Fiscal Policy for Climate Change

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Motivation

Figure: Yellow Vests Protest Movement

Public Policy to Address Climate Change

- Pigouvian Taxation is widely regarded as first best solution to Climate Change by Economists (Nordhaus (2019)). Debate on **Social Cost of Carbon** (Stern and Stiglitz (2021); Wagner et al. (2021)).
- However, implementation is constrained by politics (Hassler et al. (2021)).

Inequality Is a Key Driver of those Politics.

- Climate change **impacts** people unequally.
- Climate change mitigating **policies** impact people unequally.
- We analyse the **distributional** consequences of those policies.
- Survey evidence (Douenne and Fabre, 2022; Dechezleprêtre et al., 2024) show support for using carbon tax to **directly invest** in **decarbonization**

Contribution

1. Develop a macroeconomic heterogeneous-agent framework with environmental externality for analysing climate change mitigation policies.
2. We model carbon intensity in entire economy, both production and consumption side.
3. Allows government to reduce carbon pricing regressivity through both lump-sum transfer *and* directly investment in households' mitigation

Relation to Literature

- Nordhaus (2014, 2018) and Golosov et al. (2014): optimal price of carbon.
- Anthoff et al. (2009); Anthoff and Emmerling (2019) consider inequality in IAMs, still using representative agent frameworks.
- Bosetti and Maffezzoli (2013), Fried (2022), Känzig (2022): Heterogeneous-agent frameworks. We add carbon intensity of the final consumption good.
- Barrage (2020) looks at impact of carbon taxation (particularly on capital) - but with representative agent.
- Douenne et al. (2022) build on Barrage (2020) to examine optimal carbon pricing policy in a heterogeneous agent framework with fixed income distribution
- Benmir and Roman (2023) examine optimal carbon pricing policy in a fully heterogeneous agent framework

Outline of Paper

- Work in progress
- We focus on a single country (USA)
- We partition emissions between energy production, final goods production and direct households emissions
- Single country model: climate damages result from global emissions, climate externality is internalised as a carbon budget
- We study taxation on both production and consumption of final goods.

Model

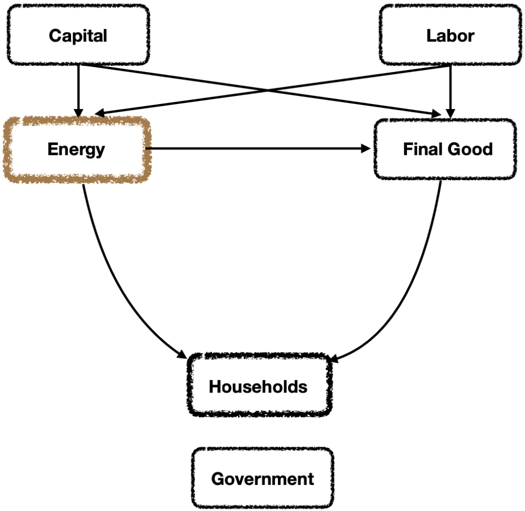
Model in a nutshell

Standard production heterogeneous-agent model with idiosyncratic productivity risk.

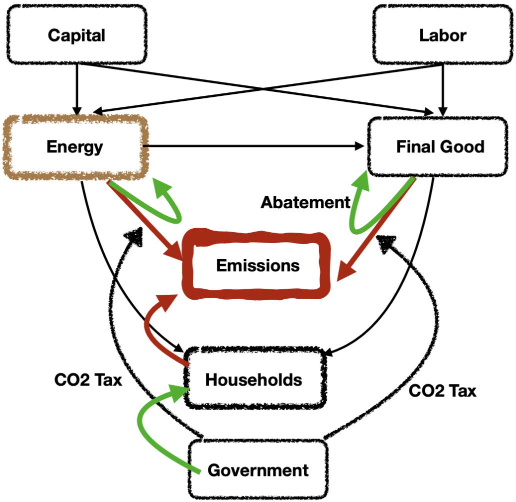
Model specificities:

- Two sectors: **energy** and **final good**.
- Producing the final good production consumes energy
- Households consume both the final good and energy
- Energy production, final good production and households' direct energy consumption all generate CO_2 emissions
- A benevolent government has a rich set of fiscal tools (taxes on consumption goods, labor, capital + lump-sum tax and/or direct subsidy to abatement) to influence CO_2 emissions.
- Rich equity-efficiency tradeoff: emissions vs capital level vs inequality.

