Unequal Climate Policy in an Unequal World

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Motivation

Climate change and inequality

- Climate change is a critical challenge for mankind.
- Addressing climate change is difficult because there is inequality: across countries, across generations, across households.

Motivation

When does Inequality Matter?

- Climate change is an externality problem ⟶ Pigouvian tax!
- Inequality is easy to fix ⟶ Transfers!
- But what if policymakers cannot eliminate inequality?
    - political/institutional constraints
    - insufficient instruments to redistribute
- We focus on climate policy, in an environment with inequality, as a means to address the climate externality, not for redistribution.

What we do

- This paper studies climate policy in an economy with heterogeneous households, clean and dirty consumption, and a climate externality from the dirty good. Three parts:
    - DATA: low-income households have higher carbon intensity per dollar spent (not today).
    - THEORY: characterize optimal carbon tax rules under different constraints on the planner's problem.
    - QUANTITATIVE: we embed the simple model in a heterogeneous-agent climate-model calibrated to the US economy, and quantify the effects of taxes on the economy, climate, and welfare (not today).

Optimal Carbon Tax

- In a large class of models, the optimal carbon tax is

$$\tau_t^\star = \boxed{\frac{\sigma_t^\star}{u_{ct}^\star}} \begin{array}{l} \text{Social Marginal Damages of Carbon} \\ \\ \\ \text{Social Value of Consumption (SVC)} \end{array}$$

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- In representative agent models, the SVC is simply the marginal utility of consumption.
- The SVC in models with heterogeneous agents where the planner has access to a full set of instruments can be analogously defined.
- But, how about when the planner lacks those instruments?

Constrained Efficient Carbon Tax

- When the planner is constrained from making transfers across households, the constrained efficient carbon tax is:

$$\tau_t^i = \boxed{\frac{\sigma_t}{u_{ct}^i}}$$

Social Marginal Damages of Carbon

Individual Value of Consumption

- The constrained efficient carbon tax is similar to the optimal one, but deviates in an important way: τ_t^i higher for wealthier households because they value consumption less, i.e. they have a lower marginal utility.

Uniform Constrained-Efficient Carbon Tax

- If the planner is further constrained to use a uniform carbon tax, the uniform constrained efficient carbon tax is given by:

$$\tau_t = \boxed{\frac{\sigma_t}{\sum_i \alpha^i u^i_{ct}}}$$

Social Marginal Damages of Carbon

Social Value of Consumption

- We show that the proper SVC is a weighted average of individual marginal utilities.
- When risk aversion is greater than 1, average marginal utility is higher than marginal utility of average consumption
- Key theoretical insight: inequality increases the SVC

Quantifying the welfare gains

- Heterogeneous carbon tax delivers highest average initial welfare gain and largest long-run temperature reduction
- Constrained efficient uniform carbon tax leads to a smaller temperature reduction but is Pareto improving
- Negishi optimal carbon tax has lowest support, hurting poor households

Policy	Avg. welfare gain (%)	Support	LR temp. reduction
Heterogeneous tax	0.068	90.0	1.9
Uniform tax	0.063	100.0	1.2
Negishi optimal tax	0.060	76.0	1.7

Generalizations of the Optimal Tax Formulas

- In the paper, we generalize the optimal tax derivations to include
    - non-homothetic preferences
    - stochastic shocks
    - endogenous labor and capital
    - ad hoc borrowing constraints
- We now turn to quantitative analysis that incorporate these features to evaluate the aggregate and welfare consequences of implementing climate policies informed by our theory.

Quantitative Model

Model

- Heterogeneous agents model with incomplete markets (Aiyagari, Bewley, Hugget, Imrohoroglu)
- Economy populated by a continuum of households, indexed by i, with measure μ_i
- Two consumption goods, clean and dirty: (c^i_{ct}, c^i_{dt})
- Production of the clean and the dirty good uses labor and capital with CRS technology: $Y_{ct} = F(K_{ct}, N_{ct})$; $Y_{dt} = F(K_{dt}, N_{dt})$
- Consumption of the dirty good adds carbon to the atmosphere:

$$S_{t+1} = S_t(1-\delta) + \upsilon \sum_i \mu_i c^i_{dt} \tag{1}$$

Households

- Preferences over consumption, leisure, and carbon:

$$\mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u(c^i_{ct}, c^i_{dt}, \ell^i_t) - x(S_{t+1}) \right]$$

