Fiscal Policy for Climate Change

François Le Grand, Florian Oswald, Xavier Ragot and Aurélien Saussay

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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)).

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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.

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. Explicitly account for both initial inequality and inequality along the transition.

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 respresentative agent frameworks.
- Bosetti and Maffezzoli (2013), Fried (2021), 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

Outline of Paper

- We focus on a single country (USA) for now.
- We categorize final good consumption into **green** and **brown** according to pollution intensity, produced in different sectors.
- Production of **brown** increases the stock of CO_2, increasing temperatures, increasing climate related damages, which destroys output and hence reduces living standards.
- We study taxation on both production and consumption of final goods.

Data

Data: How to define the Green and Brown goods?

- Based on their **Green House Gase (GHG) intensity**: the amount of emissions necessary to the production of one dollar of output
- We rank products by the **direct GHG intensity** of their production process
  - We only consider **domestic** U.S. emissions
- The top *n* products accounting for **90% of U.S. GHG emissions** form the **brown** product
- **All other products**, accounting for the remaining 10%, form the **green** product

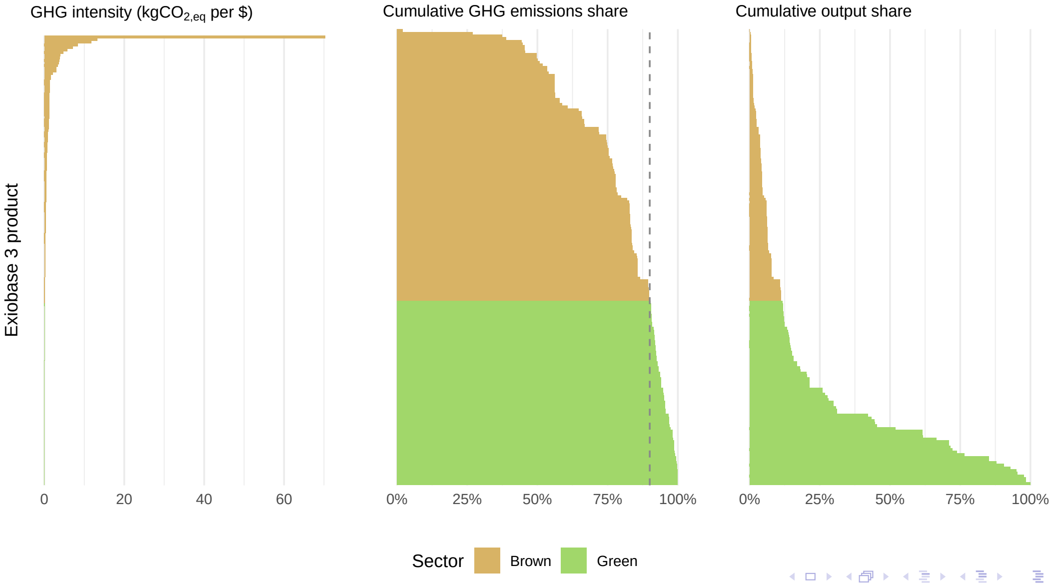
Data: Exiobase 3

- To calibrate the **green** and **brown** sectors, we need data at **high sectoral resolution** on:
  - GHG intensity of the production process
  - Capital & labor intensity
  - Wage level
- We obtain data from a large Multi-Regional Input-Output (MRIO) database, **Exiobase**
- Exiobase v3 provides hybrid economy-energy-emissions accounts for 43 major economies, across **200 products**
  - Given its emphasis on environmental impacts, Exiobase's product disaggregation is focused on energy-intensive industries (e.g. energy, chemicals etc.)
  - Exiobase is increasingly used in economic assessments of climate-related themes (see e.g. Shapiro (2021))

