Unequal Climate Policy

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Introduction

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  - carbon emissions per dollar spent is higher for low income/wealth households
- Does inequality affect the optimal carbon tax, and if so, how?
  - we show that inequality reduces the carbon tax, due to two effects

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Consumption inequality $\substack{\Longrightarrow \\ \Longleftarrow}$ Optimal carbon tax

Related literature

- **Carbon taxation with representative agent:** Nordhaus (2007), Golosov et. al. (2014), Barrage (2018), Belfiori (2017), Rausch, Mecalf and Reilly (2011), and others.
- **Carbon taxation with heterogeneous agents:** Van Der Ploeg and Jacobs (2019), Douenne, Hummel and Pedroni (2022), Belfiori and Macera (2022), Goulder et. al. (2019), Pizer and Sexton (2019), Smith and Per Krusell (2017), Känzig (2022).
- **Revenue recycling carbon policies with heterogeneous agents:** Fried and Novan (2022), Fried, Novan and Peterman (2018), Fullerton and Monti (2013).
- **Inequality and Carbon:** Sager (2019), Levinson and O'Brien (2019).

Empirical analysis

Data

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

Details on CEX

- The CEX microdata has two surveys:
  - Diary collects detailed expenditure for two consecutive weeks (especially for groceries, e.g. flour, rice, white bread)
  - Interview collects (more aggregated) monthly household expenditures for 4 consecutive quarters (e.g. food at home, college tuition, camping equipment, airline fares)
  - Estimate emission function for food and beverages from Diary data (Adjusted $R^2 \approx 0.95$) and apply to Interview data
- For all other Interview expenditures categories, use the constructed UCC-NAICS concordance to directly attribute embodied emissions
- Finally, include direct tailpipe emissions (9kg CO2 per gallon driven, or approximately 3kg CO2 per dollar)

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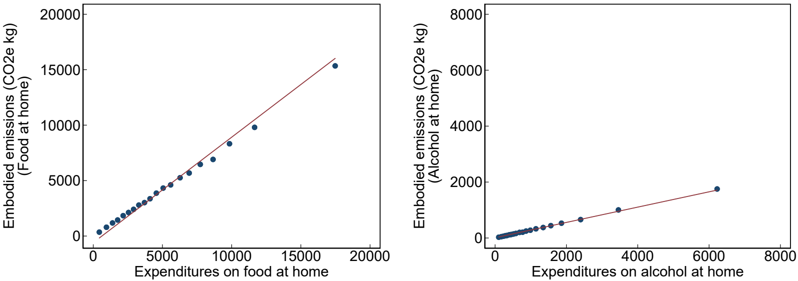
Food and beverages from Diary survey

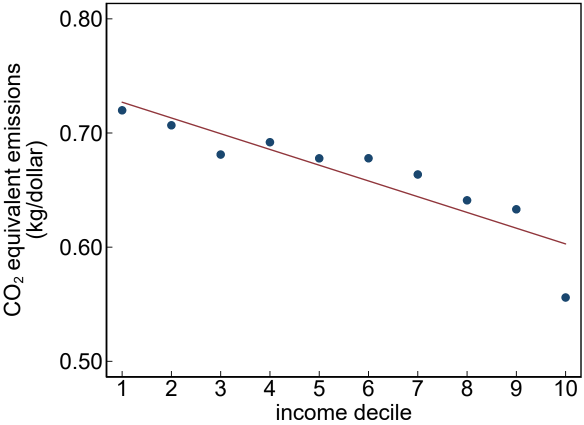


- for $j =$ "food and nonalcoholic beverages at home", "alcohol at home", estimate