Model structure



Model structure



Key model equations: Production

Energy sector

$$\max_{K_{e,t},L_{e,t},\mu_{e,t}} \tilde{p}_{e,t} Y_{e,t} - \tilde{p}_{f,t}(\tilde{r}_t + \delta_e) K_{e,t-1} - \tilde{p}_{f,t} \tilde{w}_t L_{e,t} - \tilde{p}_{f,t} \tau_{e,t} m_{e,t} - \tilde{p}_{f,t} g_e(\mu_{e,t}) \phi_e Y_{e,t},$$

$$m_{e,t} = (1 - \mu_{e,t}) \phi_e Y_{e,t}.$$

Final-good sector

$$\max_{\{K_{f,t},L_{f,t},\mu_{f,t}\}} \tilde{p}_{f,t} Y_{f,t} - \tilde{p}_{f,t}(\tilde{r}_t + \delta_f) K_{f,t-1} - \tilde{p}_{f,t} \tilde{w}_t L_{f,t} - \tilde{p}_{e,t} E_{f,t}$$
$$- \tilde{p}_{f,t} \tau_{f,t} m_{f,t} - \tilde{p}_{f,t} g_f(\mu_{f,t}) \phi_f Y_{f,t},$$

$$m_{f,t} = (1 - \mu_{f,t}) \phi_f Y_{f,t}.$$

Key model equations: Households

Households' program

$$V_\theta(a,y) = \max_{(\mu_h, c_f, c_e, a')} u\left(C_\theta(c_f, c_e)\right) + \beta \mathbb{E}_{y'}\left[V_\theta\left(a', y'\right)\right],$$

$$\text{subject to } \tilde{p}_f a' = \tilde{p}_f(1+r)a + \tilde{p}_f wy + \tilde{p}_f T - \tilde{p}_f c_f - \tilde{p}_e c_e$$
$$-\tilde{p}_f \tau_h (1-\mu_h)\phi_h c_e - (1-s)\tilde{p}_f g_h(\mu_h)\phi_h c_e,$$
$$a' \geq 0, \ (\text{and } c_f, c_e > 0).$$

Households' consumption

$$C_\theta(c_f, c_e) = \begin{cases} \left(\omega_{f,\theta}^{1-\alpha_\theta}\left(c_f - \bar{c}_{f,\theta}\right)^{\alpha_\theta} + \omega_{e,\theta}^{1-\alpha_\theta}\left(c_e - \bar{c}_{e,\theta}\right)^{\alpha_\theta}\right)^{\frac{1}{\alpha_\theta}} & \text{if } \alpha_\theta < 1 \text{ and } \alpha_\theta \neq 0 \\ \omega_{f,\theta} \ln\left(c_f - \bar{c}_{f,\theta}\right) + \omega_{e,\theta} \ln\left(c_e - \bar{c}_{e,\theta}\right) & \text{if } \alpha_\theta = 0 \end{cases}$$

with **subsistence consumption levels $\bar{c}_{s,\theta} \geq 0$**.

Key model equations: Households (cont.) & Government

Household abatement level

$$\tau_h = (1 - s) g_h'(\mu_h)$$
$$\Leftrightarrow \mu_h = g_h'^{-1}\left(\frac{\tau_h}{1 - s}\right)$$

Government budget constraint

$$\tau_h \int m_h(a, y)\Lambda(da, dy) + \tau_e m_e + \tau_f m_f + \tau_L \tilde{w}\overline{L} + \tau_K \tilde{r} K + B'$$
$$= (1 + r)B + G + T + s \int g_h(\mu_h)\phi_h c_e(a, y)\Lambda(da, dy)$$

Key model equations: Resolution

Computation of the equilibrium

- Choose a fiscal policy $(\tau_h, \tau_e, \tau_f, \tau_K, \tau_L, s, B, T)$
- Compute factor prices satisfying firms' program
- Compute the solution to the household's program
- Verify that the government budget constraint holds
- Compute total emissions: $m = m_f + m_e + \int m_h(a, y)\Lambda(da, dy)$.

$\longrightarrow$ Find the **fiscal policy** compatible with **emissions cut objective** and **maximizing welfare**.