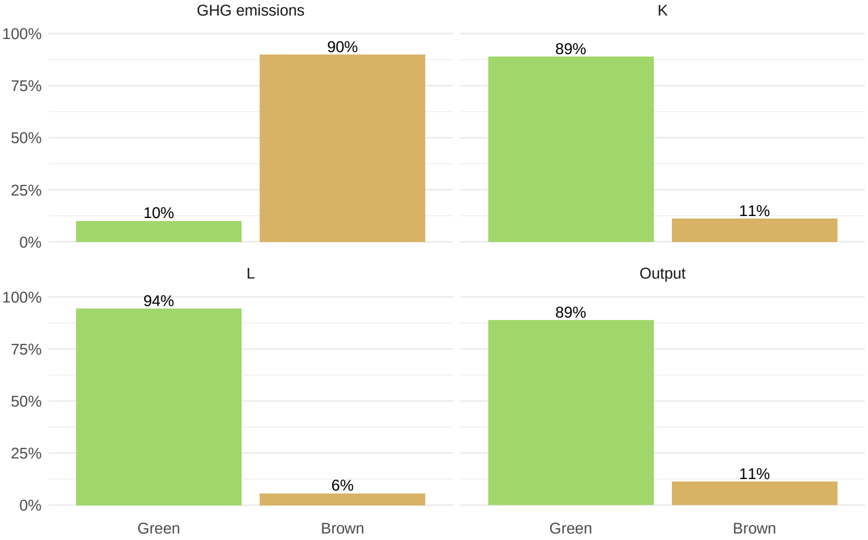
Data: Ranking products by carbon intensity

- We obtain US data for the year **2019**, from the **by-product** symmetric IO version of the dataset
- The **most carbon-intensive** products include:
  - Industrial Steam and Heat (70 $kgCO_{2,eq}$ per \$ of output)
  - Electricity from coal (13 $kgCO_{2,eq}/\$$)
  - Paddy rice (4.8 $kgCO_{2,eq}/\$$)
  - Cattle (3.8 $kgCO_{2,eq}/\$$)
  - Cement (1.4 $kgCO_{2,eq}/\$$)
- The **least carbon-intensive** products include:
  - R&D services (8.3 $gCO_{2,eq}/\$$)
  - Wholesale trade (7.2 $gCO_{2,eq}/\$$)
  - Financial services (7.2 $gCO_{2,eq}/\$$)
  - Retail trade (1 $gCO_{2,eq}/\$$)

Data: Definition of the **Green** and **Brown** Products



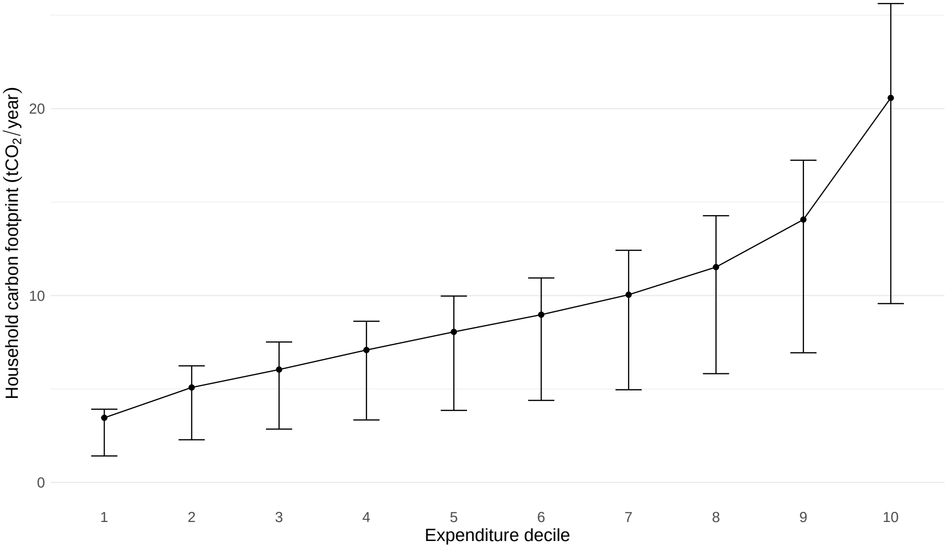
Data: Calibration of the **Green** and **Brown** Sectors



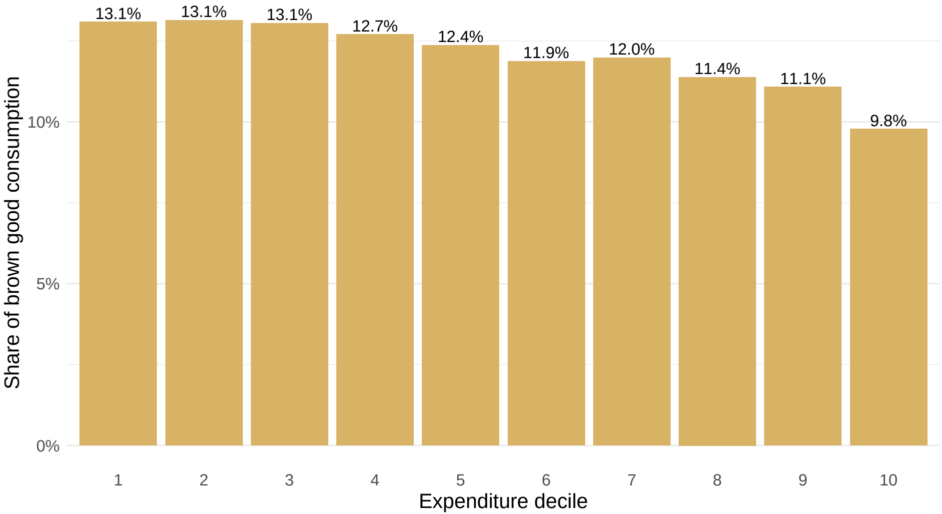
Households' consumption of green and brown goods