- Households choose consumption (c^i_{ct}, c^i_{dt}), capital k^i_t, and labor n^i_t to maximize utility subject to

$$\begin{aligned} & p_t c^i_{dt}(1+\tau_t) + c^i_{ct} + k^i_{t+1} - k^i_t \leq y^i_t, \quad \forall t \\ & k^i_{t+1} \geq 0, \quad \forall t \end{aligned}$$

where $\ell^i_t = 1 - n^i_t$, and

$$y^i_t \equiv w_t \varepsilon^i_t n^i_t - T(w_t \varepsilon^i_t n^i_t) + (r_t - \delta_k) k^i_t (1 - \tau_{kt}) + Tr^i_t$$

Calibration strategy

- Many model parameters affect both economic and climate outcomes (e.g., discount factor, disutility of work, preference for dirty good)
- Other parameters affect climate only (e.g., disutility from climate damage, carbon content of dirty consumption, carbon absorption). Why?
  1. climate damage enters separably in utility
  2. carbon does not directly affect production
- This allows us to first calibrate the model's economic parameters to an "economic" steady state, and then calibrate the model's climate parameters

Calibration: Preferences

- Utility function:

$$u\left(c_c, c_d, \ell\right) = \frac{\left(\left(c_c + \bar{c}\right)^{\gamma} c_d^{1-\gamma}\right)^{1-\kappa}}{1-\kappa} - \phi\frac{(1-\ell)^{1+\nu}}{1+\nu}$$

Parameters	Values	Targets / Source
Discount factor β	0.97	Wealth-to-GDP: 4.8 (2014)
Risk aversion κ	2	Standard value
Labor disutility, ϕ	29.6	Average hours: 30 percent
Frisch elasticity $1/\nu$	0.5	Standard value
Clean share γ	0.97	\$50/ton carbon tax leads to 0.8 degree reduction from BAU
Non-homotheticity $\bar{c}$	0.16	emissions intensity 31% higher for ▸ low-income than high-income households

Calibration: Technology and Shocks

- Production function: $F(K, N) = K^{\alpha} N^{1-\alpha}$
- Normal productivity: $\log(\varepsilon_t^i) = \rho \log(\varepsilon_{t-1}^i) + \xi_t^i,\ \xi_t^i \sim N(0, \sigma_\varepsilon^2)$
- Superstar state ε_{sup} to match wealth/earnings distribution

Parameters	Values	Targets / Source
Capital weight, α	0.36	capital income share: 36%
Capital depreciation, δ_k	0.05	standard value
Productivity persistence ρ	0.94	author estimates
Standard deviation, σ_ε	0.20	earnings Gini: 0.47
Superstar parameters		
productivity, $\varepsilon_{sup}/\varepsilon_{med}$	163	wealth share top 1.0%: 34%
persistence, $\pi(\varepsilon_{sup}, \varepsilon'_{sup})$	0.94	wealth Gini: 0.83
entry probability, $\pi(1:9, \varepsilon'_{sup})$	6e-5	fraction of superstars: 0.1%

Calibration: Government

- Progressive earnings tax (Benabou, HSV,...)

$$T(y) = y - \tilde{y}^{\nu_y} \frac{1 - \tau_y}{1 - \nu_y} y^{1-\nu_y}$$

where $\tilde{y}^{\nu_y}$ is average earnings

Parameters	Values	Targets / Source
Average tax parameter, τ_y	0.23	average labor income tax: 13%
Progressivity parameter, ν_y	0.17	37.9% marginal tax rate on top 1% earners
Capital income tax, τ_k	0.27	Carey and Rabesona (2002)
Consumption tax, τ_c	0.06	Carey and Rabesona (2002)

Calibration: Climate

- Temperature function: $T_t = \frac{\lambda}{\log(2)} \log\left(\frac{S_t}{\overline{S}}\right)$ (Golosov et al. 2014)
- Climate damage function: $x(S) = \frac{\psi}{2} S^2$