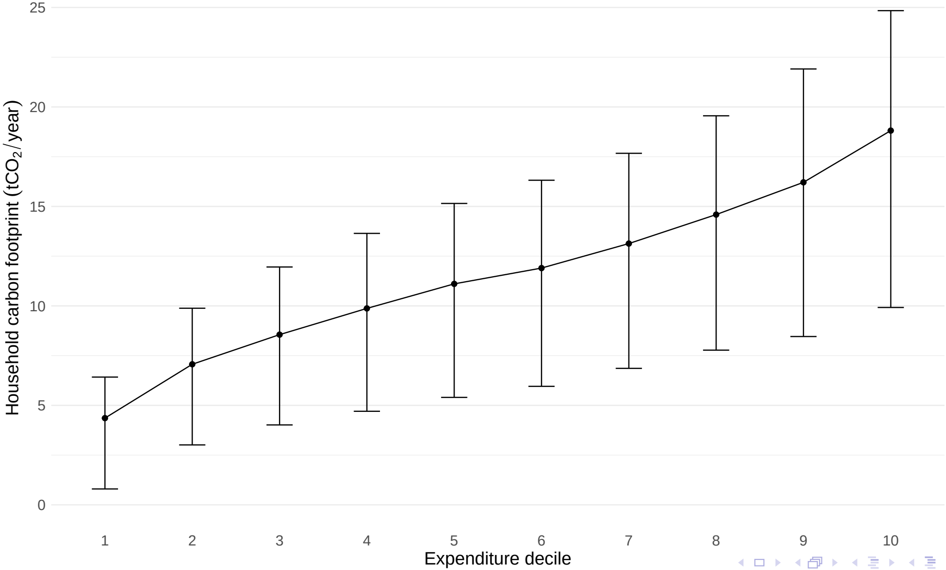
Calibration

Households' carbon footprint along the income distribution

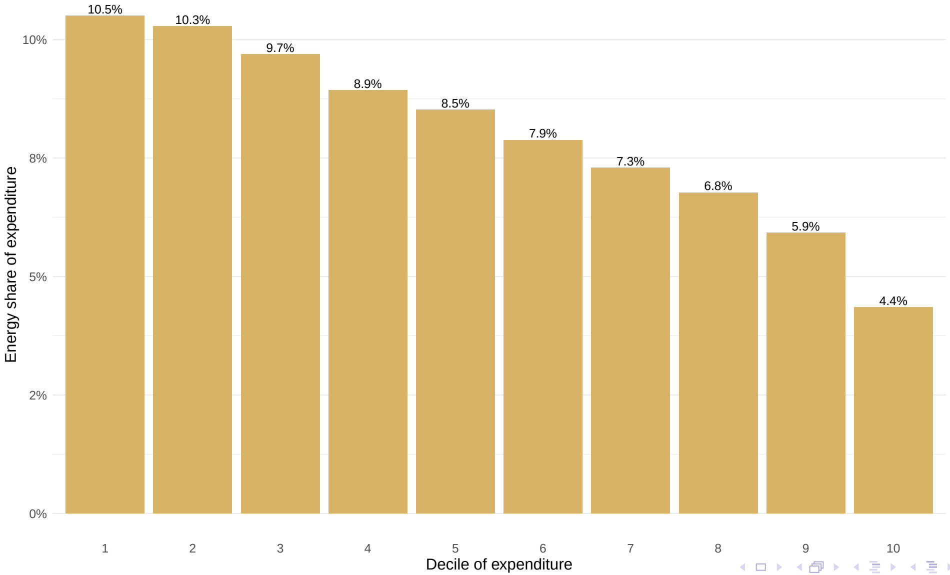
- We obtain detailed data on U.S. households' consumption basket from the **Consumer Expenditure Survey** for the year 2019
  - Each wave consists of around 6,000 households
  - Participant households are surveyed at most 4 quarters consecutively
  - Spending surveyed across 432 expenditure categories (Universal Classification Codes)
- We construct a measure of households' energy-related carbon footprint
  - Natural gas and oil products (e.g. gasoline)
  - Electricity, taking into account state-level electricity mix
- The CEX socio-economic variables allow us to stratify households' energy-related carbon footprint **by expenditure deciles**

Map of GHG footprints

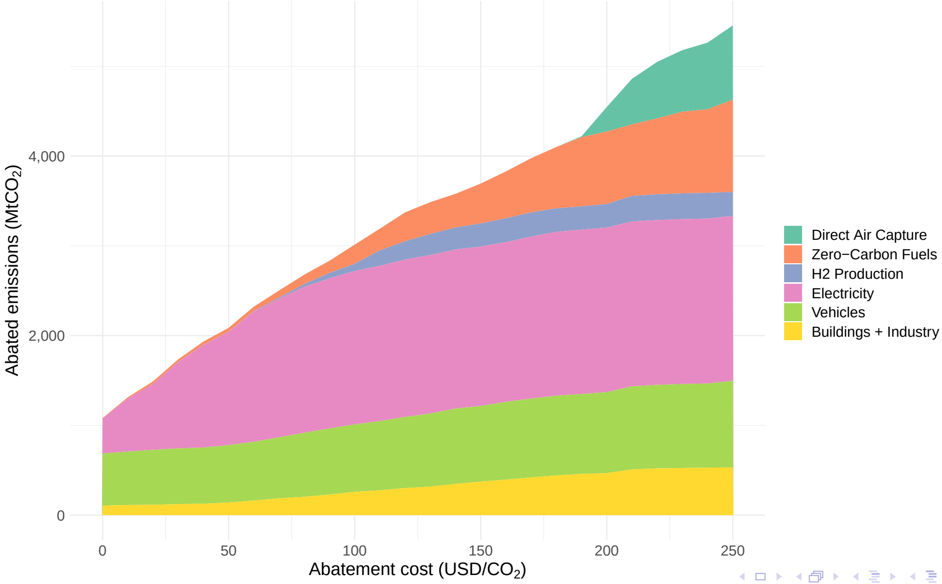
While carbon footprint increases with total expenditure...