- 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 **correspondence** between Exiobase 200 products classification and the CEX UCC
  - When a single UCC corresponds to several Exiobase products, we use the output-weighted average carbon intensity of the corresponding Exiobase products
  - Example: electricity is a single expenditure in the CEX, while Exiobase distinguishes the carbon intensity of each production technology
- The CEX socio-economic variables allow us to stratify green and brown consumption **by expenditure deciles**

While Carbon Footprint increases with total expenditure...



… the **brown** Spending Share Decreases!



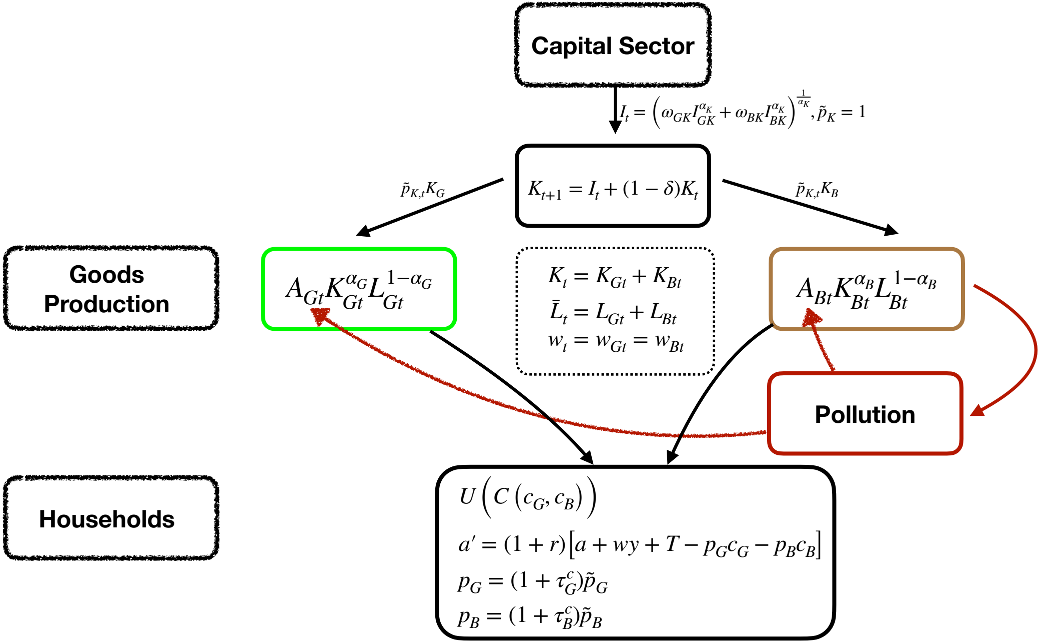
Model

Model in a nutshell

Standard production heterogeneous-agent model with idiosyncratic productivity risk.

Model specificities:

- Two final consumption goods: **brown** and **green**.
- The **brown** good production generates CO_2 emissions, whose accumulation hurts productivity.
- A benevolent government has a rich set of fiscal tools (taxes on consumption goods, labor, capital + lump-sum tax) to influence CO_2 emissions.
- Rich equity-efficiency tradeoff: emissions vs capital level vs inequality.


Capital Sector
$I_t = \left(\omega_{GK} I_{GK}^{\alpha_K} + \omega_{BK} I_{BK}^{\alpha_K}\right)^{\frac{1}{\alpha_K}}, \tilde{p}_K = 1$
$K_{t+1} = I_t + (1-\delta)K_t$
$\tilde{p}_{K,t} K_G$
$\tilde{p}_{K,t} K_B$
Goods Production
$A_{Gt} K_{Gt}^{\alpha_G} L_{Gt}^{1-\alpha_G}$
$K_t = K_{Gt} + K_{Bt}$
$\bar{L}_t = L_{Gt} + L_{Bt}$
$w_t = w_{Gt} = w_{Bt}$
$A_{Bt} K_{Bt}^{\alpha_B} L_{Bt}^{1-\alpha_B}$
Pollution
Households
$U\left(C\left(c_G, c_B\right)\right)$
$a' = (1+r)\left[a + wy + T - p_G c_G - p_B c_B\right]$
$p_G = (1+\tau_G^c)\tilde{p}_G$
$p_B = (1+\tau_B^c)\tilde{p}_B$