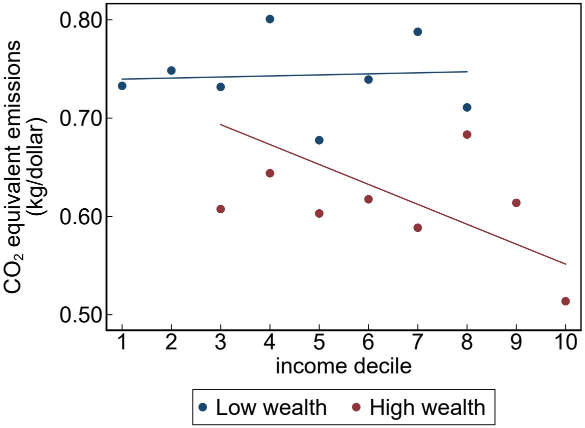
$$\log(\text{emissions}_{ij}) = \beta_j \log(\text{expenditures}_{ij}) + C_j + \varepsilon_{ij}$$

- use predicted $\widehat{emissions}_{ij}$ in Interview data

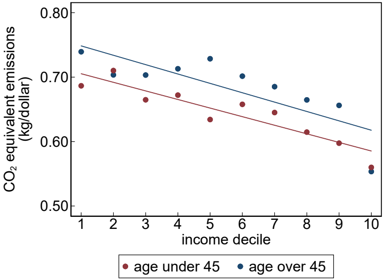
Embodied emission shares higher for low-income

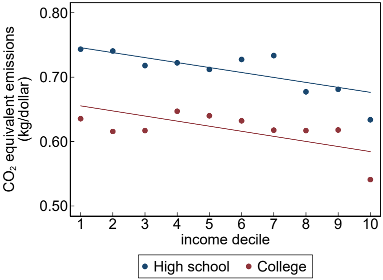


Embodied emission shares higher for low-income and low-wealth



Embodied emission shares lower for college grads





Embodied emissions and expenditure shares

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

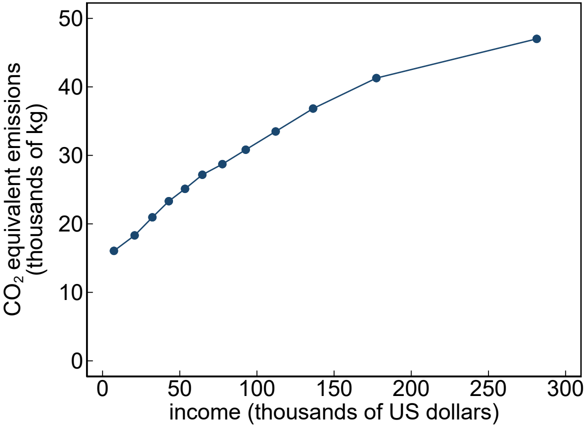
Expenditure category	Embodied emissions (CO_2 kg/dollar)	Expenditure shares (percent)	
		Low income	High income
Utilities	1.71	11.0	6.8
Transportation	1.09	22.3	21.4
Food/Beverages at home	0.80	17.1	10.2
Household furnishings/equipment	0.28	2.5	4.4
Food/Beverages away from home	0.21	5.7	8.4
Clothing 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.

Environmental Engel Curve

- A related fact is the concavity of the EEV (as in Sager, 2019)

$\Rightarrow$ A mean preserving spread in income leads to less emissions



Summary of empirical findings

- Embodied emission intensities decline with income, wealth, and education
- Robust to controlling for household characteristics: Regressions
  - household head age
  - household size
- Robust to:
  - alternative emissions dataset (FRS)
  - including owner equivalent rent $\Rightarrow$ reduce emission intensities of homeowners

Summary of empirical findings

- Embodied emission intensities decline with income, wealth, and education
- Robust to controlling for household characteristics: Regressions
  - household head age
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- Robust to:
  - alternative emissions dataset (FRS)
  - including owner equivalent rent $\Rightarrow$ reduce emission intensities of homeowners
- We now turn to a simple model to understand how inequality interacts with the optimal carbon tax

Simple Model

Model

- Households, indexed by i, with measure μ_i
  - consume clean and dirty goods
  - inelastically supply ε_i units of efficiency labor
- Two sectors, indexed by $j = C, D$
  - hire labor ℓ_j to produce
  - dirty goods add to atmospheric carbon

$$S_{t+1} = S_t(1-\delta) + \sum \mu_i c^i_{Dt} \tag{1}$$

- Government levies a carbon tax τ^i_t on the dirty good
  - uses revenue to finance wasteful government consumption and/or lumpsum transfers

