_i^\star, \mathbf{s}_i^\star, \boldsymbol{\tau}_i^\star)$ maximizes national welfare taking taxes in the RoW as given:

$$(\mathbf{t}_i^\star, \mathbf{x}_i^\star, \mathbf{s}_i^\star, \boldsymbol{\tau}_i^\star) = \arg\max \quad W_i\left(\mathbf{t}_i, \mathbf{x}_i, \mathbf{s}_i, \boldsymbol{\tau}_i; \overline{\mathbb{T}}_{-i}\right)$$

– $\mathbb{T}_i^\star$ is *free-riding-proof* but fails to internalize two externalities:

1. Country i's carbon externality on the rest of the world
2. Country i's terms-of-trade externality on the rest of the world

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Intermediate Envelope Result

- Characterizing, $\mathbb{T}_i^\star$, requires solving a complex GE optimization problem.
- We extend and refine the three-tier technique in Lashkaripour-Lugovskyy (2021) to convert our complex GE problem into *pseudo-partial equilibrium* problem.
- Our approach can be summarized as a general envelope result.

Theorem. *The F.O.C.s that determines country i's unilaterally optimal policy, $\mathbb{T}_i^\star$, can be derived and solved as if wages were constant and demand functions were income inelastic.*

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Optimal Policy Formulas

Theorem: *Country i's Unilaterally Optimal Policy*

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

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

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

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

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import demand elasticity

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correction for scale effects

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Special Cases

Theorem: *Country i's Unilaterally Optimal Policy*

Special Case I: Small Open Economy

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

[export subsidy] $1 + x^\star_{ij,k} = \left(\dfrac{\sigma_k - 1}{\sigma_k}\right)\left[1 + \dfrac{\gamma_k - 1}{\gamma_k}\tilde{\delta}_i \sum_{n \neq i} v_{n,k} \dfrac{\lambda_{nj,k}}{1 - \lambda_{ij,k}}\right]$

Theorem: *Country i's Unilaterally Optimal Policy*

Special Case II: Governments assign zero weight to ToT gains

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Carbon border taxes are less effective in high-returns to scale (low-γ) industries.

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CO_2 intensity of import good ji, k

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The Non-Cooperative Nash Equilibrium

The *non-cooperative* equilibrium corresponds to a one-shot game where each country sets its unilaterally optimal taxes taking taxes in the rest of the world as given:

$$\begin{cases} \mathbf{t}_1 = \boldsymbol{t}_1^\star(\mathbb{T}_{-1}), \quad \mathbf{x}_1 = \boldsymbol{x}_1^\star(\mathbb{T}_{-1}), \quad \mathbf{s}_1 = \boldsymbol{s}_1^\star(\mathbb{T}_{-1}), \quad \boldsymbol{\tau}_1 = \boldsymbol{\tau}_1^\star(\mathbb{T}_{-1}) \\ \vdots \\ \mathbf{t}_\mathcal{N} = \boldsymbol{t}_\mathcal{N}^\star(\mathbb{T}_{-\mathcal{N}}), \quad \mathbf{x}_\mathcal{N} = \boldsymbol{x}_\mathcal{N}^\star(\mathbb{T}_{-\mathcal{N}}), \quad \mathbf{s}_\mathcal{N} = \boldsymbol{s}_\mathcal{N}^\star(\mathbb{T}_{-\mathcal{N}}), \quad \boldsymbol{\tau}_\mathcal{N} = \boldsymbol{\tau}_\mathcal{N}^\star(\mathbb{T}_{-\mathcal{N}}) \end{cases}.$$

Note: The non-cooperative equilibrium is inefficient:

1. failure to internalize ToT externalities $\longrightarrow$ too much trade taxation
2. failure to internalize transboundary CO_2 externalities $\longrightarrow$ insufficient carbon taxation

Global Climate Cooperation

Optimal Cooperative Policy: *Global 1st-Best*

– Suppose governments act *cooperatively* to maximize global welfare $\sum_n W_n$.

– The optimal policy under ***global climate cooperation*** is the following:

$$\text{[carbon tax]} \qquad \tau^*_{i,k} = \sum_{n \in \mathbb{C}} \tilde{\delta}_n$$

$$\text{[industrial subsidy]} \qquad 1 + s^*_{i,k} = \frac{\gamma_k}{\gamma_k - 1}$$

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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.
- A bullet point summary of our quantitative strategy:
  1. Specify **optimal tax formulas** in terms of the change in equilibrium variables
  2. Specify the change in equilibrium variables as a function of optimal taxes
  3. Jointly solve the system of equations implied by (1) and (2)
- 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*:

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

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expenditure share

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CO_2 input share

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precieved cost of CO_2

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Data

Trade, Production, and Emissions

- 2009 World Input-Output Database (WIOD) & WIOD Environmental Accounts.
- 33 Countries + an aggregate of the rest of the world
- 19 broadly-defined Industries

Applied Taxes

- Import Tariffs: UNCTAD-Trains
- Environmentally-related Taxes: Eurostat & OECD-Pine

Calibration and Estimation of Parameters

Carbon input cost share ($\alpha_{i,k}$)

– calculate based on environmentally-related taxes, $\tau_{i,k}$

$$\alpha_{i,k} = \underbrace{(\gamma_k/\gamma_k - 1)}_{\text{markup}} \times \underbrace{\tau_{i,k}}_{\text{tax rate}} \times \underbrace{\nu_{i,k}}_{CO_2\text{–intensity}}$$

Markup ~ Scale Elasticity ($\frac{\gamma_k}{\gamma_k - 1}$)

– estimate by applying De Loecker–Warzynski's (2012, AER) methodology to financial accounts data from COMPUSTAT.