Model specification highlights

- Household CES consumption aggregate $C_\theta(c_G, c_B)$:

$$C_\theta(c_G, c_B) = \left(\omega_\theta \left(c_G - \bar{c}_{G,\theta}\right)^{\alpha_\theta} + (1-\omega_\theta)\left(c_B - \bar{c}_{B,\theta}\right)^{\alpha_\theta}\right)^{\frac{1}{\alpha_\theta}},$$

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

- Households are credit-constrained

$$V^\theta(a,y) = \max_{(c_G, c_B, a')} U_\theta(c_G, c_B) + \beta \mathbb{E}_{y'}\left[V^\theta\left(a', y'\right)\right],$$

$$\begin{aligned} \text{subject to } a' &= (1+r)a + wy + T - p_G c_G - p_B c_B, \\ \boldsymbol{a'} &\boldsymbol{\geq 0}, \\ c_s &> \bar{c}_{s,\theta}. \end{aligned}$$

- Aggregate capital and labor depend on $\boldsymbol{\Lambda}$, **the stationary distribution over the state space "assets** $\times$ **income"**.

$$K = K_B + K_G = \int a'(a,y)\Lambda(da, dy), \quad L = L_B + L_G = \int y\Lambda(da, dy)$$

Model: Production sector (1/3)

2 goods (brown & green) produced in 2 sectors by different representative firm out of capital and labor.

Capital sector:

- perfectly fungible capital (no difference between green or brown investments);
- a unique firm aggregates sector-specific investments $I_{G,t}$ and $I_{B,t}$ with a CES "capital" production function into aggregate investment I_t as:

$$I_t := \left(\omega_{G,K} I_{G,t}^{\alpha_K} + \omega_{B,K} I_{B,t}^{\alpha_K}\right)^{\frac{1}{\alpha_K}} ;$$

Model in details: Production sector (2/3)

Production functions.

- In each sector: Cobb-Douglas production function. Capital and labor fully mobile between sectors.
- Sector-specific productivity A_s, capital share α_s and capital depreciation δ_s.
- Sector-s firm's objective = sets capital and labor rented at prices $\tilde{w}_{s,t}$ and r_t to maximize profit:

$$\max_{(K_{s,t},L_{s,t})_{t\geq 0}} \tilde{p}_{s,t}A_{s,t}K_{s,t-1}^{\alpha_s}L_{s,t}^{1-\alpha_s} - \delta_s K_{s,t-1} - \tilde{w}_{s,t}L_{s,t} - \tilde{r}_t K_{s,t-1}$$

- Before-tax factor prices:

$$\tilde{r}_t = \alpha_s \tilde{p}_{s,t}A_{s,t}K_{s,t-1}^{\alpha_s-1}L_{s,t}^{1-\alpha_s} - \delta \text{ and } \tilde{w}_{s,t} = (1-\alpha_s)\tilde{p}_{s,t}A_{s,t}K_{s,t-1}^{\alpha_s}L_{s,t}^{-\alpha_s}.$$

Back

Model: Production sector (3/3)

Pollution.

- CO_2 atmospheric emissions generated as an externality by the brown sector only.
- Emission intensity is m and CO_2 stock depletes at natural rate d_m.
- Atmospheric CO_2 stock S_t dynamics:

$$S_t = mY_{B,t-1} + S_{t-1}(1 - d_m).$$

- CO_2 stock damages sector productivity:

$$A_{s,t} := A_{0,s}A_t(1 - D_s(S_t)),$$

  where A_t is the common productivity growth, $A_{0,s}$ a sector scaling factor.
- D_s: damage function à la Golosov et al. (2014):

$$D_s(S_t) := 1 - e^{-\gamma_s(S_t - \overline{S})},$$

  where $\gamma_s > 0$ is sector scaling parameter and $\overline{S} > 0$ is pre-industrial CO_2 concentration.

Back

Model: Government

Government. No public spending. Taxes on consumption, labor, capital, as well as a lump-sum transfer.