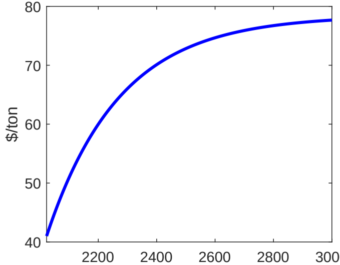
Parameters	Values	Targets / Source
Carbon absorption, δ	$1/300$	average life of carbon: 300 years
Carbon intensity, υ	326.4	1.4 degree increase by 2100 under BAU
Climate disutility, ψ	0.04	welfare loss from 2.5 degree increase $\approx$ 1.74 percent output reduction
Temperature parameters		
climate sensitivity, λ	3	doubling of carbon $\Rightarrow$ 3-degree increase
initial carbon, $\overline{S}$	581	pre-industrial carbon stock (gigatons)

Quantitative Exercises

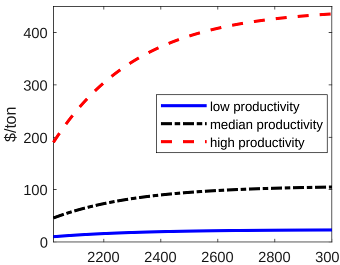
Carbon tax

- We use the Pigouvian tax formulas from our propositions
- Tax formulas depend on endogenous variables
  - carbon stocks, marginal utilities
  - start with BAU allocations to calculate carbon tax; solve transition;
  - update carbon tax with new allocations; repeat until convergence
- For today, heterogeneous carbon tax based on current productivity (+ history in progress)

(a) Uniform carbon tax

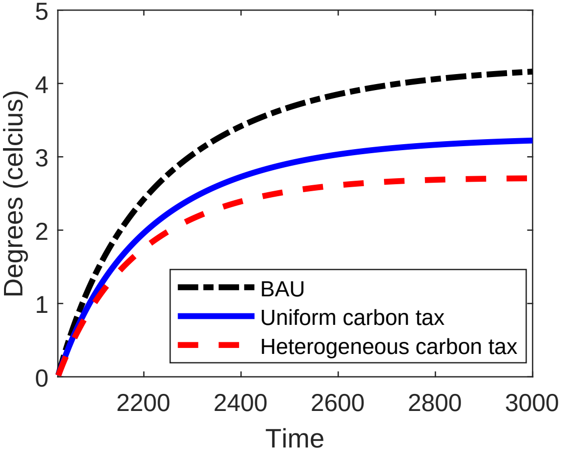


(b) Heterogeneous carbon tax



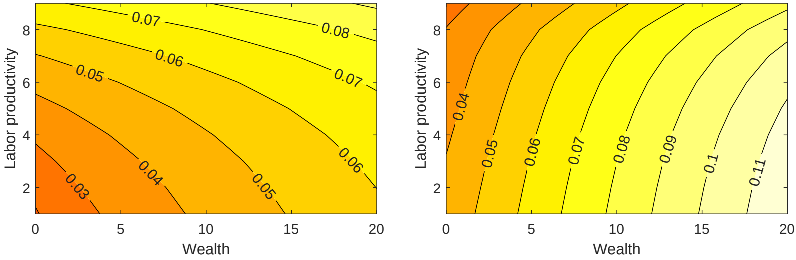
Global Temperature

- The carbon tax leads to a 1–2 degree reduction compared to BAU



Initial distribution of welfare

- Welfare gains (relative to BAU) positive for virtually all households
- Pareto improving in the uniform case

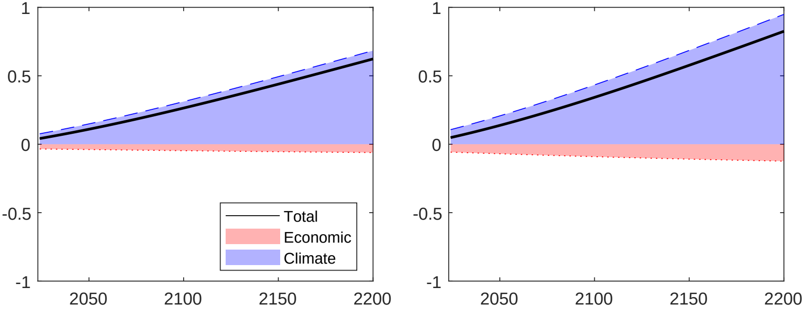


(a) Uniform carbon tax (b) Heterogeneous carbon tax

Units: Permanent consumption equivalents (percent)

Average welfare decomposition over time

- Average welfare gains become large over time



(a) Homogeneous carbon tax (b) Heterogeneous carbon tax

Units: Permanent consumption equivalents (percent)

Alternative exercises

- A more implementable policy with uniform carbon tax, uniform clean subsidy, and uniform lumpsum transfer delivers climate and welfare gains similar to the individual rebate.
- A constant carbon tax that delivers a similar level of carbon reduction has much lower welfare gains and support.