Trade Elasticity ($\sigma_k - 1$)

– estimate by applying Caliendo–Parro's (2014, ReStud) methodology to trade data from WIOD and tariff data from TRAINS. Estimated Values

Calibration and Estimation of Parameters

Carbon Input Demand Elasticity (ς)

- estimate input demand for carbon using national energy reserves as IV

$$\ln\left(\frac{\alpha_{i,k}}{1-\alpha_{i,k}}\right) = (1-\varsigma)\ln\left(\frac{\tau_{i,k}}{w_i}\right) + \varsigma \ln\left(\frac{\bar{\kappa}_{i,k}}{1-\bar{\kappa}_{i,k}}\right)$$

Disutility from Carbon ($\tilde{\delta}_i$)

- calibrated by means of revealed preference to match environmental taxes in each country *s.t.* $\sum_i \tilde{\delta}_i = SCC$.
- $SSC = 31$ \$/tC (US's Interagency Working Group on SCGG)

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Quantitative Analysis of Proposals 1-2

Proposal #1: Summary

- **Proposal 1:** Governments adopt non-cooperative **carbon border taxes** to curb transboundary CO_2 emissions.

- Note: *optimal* non-cooperative border taxes are *free-riding-proof* but inefficient from a global standpoint.

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Proposal #1: Impact of Non-Cooperative Border Taxes

	Non-Cooperative Border Taxes			Cooperative Carbon Taxes		
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%

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Inefficacy of Carbon Border Taxes: *Alternative Specifications*

	$\Delta CO2$	$\Delta CO2$ as % of 1st-best	ΔV
Main specification (SCC = 31 \$/tC, ς = 0.62)	-0.62%	1.02%	-1.71%
SCC = 68 \$/tC	-0.71%	1.01%	-1.72%
ς = 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 ς = 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%

Inefficacy of Carbon Border Taxes: *Intuition*

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

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 $\longrightarrow$ 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: 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:

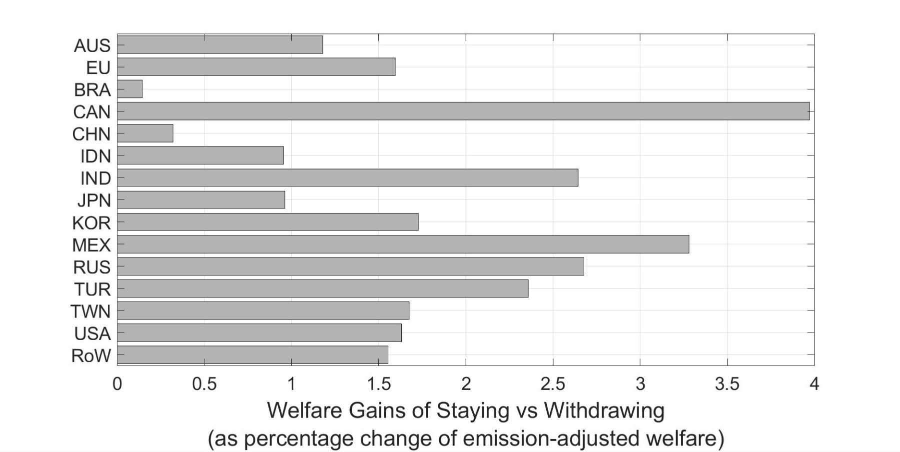
	Trade taxes set by	
	Members	*Non-members*
Against Members	zero	unilaterally optimal
Against Non-members	unilaterally optimal	status quo (i.e., applied tariffs)

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 from members' trade penalty.

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 impractical 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 $\longrightarrow$ the club-of-only-EU is also a Nash eq.
- If EU + USA are core members $\longrightarrow$ 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:

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

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Summary of Findings

- Border taxes are have limited efficacy at curbing CO_2 emissions, because
  - most high-carbon goods/services never cross international borders
  - border taxes have a limited effect 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.

Summary of Findings

- Border taxes are have limited efficacy at curbing CO_2 emissions, because
  - most high-carbon goods/services never cross international borders
  - border taxes have a limited effect 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.

Thank You.

Related Literature

Optimal policy in an open economy

- PE *w/* carbon externalities: Markusen (1975); Copeland (1996);
- GE *w/o* carbon externalities: Costinot et al. (2015, 2016); Lashkaripour and Lugovskyy (2016); Bartelme et al. (2019); Beshkar and Lashkaripour (2020).
- Weisbach and Kortum (2020): Adopts a GE Dornbusch-Fischer-Samuelson model w/ carbon externalities + explicitly specifies markets for energy.

Quantitative analyses of carbon tariffs

- Babiker (2005), Elliott et al. (2010), Nordhaus (2015), Böhringer et al. (2016). Return

Equilibrium for a given Vector of Taxes $(\mathbf{t}, \mathbf{x}, \mathbf{s}, \boldsymbol{\tau})$

1. Consumption choices are optimal: $\begin{cases} Q_{ji,k} = \mathcal{D}_{ji,k}(Y_i, \tilde{\mathbf{P}}_i) \\ \tilde{P}_{ji,k} = \frac{1+t_{ji,k}}{(1+x_{ji,k})(1+s_{j,k})} P_{ji,k} \end{cases}$

2. Production choices are optimal: $\begin{cases} P_{ij,k} = d_{ij,k}\bar{p}_{ii,k} w_i (1-a_{i,k})^{\frac{1}{\gamma_k}-1} Q_{i,k}^{-\frac{1}{\gamma_k}} \\ (1-a_{i,k}) = \left(\frac{\alpha_{i,k}}{1-\alpha_{i,k}}\right)^{\alpha_{i,k}} \left(\frac{w_i/\bar{\varphi}_{i,k}}{\tau_{i,k}}\right)^{\alpha_{i,k}} \end{cases}$

3. Wage payments equal net sales: $w_i L_i = \sum_{j=1}^{N} \sum_{k=1}^{\mathcal{K}} \left[(1-\alpha_{i,k}\frac{\gamma_k - 1}{\gamma_k}) P_{ij,k} Q_{ij,k}\right]$

4. Income equals wage payments plus tax revenues: $Y_i = w_i L_i + \mathcal{R}_i(\mathbf{t}, \mathbf{x}, \mathbf{s}, \boldsymbol{\tau})$

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$\boxed{\text{tax revenues}}$

Return

Cooperative Carbon Border Taxes: *2nd-Best*

- 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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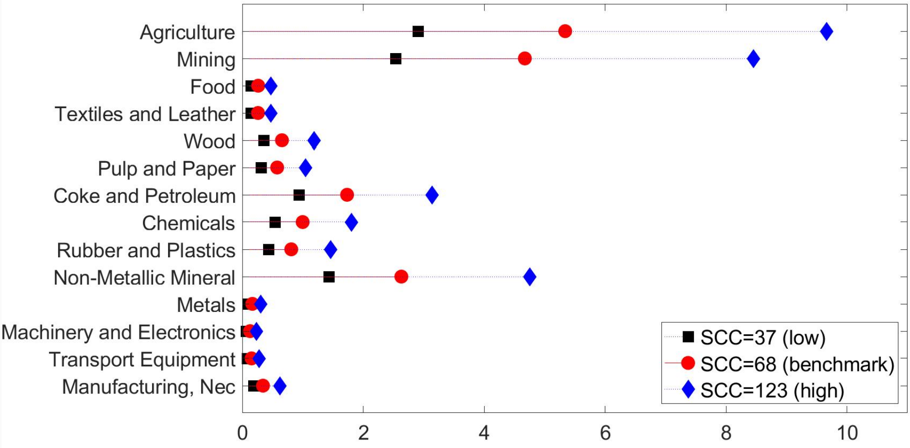
EU's Optimal Carbon Border Taxes



Return

Estimated Elasticities: *WIOD Industry Categories 1-9*

	Industry	Carbon Intensity (v)	Carbon Input Share (α)	Trade Elasticity (σ)	Markup ($\frac{\gamma}{\gamma-1}$)
1	Agriculture	1,589	0.044	4.12	1.464
2	Mining	1,372	0.025	4.12	1.529
3	Food	84	0.011	3.86	1.698
4	Textile	81	0.011	2.12	2.109
5	Wood	109	0.014	7.83	1.278
6	Paper	135	0.008	9.00	1.296
7	Refined Petroleum	376	0.015	4.31	1.178
8	Chemicals	295	0.032	11.86	2.064
9	Plastics	50	0.010	2.55	1.272

Estimated Elasticities: *WIOD Industry Categories 10-19*

	Industry	Carbon Intensity (v)	Carbon input share (α)	Trade Elasticity (σ)	Markup ($\frac{\gamma}{\gamma-1}$)
10	Nonmetallic Minerals	1,422	0.026	7.28	1.488
11	Metals	372	0.009	7.28	1.239
12	Electronics & Machinery	26	0.007	12.71	1.501
13	Motor Vehicles	30	0.006	1.59	1.211
14	Other Manufacturing	46	0.012	1.59	1.913
15	Electricity, Gas and Water	3,791	0.021	8.14	1.119
16	Construction	39	0.012	8.14	1.098
17	Retail and Wholesale	37	0.018	8.14	1.137
18	Transportation	503	0.059	8.14	1.011
19	Other Services	63	0.009	8.14	1.596

Return