Households

- Preferences:

$$\sum_{t=0}^{\infty} \beta^t U^i(c_{Ct}, c_{Dt}; S_t)$$

where

$$U^i(c_{Ct}, c_{Dt}; S_t) = u^i(c_{Ct}, c_{Dt}) - x(S_t)$$

$$u(c_{Ct}, c_{Dt}) = \frac{\left(c_{Dt}^{\gamma_i} (c_{Ct} + \bar{c})^{1-\gamma_i}\right)^{1-\sigma}}{1-\sigma}$$

  - $\beta < 1,\ \sigma \geq 1$
  - $x(S_t) = \Psi^2 S_t^2/2$: disutility from carbon
  - $\gamma_L \geq \gamma_H$: dirty good preference
  - $\bar{c} \geq 0$: Stone-Geary nonhomotheticity parameter

Household Problem

- Households choose clean and dirty consumption to solve

$$\max_{\{c_{Ct}, c_{Dt}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U^i(c_{Ct}, c_{Dt}; S_t) \tag{2}$$

$$\text{s.t. } c^i_{Ct} + (1+\tau^i_t) p_{Dt} c^i_{Dt} \leq w_t \varepsilon_i + p_{Dt} T^i_t, \quad \forall t \geq 0$$

- Solution:

Household Problem

- Households choose clean and dirty consumption to solve

$$\max_{\{c_{Ct}, c_{Dt}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U^i(c_{Ct}, c_{Dt}; S_t) \tag{3}$$

$$\text{s.t. } c^i_{Ct} + (1+\tau^i_t) p_{Dt} c^i_{Dt} \leq w_t \varepsilon_i + p_{Dt} T^i_t, \quad \forall t \geq 0$$

- Solution:

$$\boxed{\frac{u^i_{Dt}}{u^i_{Ct}} = p_{Dt}(1+\tau^i_t)}$$

Firms

- A representative firm in sector $j = C, D$ chooses labor, ℓ, to maximize profits:

$$\max_{\ell} p_{jt} y_{jt} - w_t \ell \tag{4}$$
$$\text{s.t. } y_{jt} = \ell$$

  where $p_{Ct} = 1$.

- Solution:

Firms

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$$\max_{\ell} p_{jt} y_{jt} - w_t \ell$$

$$\text{s.t. } y_{jt} = \ell$$

  where $p_{Ct} = 1$.

- Solution:

$$w_t = p_{Dt} = 1$$

Equilibrium

A *competitive equilibrium*, given fiscal policies $\left\{\tau_t^i, T_t^i\right\}_{t=0}^{\infty}$, is

- prices $\{p_{Dt}, w_t\}_{t=0}^{\infty}$
- household allocations $\left\{c_{Ct}^i, c_{Dt}^i\right\}_{t=0}^{\infty}$ $\forall i$
- firm allocations $\{y_{jt}, \ell_{jt}\}_{t=0}^{\infty}$ for $j = C, D$,

such that, for all $t \geq 0$,

1. given prices, households of type i choose $\left\{c_{Ct}^i, c_{Dt}^i\right\}_{t=0}^{\infty}$ to solve (3)
2. given prices, firms of sector $j = C, D$ choose $\{\ell_{jt}, y_{jt}\}_{t=0}^{\infty}$ to solve (4)

3. labor markets clear,

$$\ell_{Ct} + \ell_{Dt} = \sum_i \mu_i \varepsilon_i \tag{5}$$

4. goods markets clear, for $j = C, D$,

$$y_{Ct} = \sum_i \mu_i c^i_{Ct} \tag{6}$$

$$y_{Dt} = g_t + \sum_i \mu_i c^i_{Dt} \tag{7}$$

5. government budget is satisfied,

$$\sum_i \tau^i_t \mu_i c^i_{Dt} = g_t + \sum_i \mu_i T^i_t \tag{8}$$

6. the stock of atmospheric carbon evolves according to (1).