- Sector-specific consumption tax $\tau^c_{s,t}$. Post-tax prices: $p_{s,t} = (1 + \tau^c_{s,t})\tilde{p}_{s,t}$.
- Sector-specific labor tax $\tau^w_{s,t}$. Because of labor mobility, unique post-tax wage w_t:

$$w_t = (1 - \tau^w_{B,t})\tilde{w}_{B,t} = (1 - \tau^w_{G,t})\tilde{w}_{G,t}.$$

- Capital tax τ^K_t and post-tax rate: $r_t = (1 - \tau^K_t)\tilde{r}_t$.
- Government budget constraint:

$$\begin{aligned} T_t \leq \tau^K_t \tilde{r}_t (K_{B,t-1} + K_{G,t-1}) + (\tau^w_{B,t} L_{B,t} + \tau^w_{G,t} L_{G,t})\tilde{w}_t \\ + \tilde{p}_{G,t}\tau^c_{G,t} C_{G,t} + \tilde{p}_{B,t}\tau^c_{B,t} C_{B,t}. \end{aligned}$$

Lump-sum transfer financed out of capital, labor and consumption tax government incomes.

Model: Households (1/4)

Unit mass of households facing productivity risk y. Each household supplies inelastically one unit of labor.

- Ex-ante heterogeneity of households. Type θ affecting preferences.
- Time-additive utility function with discount factor $\beta \in (0, 1)$. Period utility function depending on brown and green goods consumption:

$$U_\theta(c_G, c_B) = \begin{cases} \frac{C_\theta(c_G, c_B)^{1-\sigma} - 1}{1-\sigma} & \text{if } \sigma \neq 1, \\ \log(C_\theta(c_G, c_B)) & \text{otherwise.} \end{cases}$$

with:

- $1/\sigma$ intertemporal elasticity of substitution,
- $C_\theta(c_G, c_B)$ consumption aggregate.

Back

Model in details: Households (2/4)

CES consumption aggregate $C_\theta(c_G, c_B)$:

$$C_\theta(c_G, c_B) = \left(\omega_\theta \left(c_G - \bar{c}_{G,\theta}\right)^{\alpha_\theta} + \left(1 - \omega_\theta\right)\left(c_B - \bar{c}_{B,\theta}\right)^{\alpha_\theta}\right)^{\frac{1}{\alpha_\theta}},$$

with:

- share parameter $\omega_\theta \in [0, 1]$,
- elasticity of substitution $(1 - \alpha_\theta)^{-1}$ $(\alpha_\theta \in [0, 1))$,
- subsistence consumption levels $\bar{c}_{s,\theta} \geq 0$.

Back

Model in details: Households (3/4)

Households' program in recursive form:

$$
\begin{aligned}
V^{\theta}(a,y) = \max_{(c_G, c_B, a')} \; & U_{\theta}(c_G, c_B) + \beta \mathbb{E}_{y'} \left[V^{\theta}\left(a', y'\right) \right], \\
\text{subject to } a' &= (1+r)a + wy + T - p_G c_G - p_B c_B, \\
a' &\geq 0, \\
c_s &> \bar{c}_{s,\theta}.
\end{aligned}
$$

with:

- $V^{\theta}(a,y)$ value function of type θ, beginning-of-period wealth a, and income y;
- $\mathbb{E}_{y'}$ expectation over future income realizations;
- household budget constraint featuring post-tax prices;
- credit-constraint and feasibility constraint.

Back

Model in details: Households (4/4)

Households' FOCs (assuming that green good consumption is never constrained):

- Euler equation:

$$(c_G - \bar{c}_{G,\theta})^{-\sigma} = \beta \mathbb{E}\left[(1+r')(c'_G - \bar{c}_{G,\theta})^{-\sigma}\right], \text{ for unconstrained household,}$$
$$a' = 0, \text{ for constrained household.}$$

- Consumption tradeoff:

$$c_B - \bar{c}_{B,\theta} = \left(\frac{p_B \omega_{G,\theta}}{p_G \omega_{B,\theta}}\right)^{\frac{1}{\alpha_\theta - 1}} (c_G - \bar{c}_{G,\theta}), \text{ for unconstrained brown good consumption,}$$
$$c_B = \bar{c}_{B,\theta} \text{ otherwise.}$$