Policy	Avg. welfare gain (%)	Support	LR temp. reduction
Heterogeneous tax with rebate	0.052	99.9	1.6
Uniform tax with rebate	0.045	100.0	1.0
Uniform tax with subsidy/transfer	0.047	100.0	1.0
Constant tax ($100/ton) w/ rebate	0.009	49.7	1.2

Conclusion

- We derive optimal carbon tax rules for economies with inequality.
- Well-designed (informed by theory) climate policies can lead to Pareto improving welfare gains.
- Next steps:
  - Heterogeneous climate damages (if low-income households are more vulnerable to climate damages, there is more room for a Pareto-improvement)
  - Implementation of the constrained-efficient allocation with climate targets.

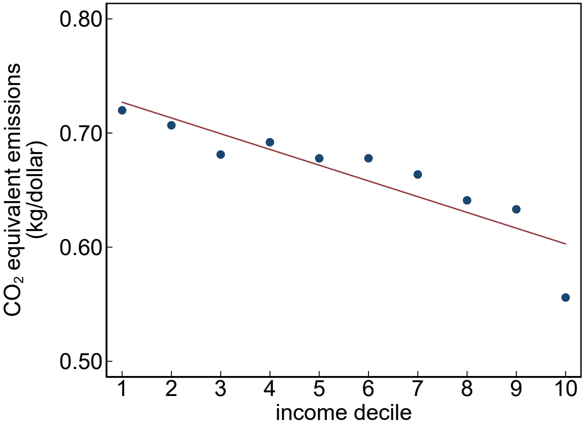
Appendix

Data

back to calibration

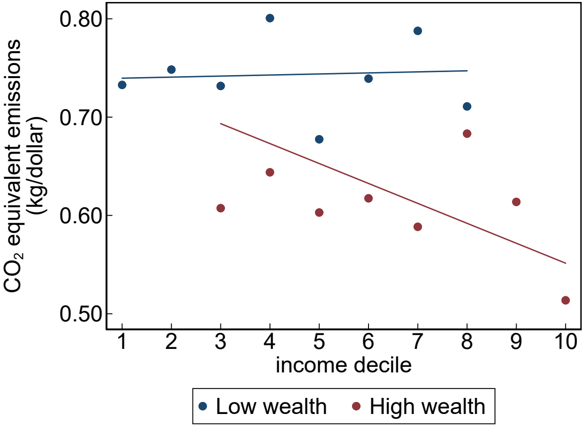
- We combine two datasets
- Environmental Protection Agency (EPA)
  - embodied emissions for 460 commodities (covering cradle → factory gate → shelf) details
- Consumer Expenditure Survey (CEX, 2019)
  - 671 expenditure categories
  - 5000+ working-age households
  - construct CEX-NAICS concordance examples
- Compute CO_2-equivalent embodied emissions per dollar spent, for each household

Embodied emission shares higher for low-income



back to calibration PSID

Embodied emission shares higher for low-income and low-wealth



back to calibration PSID

Embodied emissions and expenditure shares

- Emission intensities are higher for low-income households because they spend relatively more on high-intensity goods

Expenditure category	Embodied emissions (CO_2 kg/dollar)	Expenditure shares (percent)	
		Low income	High income
Utilities	1.71	11.0	6.8
Transportation	1.09	22.3	21.4
Food/Beverages at home	0.80	17.1	10.2
Household furnishings/equipment	0.28	2.5	4.4
Food/Beverages away from home	0.21	5.7	8.4
Clothing and footwear	0.20	2.3	3.5
Education and child care	0.18	1.0	9.3
Entertainment	0.15	4.0	7.2
Health care	0.14	7.2	9.5
Shelter	0.11	21.4	11.8
Other expenditures	0.10	5.6	7.6

High and low income correspond to the top and bottom deciles of income, respectively, conditional on working age.

back to calibration

Summary of empirical findings back to calibration

- Embodied emission intensities decline with income and wealth
- Robust to controlling for household characteristics: Regressions
  - household head age
  - household head education
  - household size
- Robust to:
  - alternative emissions dataset (FRS)
  - alternative expenditure dataset (PSID)