Roadmap

- We start by characterizing the first-best allocation
  - derive the Pigouvian formula
  - dichotomy: a carbox tax solves the externality and transfers solve the distributional concerns
- We then restrict the tax and transfers to investigate how the presence of inequality may change the optimal carbon tax

Planner's problem

- The optimal allocation (with weights α_i) is the solution to

$$\max_{\left\{c^i_{c,t}, c^i_{Dt}, S_{t+1}\right\}_t} \sum_{t=0}^{\infty} \beta^t \sum_i \alpha_i \left[u\left(c^i_{Dt}, c^i_{c,t}\right) - x(S_{t+1})\right] \tag{9}$$

$$\text{s.t. } S_{t+1} \geq (1-\delta)S_t + \sum_i \mu_i c^i_{Dt} \ \ \ldots \ \ (\beta^t \sigma_t)$$

$$\sum_i \mu_i \left(c^i_{c,t} + c^i_{Dt}\right) \leq \sum_i \mu_i \varepsilon_i \ \ \ldots \ \ (\beta^t \lambda_t)$$

- The first order conditions for this problem are:

$$\left(c^i_{Dt}\right) : \alpha_i u^i_{Dt} - \mu_i \sigma_t - \mu_i \lambda_t = 0$$

$$\left(c^i_{c,t}\right) : \alpha_i u^i_{c,t} - \mu_i \lambda_t = 0$$

$$\left(S_{t+1}\right) : -\beta^t x'(S_{t+1}) + \sigma_t \beta^t - \sigma_{t+1}\beta^{t+1}(1-\delta) = 0$$

Planner's problem

- The first order conditions for this problem are:

$$(c^i_{Dt}) : \alpha_i u^i_{Dt} - \mu_i \sigma_t - \mu_i \lambda_t = 0 \tag{10}$$

$$(c^i_{c,t}) : \alpha_i u^i_{c,t} - \mu_i \lambda_t = 0 \tag{11}$$

$$(S_{t+1}) : -\beta^t x'(S_{t+1}) + \sigma_t \beta^t - \sigma_{t+1} \beta^{t+1}(1-\delta) = 0 \tag{12}$$

- Iterating forward from (12), we have the social cost of carbon:

$$\sigma_t = \sum_{j=1}^{\infty} [\beta(1-\delta)]^{j-1} x'(S_{t+j})$$

- Notice that equations (10)–(11) hold for all i. Thus,

$$\lambda_t + \sigma_t = \qquad \boxed{\frac{\alpha_L}{\mu_L} u^L_{d,t} = \frac{\alpha_H}{\mu_H} u^H_{d,t}}$$

$$\lambda_t = \qquad \boxed{\frac{\alpha_L}{\mu_L} u^L_{c,t} = \frac{\alpha_H}{\mu_H} u^H_{c,t}}$$

Planner's problem

- These conditions imply that weighted marginal utilities are equated across agents

$$\frac{\alpha_L}{\mu_L} u^L_{d,t} = \frac{\alpha_H}{\mu_H} u^H_{d,t}$$
$$\frac{\alpha_L}{\mu_L} u^L_{c,t} = \frac{\alpha_H}{\mu_H} u^H_{c,t}$$

- And, the MRS between goods is also equated across agents:

$$\boxed{\frac{u^L_{d,t}}{u^L_{c,t}} = \frac{u^H_{d,t}}{u^H_{c,t}}}$$

Pigouvian tax

- The FOCs can also be arranged to obtain:

$$u^i_{d,t} = u^i_{c,t}\left(1 + \frac{\mu_i \sigma_t}{\alpha_i u^i_{c,t}}\right)$$

- Then, with Utilitarian weights ($\alpha_i = \mu_i$),

$$\boxed{\tau^\star_t \equiv \frac{\sigma_t}{u_{c,t}}}$$

- This is the Pigouvian carbon tax that decentralizes the optimal allocation and lumpsum transfers are set such that marginal utilities are equalized