Back

Parameterization: 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

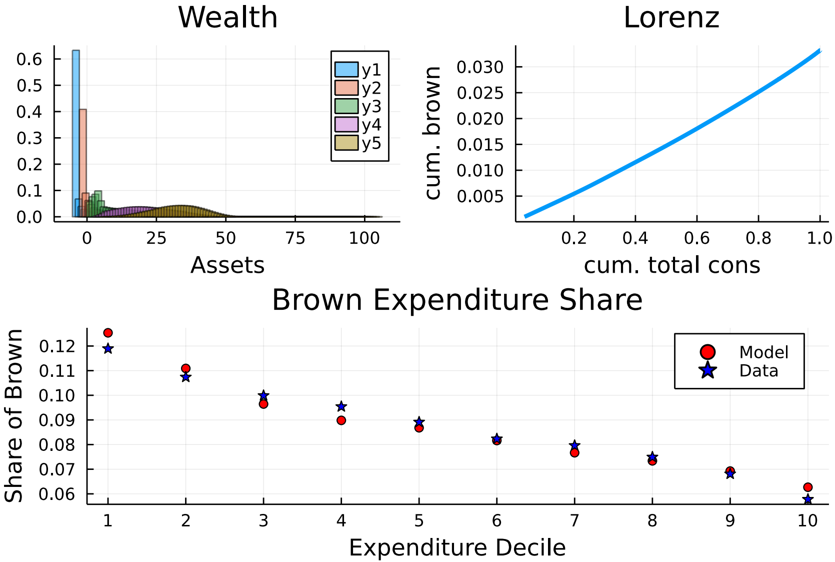
Parameterization: Firms and Climate

	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

Calibration

- We target spending share in **brown** good by decile of the US expenditure distribution.
- We are planning to add estimates about demand elasticity for **brown** goods (e.g. from gasoline demand literature).
- 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.

Model Fit



Wealth
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
Assets
y1
y2
y3
y4
y5
Lorenz
cum. brown
0.030
0.025
0.020
0.015
0.010
0.005
0.2
0.4
0.6
0.8
1.0
cum. total cons
Brown Expenditure Share
Share of Brown
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1
2
3
4
5
6
7
8
9
10
Expenditure Decile
Model
Data