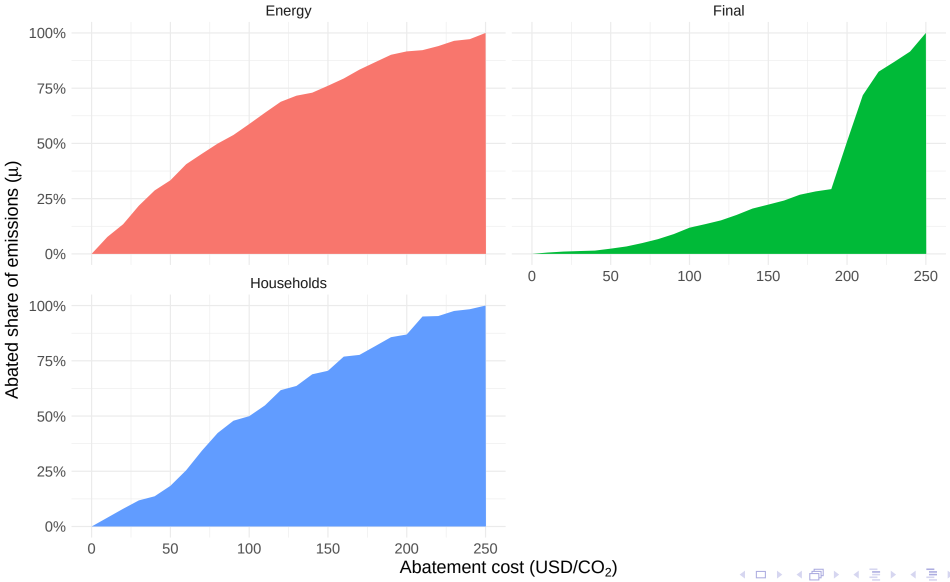
...energy spending share decreases



Abatement calibration: EDF's MACC 2.0



Allocate technologies to obtain an abatement cost curve for each sector



Calibration

We target the following moments in the calibration data:

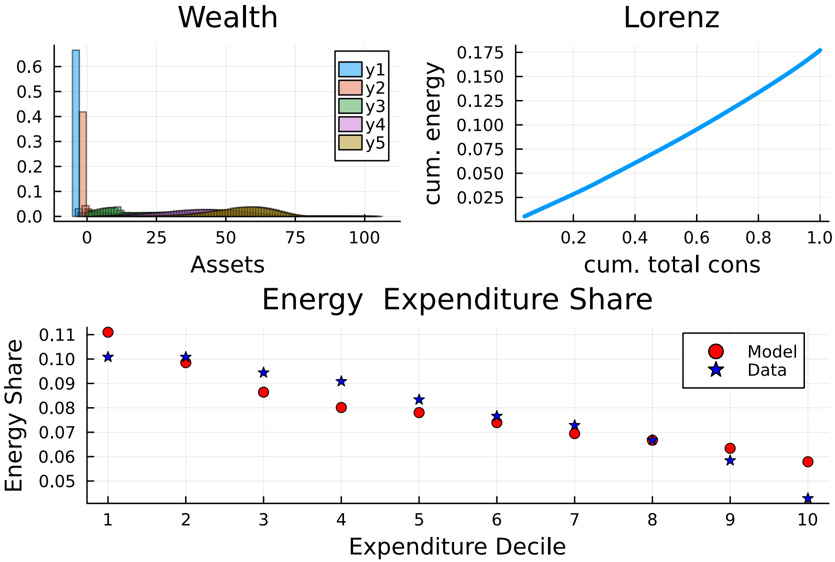
- Ratio between the output of the energy sector and final sector
- Emissions of the energy sector, final good sector and households, summing to total US emissions
- Energy spending share by decile of the US expenditure distribution.

Most other parameters set following the literature (in particular: damage function)

We optimize a quadratic moment function measuring the distance between model and data moments - standard SMM.

Details

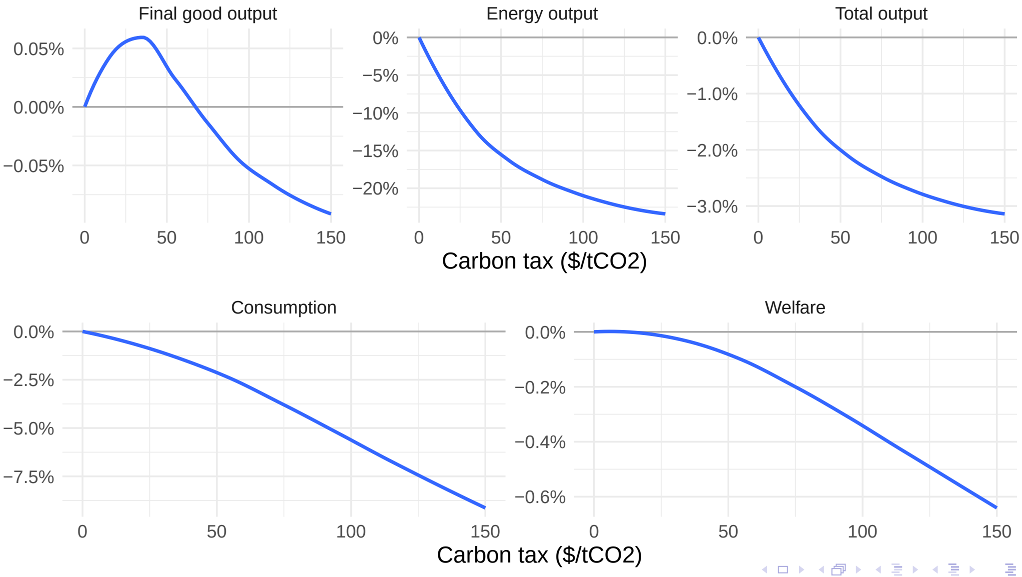
Model Fit



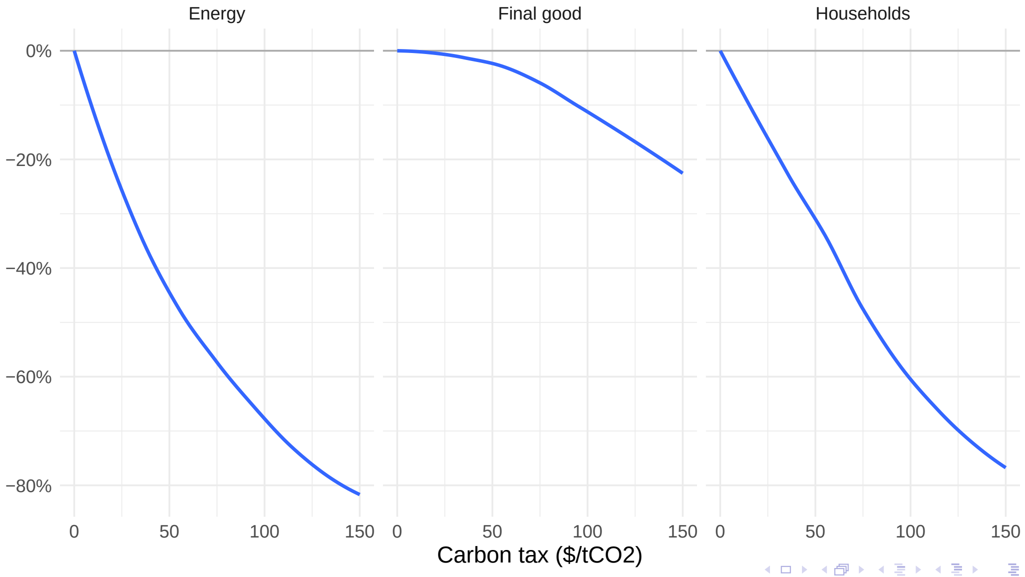
Wealth
y1
y2
y3
y4
y5
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
Assets
Lorenz
cum. energy
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.2
0.4
0.6
0.8
1.0
cum. total cons
Energy Expenditure Share
Energy Share
Model
Data
0.11
0.10
0.09
0.08
0.07
0.06
0.05
1
2
3
4
5
6
7
8
9
10
Expenditure Decile

Policy experiments & preliminary results

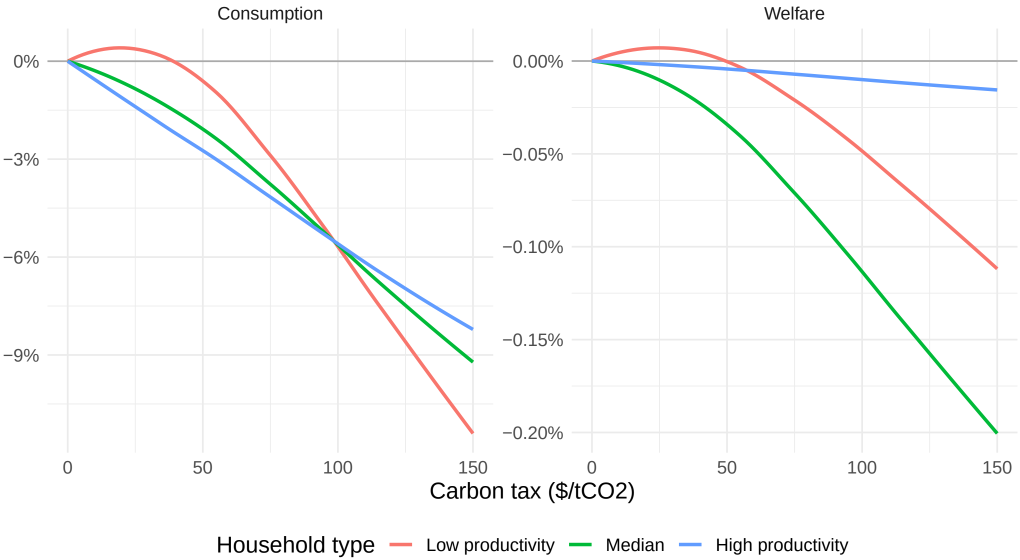
Impacts of lump-sum redistributed carbon taxation from \$0 to \$150/tCO_2



Carbon taxation reduces emissions heterogeneously across sectors

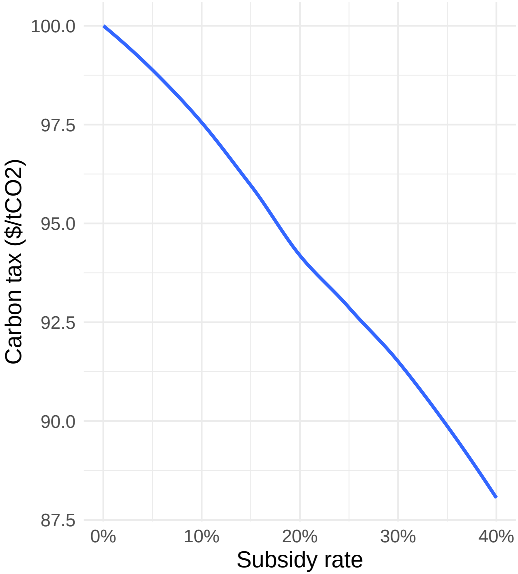


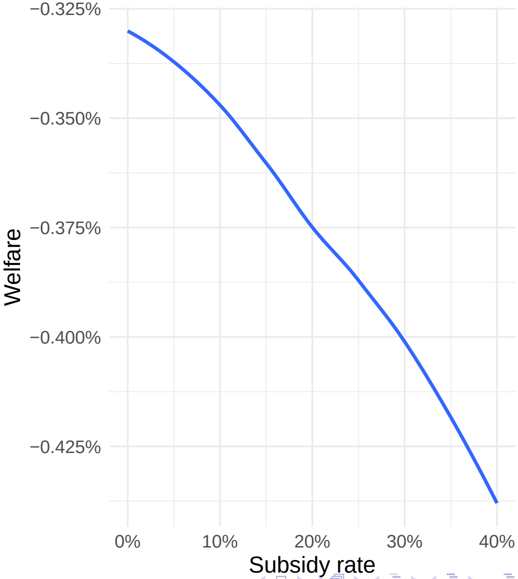
Uniform lump-sum transfer only partially compensates regressivity



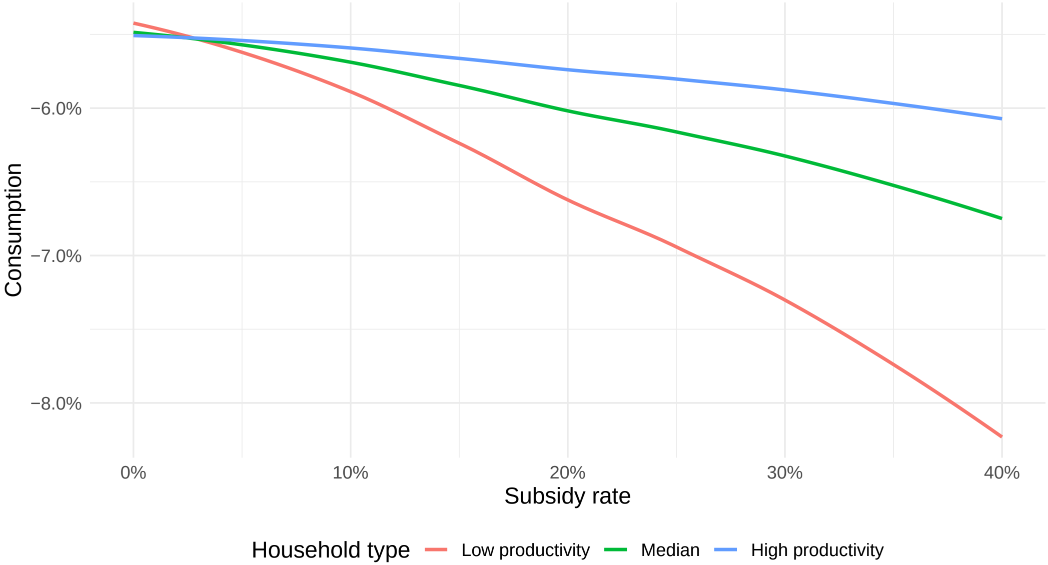
Capital and labour taxation ineffective to cut emissions

Abatement subsidy worsens welfare impacts





Directly subsidizing abatement increases negative consumption impacts



Conclusion & next steps

- Uniform lump-sum transfer only **partially** offsets carbon taxation regressivity
- **Directly subsidizing** household abatement using carbon tax receipts allows to achieve emissions cuts with **lower carbon taxes**
- But comes at **higher welfare costs**

Next steps

- Solve for the transition using the **Sequence Space Jacobian** framework (Auclert et al., 2021)
- Role of **public debt** in financing the transition
- Role of **heterogeneous abatement technologies**
- **Fiscal policy mixes** compatible with **Net Zero** emissions

Appendix

Model specification: Energy sector

- Cobb-Douglas production function: sector-specific productivity A_e, capital share α_e, capital depreciation δ_e and climate-related damages D (identical in both sectors):

$$Y_{e,t} = \bar{A}_{e,t} K_{e,t-1}^{\alpha_e} L_{e,t}^{1-\alpha_e} \quad \text{and} \quad \bar{A}_{e,t} = A_{e,t}(1 - D_t)$$

- With abatement share $\mu_{e,t}$, energy sector's emissions follow:

$$m_{e,t} = (1 - \mu_{e,t})\phi_e Y_{e,t}$$

- Faced with sector-specific carbon tax $\tau_{e,t}$, the energy firm sets capital and labor rented at prices $\tilde{w}_{s,t}$ and r_t to maximize profit:

$$\max_{\{K_{e,t}, L_{e,t}, \mu_{e,t}\}} \tilde{p}_{e,t} Y_{e,t} - \tilde{p}_{f,t}.(r_t + \delta_e) K_{e,t-1} - \tilde{p}_{f,t}.\tilde{w}_t L_{e,t} - \tilde{p}_{f,t}.\tau_{e,t} m_{e,t} - \tilde{p}_{f,t}.g_e(\phi_e \mu_{e,t} Y_{e,t})$$

- Before-tax factor prices:

$$\tilde{p}_{f,t} r_t = \alpha_e p_{e,t}(1 - D_t) A_{e,t} K_{e,t-1}^{\alpha_e - 1} L_{e,t}^{1-\alpha_e} - \tilde{p}_{f,t}\delta_e$$
$$\tilde{p}_{f,t}\tilde{w}_t = (1 - \alpha_e) p_{e,t}(1 - D_t) A_{e,t} K_{e,t-1}^{\alpha_e} L_{e,t}^{-\alpha_e}$$

Model specification: Final good sector

- Final good production:

$$Y_{f,t} = (1 - D_t) A_{f,t} K_{f,t-1}^{\alpha_f} L_{f,t}^{\alpha_l} E_{f,t}^{1-\alpha_f-\alpha_l}$$

- With abatement share $\mu_{f,t}$, final good sector's emissions (*from its own production processes*) follow:

$$m_{f,t} = (1 - \mu_{f,t}) \phi_f Y_{f,t}$$

- Before-tax factor prices:

$$\tilde{p}_{f,t} r_t = p_{f,t} \alpha_f (1 - D_t) A_{f,t} K_{f,t-1}^{\alpha_f - 1} L_{f,t}^{\alpha_l} E_{f,t}^{1-\alpha_f-\alpha_l} - \tilde{p}_{f,t} \delta_f$$

$$\tilde{p}_{f,t} \tilde{w}_t = p_{f,t} \alpha_l (1 - D_t) A_{f,t} K_{f,t-1}^{\alpha_f} L_{f,t}^{\alpha_l - 1} E_{f,t}^{1-\alpha_f-\alpha_l}$$

$$\tilde{p}_{e,t} = p_{f,t} (1 - \alpha_f - \alpha_l)(1 - D_t) A_{f,t} K_{f,t-1}^{\alpha_f} L_{f,t}^{\alpha_l} E_{f,t}^{-\alpha_f-\alpha_l}$$

Back

Model specification: Households

- Household CES consumption aggregate $C_\theta(c_f, c_e)$:

$$C_\theta(c_f, c_e) = \begin{cases} \left(\omega_{f,\theta}^{1-\alpha_\theta}\left(c_f - \bar{c}_{f,\theta}\right)^{\alpha_\theta} + \omega_{e,\theta}^{1-\alpha_\theta}\left(c_e - \bar{c}_{e,\theta}\right)^{\alpha_\theta}\right)^{\frac{1}{\alpha_\theta}} & \text{if } \alpha_\theta < 1 \text{ and } \alpha_\theta \neq 0 \\ \omega_{f,\theta} \ln\left(c_f - \bar{c}_{f,\theta}\right) + \omega_{e,\theta} \ln\left(c_e - \bar{c}_{e,\theta}\right) & \text{if } \alpha_\theta = 0 \end{cases}$$

  with **subsistence consumption levels** $\bar{c}_{s,\theta} \geq 0$.

- Households are credit-constrained

$$V_\theta(a, y) = \max_{(c_f, c_e, \mu_h, a')} u\left(C_\theta(c_f, c_e)\right) + \beta \mathbb{E}_{y'}\left[V_\theta\left(a', y'\right)\right],$$

$$\text{subject to } a' = Ra + wy + T + T^g - c_f - \left(\frac{\tilde{p}_e}{\tilde{p}_f} + \phi_h \tau_h\right) c_e - g_h(\phi_h \mu_{h,t} c_{e,t}),$$

$$a' \geq 0,$$

$$c_f, c_e > 0$$

Back

Model specification: Market clearing

- Aggregate capital and labor depend on **Λ, the stationary distribution over the state space "assets × income"**.

$$K' + B' = K'_e + K'_f + B' = \int a'(a,y)\Lambda(da,dy)$$

- Market clearing for energy:

$$Y_e = E + \int c_e(a,y)\Lambda(da,dy),$$

- Market clearing for the final good:

$$G + K' + \int c_f(a,y)\Lambda(da,dy) + \int g_h(\mu_h, c_e(a,y)\Lambda(da,dy)) + g_e(\mu_e, Y_{e,t}) + g_f(\mu_f, Y_{f,t}) = (1-\delta)K + Y_f$$

◂ Back

Model specification: Government

Government: Taxes on emissions and labor as well as a lump-sum transfer. Government can further invest directly in households' abatement.

- Sector-specific carbon tax $\tau_{s,t}$. Post-tax prices:

$$p_{s,t} = \tilde{p}_{s,t}\left(1 - \tau_{s,t}\phi_s\right)$$

- Because of labor mobility, unique pre-tax wage w_t. Government taxes labor at rate τ_l:

$$w_t = (1 - \tau_{l,t})\tilde{w}_t$$

- Government budget constraint:

$$\frac{\Pi_e}{\tilde{p}_f} + \frac{\Pi_f}{\tilde{p}_f} + \tau_h \int m_h(a,y)\Lambda(da,dy) + \tau_e m_e + \tau_f m_f + \tau_L w\bar{L} + \tau_K r_t K + B'$$
$$= (1+r)\,B' + G + T + \tau^s \int g_h(\phi_h \mu_h, c_e(a,y))\Lambda(da,dy)$$

Lump-sum transfer T financed out of labor and carbon tax government incomes.

Back

Model specification: Emissions and abatement

- CO_2 atmospheric emissions generated as an externality by both sectors and households' direct consumption of energy.
- Each agent face their own abatement cost function g_s.
- When a carbon tax τ_s is in place in each sector, this yields:

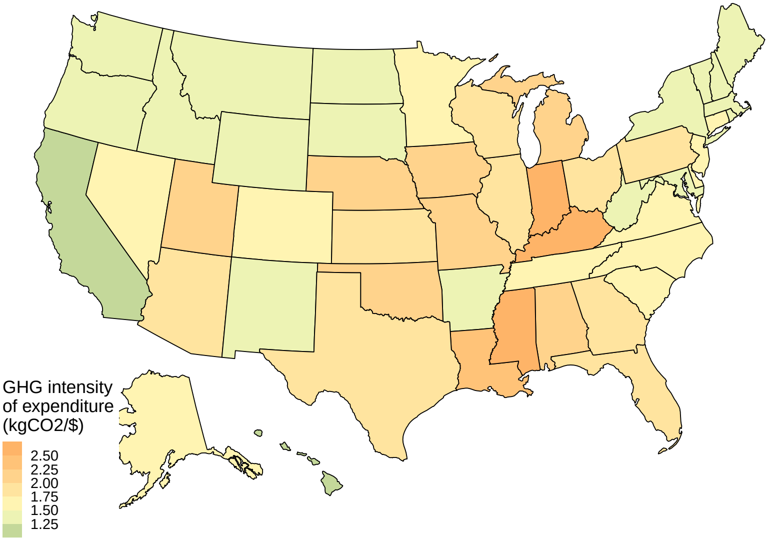
$$g_e'(\phi_e \mu_{e,t} Y_{e,t}) = \tau_{e,t}$$
$$g_f'(\phi_f \mu_{f,t} Y_{f,t}) = \tau_{f,t}$$

- Households' abatement rate is decided by the government (for now), and is subsidised at rate τ_s. Their abatement cost is thus:

$$(1 - \tau^s)\, \tilde{p}_f g_h(\mu_h c_e)$$

Back

Households' energy-related carbon footprint by state (US, 2019)



Parametrization: Households

Parameter	Description	Value
r	Interest rate	0.028
w	Wage	0.37
σ	Utility Function Curvature	2.0
$\bar{c}$	Brown Minimal Consumption	0.02
ρ	Income Shock Persistence	0.96
ϵ	Income Shock Std. Dev.	0.1
$\omega_{G,\theta}$	Green Consumption Utility Weight	0.97
$\omega_{B,\theta}$	Brown Consumption Utility Weight	0.03
α_{θ}	CES Substitution Parameter	-0.04
p_G	Post-tax Price of Green Good	1.0
p_B	Post-tax Price of Brown Good	1.0
τ_G^c	Tax on Green Consumption	0.0
τ_B^c	Tax on Brown Consumption	0.0
T	Government Transfer	0.0

Back

Parametrization: Firms and Climate

	Production	
α_G	Capital Share Green	0.3
α_B	Capital Share Brown	0.3
δ	Captial Depreciation	0.1
α_K	Elast. Subst. Capital	-0.4
	Climate Module	
γ_S	Damage Function Parameter	$5.3e{-5}$
$\bar{S}$	Pre-industrial CO2 stock	0.0
S_0	Current CO2 Stock	$8.45e11$
δ_m	Emissions Decay Parameter	0.0006
m	Emissions Intensity	1.63863

Back

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