Selected examples of UCC-Naics concordance back

UCC	Description	NAICS	Description	$C0_2e$ emissions (kg/2018 USD)
100210	Cheese	311513	Cheese Manufacturing	1.585
90110	Fresh Milk All Types	311511	Fluid Milk Manufacturing	1.323
80110	Eggs	112300	Chicken Egg Production	1.052
140110	Frozen Vegetables	311411	Frozen Fruit, Juice, Vegetable Mfg.	.846
610310	Pet Food	311111	Dog and Cat Food Mfg.	.75
530210	Intercity bus fares	485210	Interurban/Rural Bus Transportation	.515
170110	Cola Drinks	312111	Soft Drink Manufacturing	.444
190212	Dinner At Full Service	722511	Full-Service Restaurants	.255
450220	New Motorcycles	336991	Motorcycle, Bicycle, and Parts Mfg.	.254
370314	Boys pants and shorts	315220	Men's/Boys' Cut/Sew Apparel Mfg.	.187
630110	Cigarettes	312230	Tobacco Manufacturing	.153
560110	Physicians Services	621111	Offices of Physicians	.082

Details on embodied emissions data (EPA) back

- Included greenhouse gases: CO_2, Methane (CH_4), Nitrous Oxide (N_2), Other GHGs
- Convert to CO_2 using IPCC (The Intergovernmental Panel on Climate Change) AR4 (Assessment Report) GWP-100 (Global warming potential over 100 years, compared to CO_2)
- covers supply chain emissions (cradle to factory gate) and also margins (factory gate to shelf, including transportation, wholesale and retail)
- Environmentally-Extended Input-Output (EEIO) model
  - compute direct requirement matrix using Make/Use Tables
  - compute total requirement matrix using Leontief Inverse
  - combine with direct emissions factors from National Greenhouse Gas Industry Attribution Model (NGIAM)

Embodied emission shares back

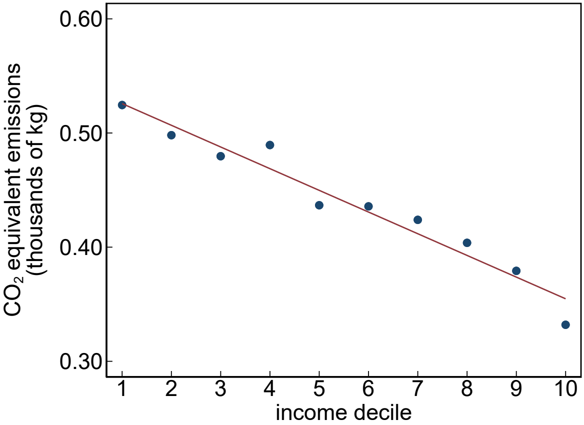
	(1)	(2)	(3)	(4)
Wealth	-1.68^{***}		-1.35^{***}	-1.10^{***}
	(0.053)		(0.068)	(0.070)
Income		-3.69^{***}	-1.79^{***}	-2.83^{***}
		(0.095)	(0.224)	(0.247)
College=1				-4.51^{***}
				(0.381)
Observations	16368	56122	16368	16368
Adjusted R^2	0.057	0.026	0.060	0.135

Standard errors in parentheses. $* \; p < 0.10$, $** \; p < 0.05$, $*** \; p < 0.01$
(4) additionally includes age and family size fixed effects.

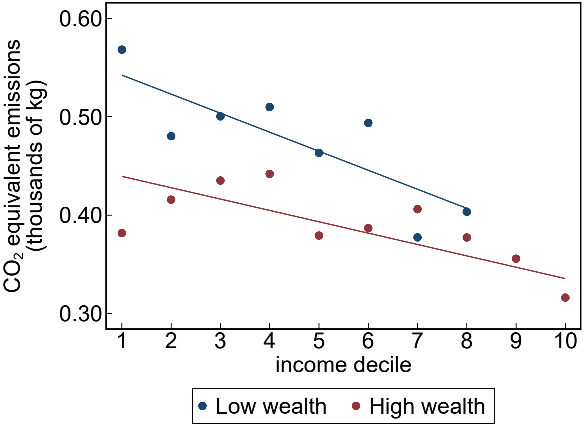
- sd(log(wealth)) = 3.3
- sd(log(income)) = 1.0

Emission shares higher for low-income (PSID)

back



Embodied emission shares higher for low-income and low-wealth (PSID) back



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