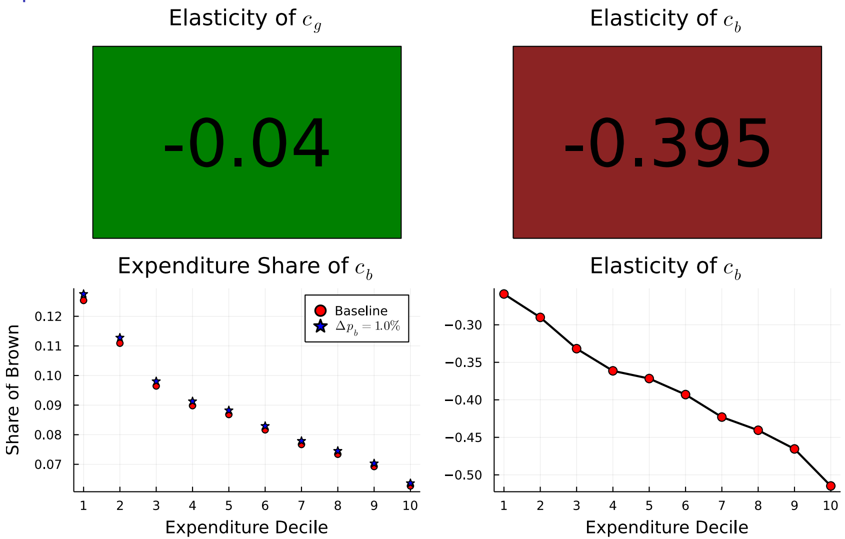
Partial Equilibrium Experiments

Increase p_b by 1 percent

Elasticity of c_g	Elasticity of c_b
-0.04	-0.395

Partial Equilibrium Experiments

Increase p_b by 1 percent



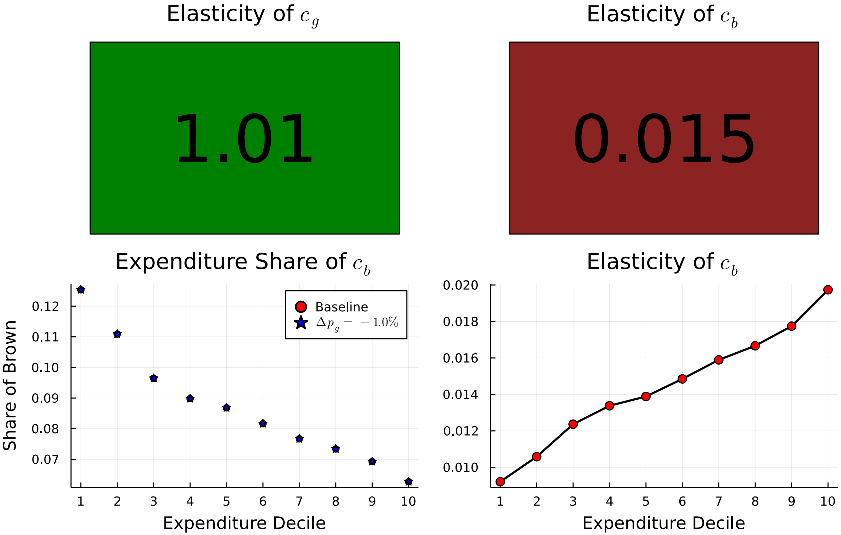
Partial Equilibrium Experiments

Decrease p_g by 1 percent

Elasticity of c_g	Elasticity of c_b
1.01	0.015

Partial Equilibrium Experiments

Decrease p_g by 1 percent



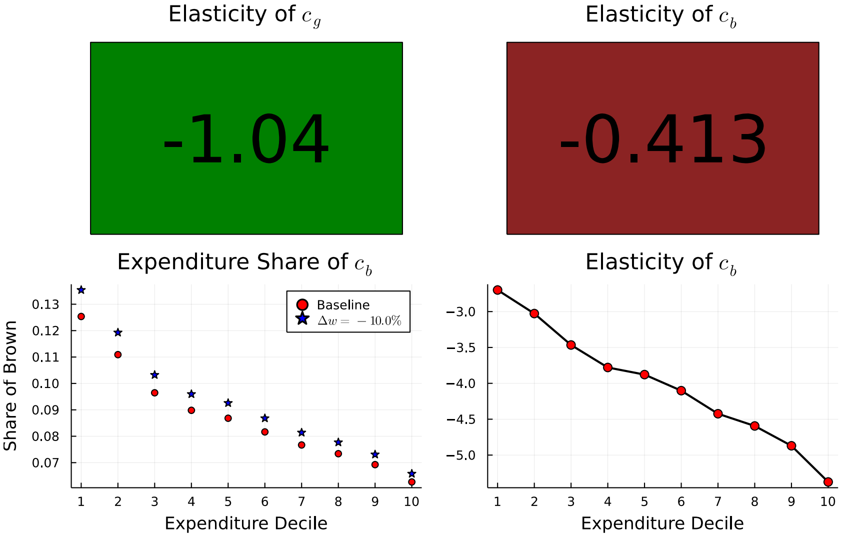
Partial Equilibrium Experiments

Decrease wage w by 10 percent

Elasticity of c_g	Elasticity of c_b
-1.04	-0.413

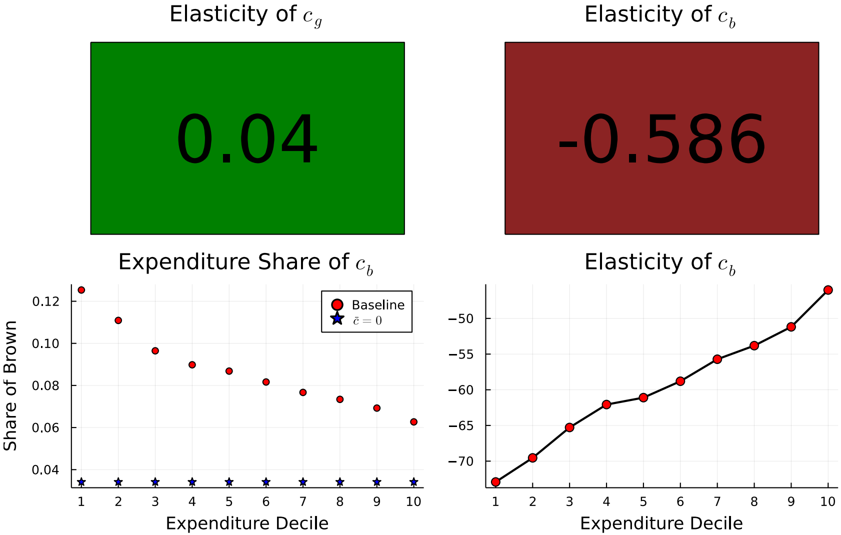
Partial Equilibrium Experiments

Decrease wage w by 10 percent



Partial Equilibrium Experiments

Importance of $\bar{c}$: Cannot fit decreasing spending shares without it!



Focus: Fiscal Policy Compatible with Net Neutral by 2050

Towards the next version...

