Optimal Climate Policy with Incomplete Markets

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Motivation

- Governments use fiscal policy to pursue multiple goals:
  - ➢ redistribution;
  - ➢ insurance;
  - ➢ climate change mitigation.

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  - ➢ redistribution;
  - ➢ insurance;
  - ➢ climate change mitigation.

- Two questions:
  1. How should climate policy be designed in this context?
  2. What is the effect of climate policy on the economy?

What we do

- Theoretically, study optimal climate policy in a two-period model with inequality, risk, and borrowing constraints ($\rightarrow$ RE breaks down).
- Develop a fiscal climate-economy model in the spirit of Barrage (2020), featuring inequality and idiosyncratic risk à la Aiyagari (1994).
- Calibrate the model to accurately reflect macroeconomic variables, inequality, and idiosyncratic risk based on the U.S. economy.
- Solve a Ramsey problem in this economy to study
  1. the optimal climate policy, and
  2. its impacts on aggregates, inequality, risk, and welfare.

What we find

- Theoretically:
  - ➢ inequality, risk, and borrowing constraints affect both benefits and (opportunity) costs of climate policy.

- Quantitatively:
  - ➢ the optimal carbon tax grows faster than GDP;
  - ➢ the use of its revenue critically affects the optimal carbon tax path;
  - ➢ the ability to use debt is critical for all aspects of the economy, but has only modest implications for optimal climate policy.

Related literature

We contribute to three strands of literature:

- Optimal climate policy with distortionary taxation (e.g., Bovenberg and de Mooij, 1994; Jacobs and de Mooij, 2015; Barrage, 2020; Douenne et al, 2023).
  - ➢ **Novelty**: introduce incomplete markets.
- Distributional effects of climate policy (e.g., Känzig, 2023; Fried et al, 2018 and 2023; Benmir and Roman, 2022, Kuhn and Schlattmann, 2024).
  - ➢ **Novelty**: study optimal policy, analyze the transition, and account for welfare benefits of mitigation.
- Optimal fiscal policy with incomplete markets (e.g., Conesa et al, 2009; Dyrda and Pedroni, 2023).
  - ➢ **Novelty**: introduce climate change and study climate policy.

Model: Households

- Continuum of households of size N_t, with preferences over consumption, labor, and temperature: $\mathbb{E}_0\left[\sum_t \beta^t u(c_t, h_t, Z_t)\right]$.

- Individuals characterized by assets $a \in A$ and stochastic productivity $e \in E$ that follows a Markov process with matrix Γ.

- Given a sequence of prices and taxes, the household solves

$$v_t(a, e) = \max_{c_t, h_t, a_{t+1}} u\big(c_t(a, e), h_t(a, e), Z_t\big) + \beta \sum_{e_{t+1} \in E} v_{t+1}\big(a_{t+1}(a, e), e_{t+1}\big)\Gamma_{e, e_t+1},$$

subject to

$$c_t(a, e) + a_{t+1}(a, e) = (1 - \tau_t^h) w_t e h_t(a, e) \quad + (1 + (1 - \tau_t^k) r_t) a_t + T_t,$$
$$a_{t+1}(a, e) \geq \underline{a}.$$

Model: Firms

- Final good sector

$$Y_{1,t} = (1 - D(Z_t))A_{1,t}F(K_{1,t}, H_{1,t}, E_t).$$

- Energy sector

$$E_t = A_{2,t}G\left(K_{2,t}, H_{2,t}\right)$$

- Energy production generates emissions $E_t^M = (1 - \mu_t)E_t$, with μ_t fraction of pollution abated at total costs $\Theta_t(\mu_t, E_t)$.

- With τ^e denoting carbon taxes, profits are

$$\mathcal{P}_t = p_{E,t}E_t - w_t H_{2,t} - (r_t + \delta)K_{2,t} - \tau_t^e E_t^M - \Theta_t\left(\mu_t, E_t\right)$$

Model: Government and Climate

- The government's budget constraint is

$$G_t + T_t + r_t B_t = \tau_t^h w_t H_t + \tau_t^k r_t (K_t + B_t) + \tau_t^e E_t^M + (B_{t+1} - B_t).$$

- The climate model builds on Dietz and Venmans (2019):

$$Z_{t+1} = Z_t + \epsilon\big(\zeta \mathcal{E}_t - Z_t\big),$$

with

$$\mathcal{E}_{t+1} = \mathcal{E}_t + E_t^M + E_t^{\text{ex}}.$$

Competitive equilibrium and Ramsey problem

- The **competitive equilibrium** is defined as usual: households and firms maximize given prices and policies, laws of motion are consistent, and markets clear.