Constrained optimal allocations

- Now, we restrict the tax and transfers in various ways.
- First, consider the restriction that the planner cannot directly transfer resources across agents, i.e. $T_t^i = \tau_t^i c_{Dt}^i$.
- In this case, the Ramsey planner faces the additional implementability conditions, $c_{c,t}^i + c_{d,t}^i \leq \varepsilon_i$

No direct transfers

- The constrained allocation is the solution to:

$$\max_{\{c^i_{c,t}, c^i_{d,t}, S_{t+1}\}_t} \sum_{t=0}^{\infty} \beta^t \sum_{i=L,H} \alpha_i U(c^i_c, c^i_d, S_{t+1})$$

$$\text{s.t. } S_{t+1} \geq (1-\delta)S_t + \sum_i \mu^i c^i_{d,t} \text{ ... } (\beta^t \sigma_t)$$

$$c^i_{c,t} + c^i_{d,t} \leq \varepsilon_i \text{ ... } (\beta^t \lambda^i_t)$$

- We can derive the constrained optimal carbon tax (Utilitarian):

$$\boxed{\tau^i_t = \frac{\sigma_t}{u^i_{c,t}} = \tau^\star_t \frac{\sigma_t}{\sigma^\star_t} \frac{u^\star_{ct}}{u^i_{ct}}}$$

- we can argue that, for $\varepsilon_i < \varepsilon_j$,

$$u^i_{c,t} \geq u^\star_{c,t} \geq u^j_{c,t}$$

No direct transfers + homogenous carbon tax

- If we further restrict the tax to be identical across agents:

$$\max_{\left\{c^i_{c,t},c^i_{d,t},S_{t+1}\right\}_t} \sum_{t=0}^{\infty} \beta^t \sum_{i=L,H} \alpha_i U(c^i_c, c^i_d, S_{t+1})$$

$$\text{s.t. } S_{t+1} \geq (1-\delta)S_t + \sum_i \mu^i c^i_{d,t} \ \dots \ (\beta^t \sigma_t)$$

$$c^i_{c,t} + c^i_{d,t} \leq \varepsilon_i \ \dots \ (\beta^t \lambda^i_t)$$

$$u^j_{d,t} u^i_{c,t} \leq u^i_{d,t} u^j_{c,t} \ \dots \ (\beta^t \eta^{ij}_t)$$

- We can derive the constrained optimal carbon tax:

$$\boxed{\tau_t = \frac{\sigma_t}{\sum_i \hat{\alpha}_i u^i_{c,t}} = \tau^\star \frac{\sigma_t}{\sigma^\star_t} \frac{u^\star_{ct}}{\sum_i \hat{\alpha}^i u^i_{ct}}}$$

A back of the envelope calculation

- The constrained optimal carbon tax can be expressed as:

$$\boxed{\frac{\tau_t}{\tau^\star} \approx \frac{c_t^{1-\sigma}}{\sum_i \mu_i {c_t^i}^{1-\sigma}}}$$

- Using the 2019 CEX, we find that for $\sigma = 1$, the ratio is $2/3$, implying the tax in an economy with equality is $1/3$ lower
- More generally, if consumption is Pareto distributed, with tail parameter α,

$$\frac{c_t^{1-\sigma}}{\sum_i \mu_i {c_t^i}^{1-\sigma}} = \frac{\mathbb{E}\left[c_i\right]^{1-\sigma}}{\mathbb{E}\left[c_i^{1-\sigma}\right]} = \frac{\alpha + \sigma - 1}{\alpha}\left(\frac{\alpha - 1}{\alpha}\right)^{\sigma - 1}$$

- For $\alpha = 2, \sigma = 2$, the optimal tax is $1/4$ lower than in a representative agent framework.

Other restrictions

- We have also characterized the optimal carbon tax under further restrictions such as no transfers at all.
- Inequality matters for the social cost of carbon and the dispersion in marginal utilities

Conclusion

- Carbon emissions embodied in household expenditure (per dollar) are decreasing in income/wealth
- Next steps
  - quantify the magnitude in a calibrated model
  - compute distributional consequences on welfare

Appendix

Selected examples of UCC-Naics concordance back

UCC	Description	NAICS	Description	$C0_2$e 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