- We want $mY_{B,2050} = S_{2050}(1 - d_m)$.
- At least 2 complementary strategies:
  1. Reduce **Brown** Production (and Consumption) $Y_{B,2050}$ via aggressive taxation (τ_c^b). Or:
  2. Improve technology s.t. brown production becomes **greener** : Abatement!

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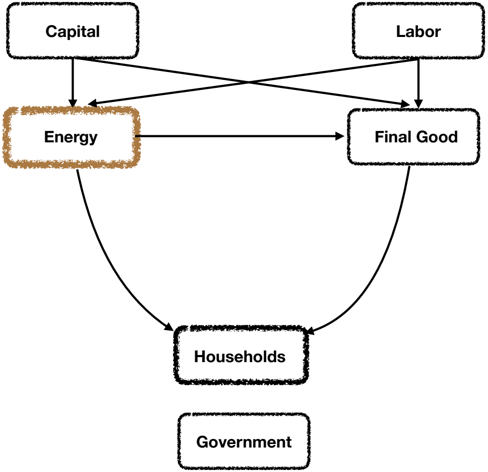
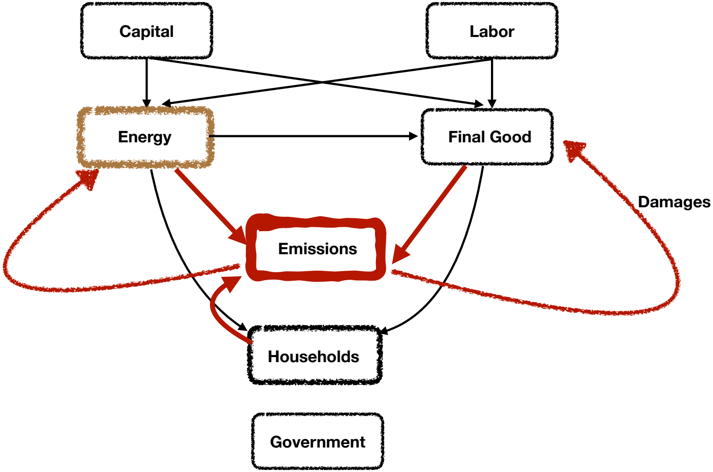
  2. Improve technology s.t. brown production becomes **greener** : Abatement!

  $\rightarrow$ Or of course: both.
- Emphasize role of government in greening brown via $m_t(G_t, S_t)$. Costly investment technology.
- Want: Pareto Efficiency Frontier plotting welfare in (τ_c^b, G)-space.

Next Version



Next Version



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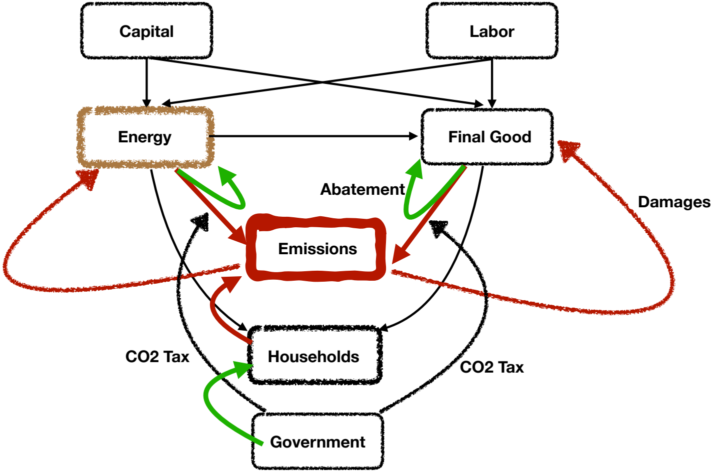

~~Conclusion~~ Preview of New Version

- Most of the literature has focused so far on compensating the regressivity of carbon pricing through direct transfers
- Yet policymakers also contemplate investing in the energy transition directly: how to model this?
- 2-Sector Model: Energy and Final Good

Household Budget Constraint

$$\text{OLD: } a' = (1+r)a + wy + T - p_G c_G - p_B c_B \tag{1}$$

$$\text{NEW: } a' = (1+r)a + wy + T - \tilde{p}_f c_f - (\tilde{p}_e + (1-\mu_h)\varphi_h \tau_h) c_e, \tag{2}$$

~~Conclusion~~ Preview of New Version

- Damages impact output in both sectors
- Households: consume bundle of final and energy good, with some required energy. HH-specific abatement cost curve.
- Government provides direct transfer **and** invests in HH abatement technology.
- Policy Tools: Emissions tax, direct transfers, **investment in HH abatement**.

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