- **Ramsey problem**: choose time path of policies $\pi \equiv \{\tau_t^h, \tau_t^k, \tau_t^e, T_t\}_{t=0}^{\infty}$ to maximize the (utilitarian) social welfare function

$$\mathcal{W}(\pi) = \int_S \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \tilde{\beta}^t u\big(c_t(a_0, e_0|\pi), h_t(a_0, e_0|\pi), Z_t(\pi)\big) \right] d\lambda_0.$$

Computational method

- If optimal paths are smooth over time, we can approximate them with polynomials, as in Dyrda and Pedroni (2023). ▸ Details
- Polynomial parameters → path of fiscal instruments → transition to new balanced-growth path → welfare.
- Optimize welfare by choosing polynomial parameters.
- This approach bypasses the need to rewrite the Ramsey problem recursively (optimal policy typically not time-consistent).

Calibration strategy

- Households: following Dyrda and Pedroni (2023), we target three sets of statistics:
  i) macroeconomic variables; ▸ See details
  ii) inequality statistics; ▸ See details
  iii) measures of idiosyncratic risk. ▸ See details

- Firms: as in Douenne et al (2023), updated based on Friedlingstein et al. (2022) and Barrage and Nordhaus (2023).

- Government: extend procedure of Trabandt and Uhlig (2011) up to 2019.

- Climate: calibrated based on IPCC (2021), remaining parameters from Friedlingstein et al. (2022) and Barrage and Nordhaus (2023).

Policy experiments

- We study several policy experiments, where – for now – capital and labor taxes are kept fixed at their current level.

- We consider 2×2 scenarios where we optimize over carbon taxes, depending on whether or not
  1. debt-to-output is kept fixed,
  2. carbon tax revenue is absorbed by higher government spending.

- Goal is to study the importance of (1) ability to use government debt, (2) use of carbon tax revenue for *optimal carbon pricing*.

Results: Optimal carbon tax

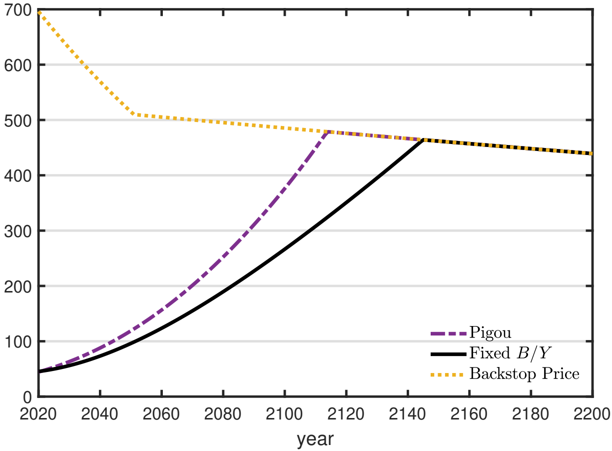
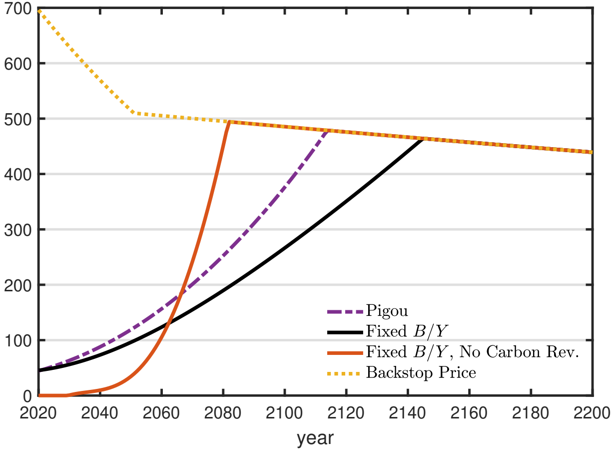


Figure: Optimal Carbon Taxes and Backstop Price (in \$/tCO_2).

▸ Temperature path

Results: Optimal carbon tax



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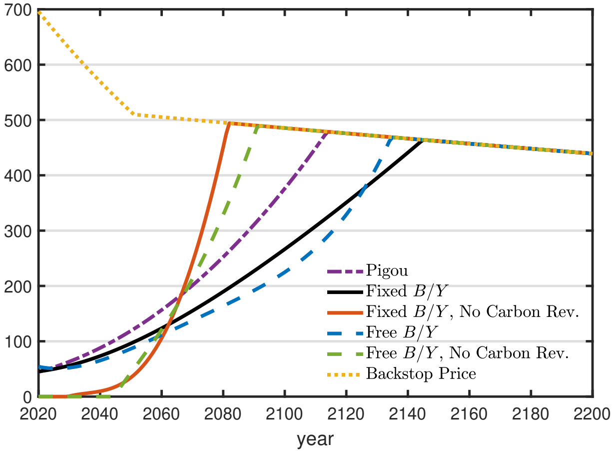

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Optimal lump-sum transfers

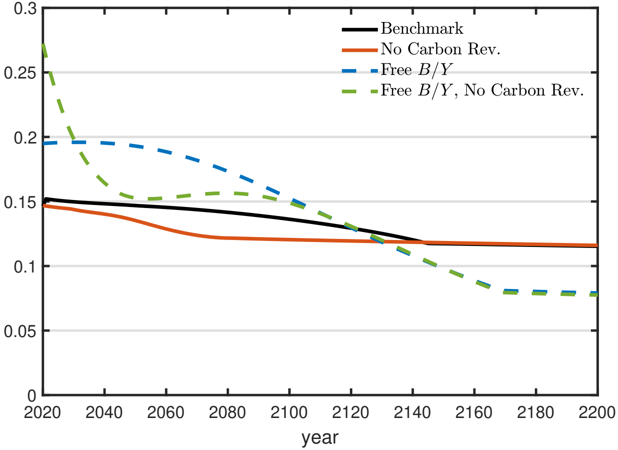

Figure: Lump-sum Transfers to GDP Ratio.

▸ See capital path

▸ See labor path

Final remarks

Main takeaways:

- Optimal climate policy is substantially affected by what carbon tax revenues are used for, but not by the government's ability to use debt.

Next steps:

- Optimize over income taxes to reduce third-best considerations.
- Introduce heterogeneity in energy budget shares as in Fried et al, 2018, 2023; Douenne et al (2023).
- Compute the distribution of welfare gains.
- Other policy scenarios, alternative welfare functions?

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Thank you!

Computational Method — Details

- Solving this problem involves searching on the space of sequences $\{\tau^k_t, \tau^h_t, \tau^e_t, T_t\}_{t=0}^{\infty}$.
- To reduce the dimensionality of the problem, we follow Dyrda and Pedroni (2023) and parameterize the time paths of fiscal instruments:

$$x_t = \left(\sum_{i=0}^{m_{x0}} \alpha_i^x P_i(t)\right) \exp\left(-\lambda^x t\right) + \left(1 - \exp\left(-\lambda^x t\right)\right) \left(\sum_{j=0}^{m_{xF}} \beta_j^x P_j(t)\right), \quad (1)$$

where

- ➢ x_t can be any of the fiscal instruments $\{\tau^h_t, \tau^k_t, \tau^i_t, \tau^e_t, T_t\}$;
- ➢ $\{P_i(t)\}_{i=0}^{m_{x0}}$ and $\left\{P_j(t)\right\}_{j=0}^{m_{xF}}$ are families of Chebyshev polynomials;
- ➢ $\{\alpha_i^x\}_{i=0}^{m_{x0}}$ and $\left\{\beta_j^x\right\}_{j=0}^{m_{xF}}$ are weights on the consecutive elements of the family;
- ➢ λ^x controls the convergence rate of the fiscal instruments.

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Calibration: macroeconomic variables

Macroeconomic aggregates		
	Target	**Model**
Intertemporal elasticity of substitution	0.66	0.66
Capital to output	2.57	2.54
Average Frisch elasticity (Ψ)	1.0	1.0
Average hours worked	0.24	0.25
Transfer to output (%)	14.7	14.7
Debt to output (%)	104.5	104.5
Fraction of hhs with negative net worth (%)	10.8	11.5
Correlation between earnings and wealth	0.51	0.43

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Calibration: inequality

Cross-sectional distributions								
	Bottom (%)	**Quintiles**					**Top (%)**	**Gini**
	0–5	**1st**	**2nd**	**3rd**	**4th**	**5th**	**95–100**	
				Wealth				
Data	−0.5	−0.5	0.8	3.4	8.9	87.4	65.0	0.85
Model	−0.2	0.1	1.7	3.6	6.7	88.1	70.0	0.85
				Earnings				
Data	−0.1	−0.1	3.5	10.8	20.6	65.2	35.3	0.65
Model	0.0	0.1	3.6	12.0	17.7	66.6	37.5	0.65
				Hours				
Data	0.0	2.7	13.8	19.2	27.9	36.4	11.1	0.34
Model	0.0	0.4	11.4	26.1	28.3	33.9	8.9	0.35

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Calibration: risk

Statistical properties of labor income

	Target	**Model**
Variance of 1-year growth rate	2.33	2.32
Kelly skewness of 1-year growth rate	−0.12	−0.13
Moors kurtosis of 1-year growth rate	2.65	2.65

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Optimal temperatures

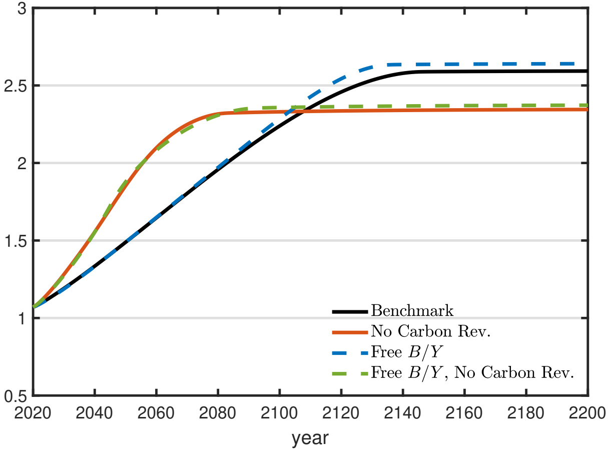

Figure: Temperature Change.

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Capital path

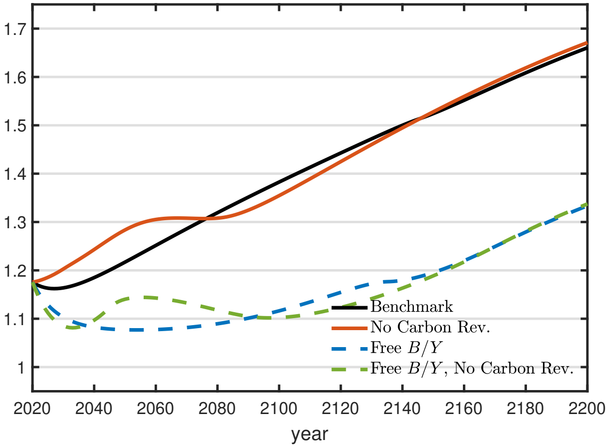

Figure: Capital Path.

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Labor path

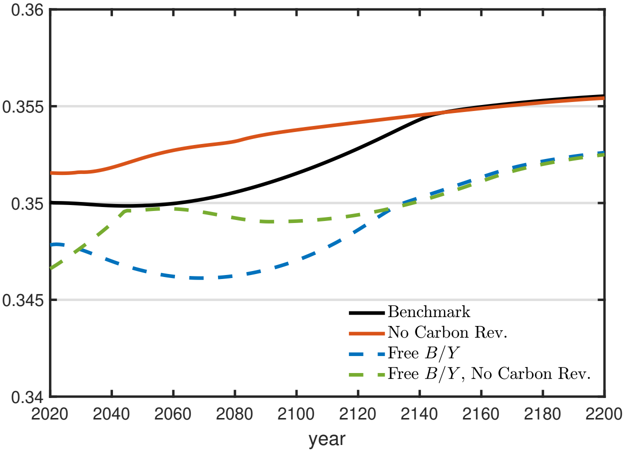

Figure: Labor Path.

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