The Composition Effect of the Socially Optimal Green Transition

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Introduction

Prior lit derives carbon tax sequence that implements optimal green transition, in rep-firm economies

- Ex.: Nordhaus (2008), Golosov, Hassler, Krussell, & Tsyvinski (2014), Krusell & Smith (2022)

Firms vary: carbon dependence, TFP. Firm exits endogenous, composition effect in Planner allocation

- Utilized production technology change at extensive margin, in addition to intensive margin

This Paper: Quantify effect of het on optimal carbon tax sequence, and consequences of ignoring het

Theory: Tractible het-firm model, characterize Planner allocation & implement w/ carbon tax sequence

Quantify: Match empirical emission intensity distribution, solve for optimal transition & tax scheme

- Compare tax sequence after shutting down carbon dependence heterogeneity
- Compute welfare consequences of implementing no-het tax scheme in with-het world

Findings: Optimal tax path is much higher without heterogeneity ($\sim$ 150% of with-heterogeneity)

- Implementing no-het taxes in w/-het economy results in $\sim$90% of welfare gain relative to first-best

Quantitative Model

Model Overview

The model consists of four blocks:

1) Firm Block [Hopenhayn 1992, Clementi and Palazzo 2016]
   - Atomistic firms take as given aggregates and prices
   - Choose quantity and 'greenness' of investment; demand labor and produce goods; can exit

2) Environmental Block [Nordhaus (2008), GHKT (2014), Krusell and Smith 2022]
   - Emissions from production contribute to atmospheric carbon stock [not internalized!]
   - Carbon stock causes economic damages which ultimately reduce aggregate consumption

3) Consumer Block [standard representative]
   - Inelastically supply labor; own firms; price risk-free bond (net 0 supply)

4) Government Block [standard]
   - Government budget constraint clears through lump-sum tax/subsidy on consumer

Firm Problem

- Firms maximize stream of dividends discounted at risk-free rate R_t
- Firms heterogeneous in TFP z, carbon dependence a, brown capital k_b, and green capital k_g
- Cobb-Douglas production w/ labor L and CES aggregate of capital k_b, k_g

$$\pi_t(z, a, k_b, k_g) = \max_L [1 - D(S_t)] \exp(z) A_t^{1-\alpha} [a^{1-\rho} {k_b}^{\rho} + (1-a)^{1-\rho} {k_g}^{\rho}]^{\frac{\alpha}{\rho}} L^{\nu} - w_t L - w_t c_f - \tau_t k_b$$

where climate damage $D(S_t)$ from stock of emissions S_t, fixed cost c_f, and brown capital tax τ_t

- Exogenous exit probability $\lambda \in [0, 1]$, surviving firms can choose to exit or continue
- Capital adj. cost $\psi(x_i, k_i)$ for investment x_i, $\psi^X(k_i) \equiv \psi\left[-(1-\delta)k_i, k_i\right]$ from liquidating k_i
- New firms pay κ [of labor] to enter competitively; endogenous mass of entrants $B_t \geq 0$
  - Firms observe a and productivity signal q after entry cost paid, then choose initial capital investment

Firm Bellman

- Value of firm in state (z, a, k_b, k_g) prior to exit shock realization

$$V_t(z, a, k_b, k_g) = \pi_t(z, a, k_b, k_g) + \lambda V_t^X(k_b, k_g) + (1-\lambda)\max\{V_t^C(z, a, k_b, k_g), V_t^X(k_b, k_g)\}$$

- