Optimal Carbon Prices in an Unequal World: The Role of Regional Welfare Weights

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Why, what, and how?

Inequality & equity:
At the heart of international climate policy

- Yet, standard estimates of optimal carbon prices focus solely on efficiency

  Previous inequality-sensitive estimates: e.g. Chichilnisky and Heal (1994), Shiell (2003), Azar and Sterner (1996), Anthoff (2011), Budolfson and Dennig (2019)

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Research question

How does the treatment of global inequality, captured by regional welfare weights, affect the optimal stringency of global climate policy?

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Methods:

- Theory: North-South model
- Simulations: RICE-2010 model (Nordhaus, 2010)

Planner's problem

Model setup: two regions $i \in \{N, S\} = \mathcal{I}$, one period

The **optimization problem** is:

$$\max_{X_i, A_i} \sum_i \alpha_i u(X_i)$$

$$\text{subject to: } X_i = W_i - C_i(A_i) - D_i(A), \quad \forall i \quad \text{(budget constraint)}$$

$$[C'_N(A_N) = C'_S(A_S)] \quad \text{(uniform MAC; optional)}$$

Notation: consumption X_i, endowment W_i, abatement costs C_i, climate damages D_i, abatement A_i, aggregate abatement $A = \sum_i A_i$, welfare weights α_i, utility u

Assumptions: $\frac{dC_i}{dA_i} > 0$, $\frac{d^2 C_i}{dA_i^2} > 0$, $\frac{d^3 C_i}{dA_i^3} = 0$, $\frac{dD_i}{dA} < 0$, $\frac{d^2 D_i}{dA^2} > 0$, $\frac{du}{dx_i} > 0$, $\frac{d^2 u}{dx_i^2} < 0$, $W_N \gg W_S$

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Negishi weights: $\tilde{\alpha}_i = \frac{\tilde{u}_i'^{-1}}{\sum_{j \in \mathcal{I}} \tilde{u}_j'^{-1}}$ Utilitarian weights: $\alpha_i^U = \frac{1}{2}$

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Cost-Effectiveness vs Welfare-Cost-Effectiveness

Negishi-weighted carbon prices are cost-effective:

$$\tilde{C}'_S = \tilde{C}'_N = -\sum_{j \in \mathcal{I}} \tilde{D}'_j$$

Utilitarian differentiated carbon prices are **welfare-cost-effective**:

$$\hat{u}'_S \hat{C}'_S = \hat{u}'_N \hat{C}'_N = -\sum_{j \in \mathcal{I}} \hat{u}'_j \hat{D}'_j.$$

Uniform carbon prices: Utilitarian vs Negishi

Proposition (Utilitarian vs Negishi)

The utilitarian uniform carbon price is greater than the Negishi-weighted carbon price if and only if $\frac{\check{D}'_S}{\check{D}'_N} > \frac{C''_N}{C''_S}$.

The condition is more likely to be satisfied if the South has relatively:

- Higher marginal damages ($\rightarrow$ larger benefits)
- Steeper marginal abatement cost function ($\rightarrow$ lower costs; $\frac{dA_i}{d\tau} = \frac{1}{C''_i}$)

Graphical intuition

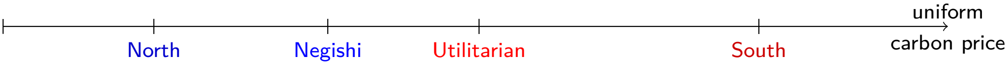
Aggregating heterogeneous preferences

Regional welfare weights: $\alpha_i = 1$, $\alpha_j = 0$

▸ Formal expression

Proposition (Connection to regions' preferred uniform carbon prices)

The utilitarian uniform carbon price is greater than the Negishi-weighted carbon price if and only if the preferred uniform carbon price of the South is greater than the preferred uniform carbon price of the North.



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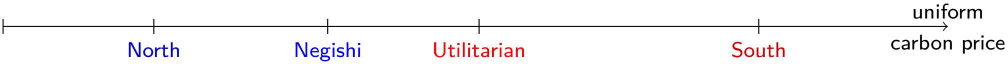

Intuition:

- Optimal uniform carbon prices as "weighted averages" of regions' preferred uniform carbon prices
- The Negishi-weighted SWF gives more weight to the preferences of the North

“One dollar, one vote” vs “one person, one vote”

Proposition (A voting interpretation)

Suppose marginal damages are constant and $C_i'' = \frac{\kappa}{W_i}$, for some $\kappa > 0$.

(i) *Then, the Negishi-weighted carbon price is the endowment-weighted average of regions' preferred uniform carbon prices:*

$$\tilde{\tau} = \sum_i \frac{W_i}{\sum_j W_j} \mathring{\tau}^i .$$

(ii) *If, in addition, utility is logarithmic, and the per capita consumption and endowment ratios are approximately equal, then the utilitarian uniform carbon price approximately equals the population-weighted average of regions' preferred uniform carbon prices:*

$$\check{\tau} \approx \sum_i \frac{L_i}{\sum_j L_j} \mathring{\tau}^i .$$

Main quantitative findings

Utilitarian weights increase policy stringency

- Uniform carbon price: $\uparrow$ 15%
- Differentiated carbon prices: cumulative global emissions $\downarrow$ 21% (Rich: $> 200\$/tCO_2$, Poor: $< 10\$/tCO_2$)

Main quantitative findings

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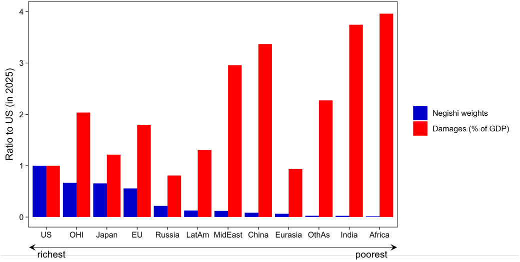
Main driver: Negishi weights down-weight poor regions, which are most affected by climate change



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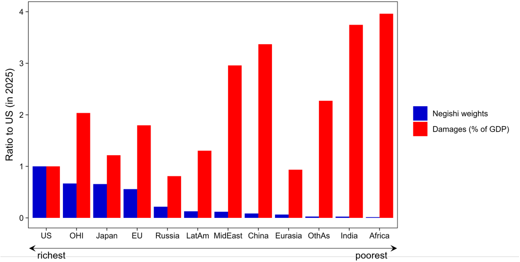
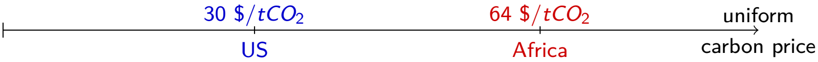


Regions' preferred uniform carbon prices (in 2025, $\rho = 1.5\%$):



Comments or questions?

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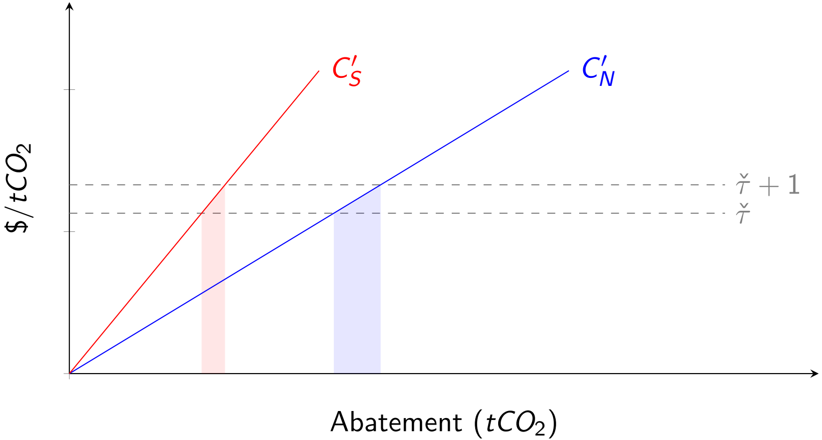
Graphical illustration of the role of C_i''



Steeper C' (larger C'') $\rightarrow$ lower cost burden from carbon price increase

$$\frac{dA_i}{d\tau} = \frac{1}{C_i''}$$

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A region's preferred uniform carbon price

"Edge weights": $\mathring{\alpha}_i = 1$, $\mathring{\alpha}_j = 0$

A **region's preferred uniform carbon price** is implicitly defined by

$$\mathring{\tau}_i = \mathring{C}'_i = -\mathring{D}'_i \underbrace{\frac{\mathring{C}''_i + \mathring{C}''_{-i}}{\mathring{C}''_{-i}}}_{\in[1,\infty]} .$$

- The last term determines by how much a region's preferred uniform carbon price exceeds its own marginal benefits of abatement
- This can be compared to the optimality condition of the Nash equilibrium, $C'_i = -D'_i$

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Regions' preferred uniform carbon prices

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Table 6: Regions preferred uniform carbon prices (in 2022 \$/tCO_2) and resulting peak warming. For comparison, the uniform utilitarian and Negishi-weighted carbon prices are also shown.

	Carbon prices			
Social welfare function	2025	2055	2085	Peak warming (°C)
Negishi	25	60*	116**	3.00
Utilitarian	29	68	128	2.93
US	30	64	111	2.99
OHI	34	77	146	2.86
Japan	35	90	174	2.72
EU	63	133	224	2.42
Russia	7	17	35	3.98
LatAm	38	79	138	2.91
MidEast	37	72	118	3.00
China	13	40	94	3.00
Eurasia	7	20	43	3.65
OthAs	27	62	120	3.00
India	29	67	129	2.94
Africa	64	134	225	2.40

Note: The table shows the results for the utility discount rate of 1.5%. Temperature changes are relative to 1900. Mimi-RICE-plus only yields an approximately equalized carbon price for the Negishi solution. Specifically, it varied across regions between (*) 59 and 63 \$/tCO_2 in 2055, and (**) 113 and 121 \$/tCO_2 in 2085.

Regions' preferred uniform carbon prices

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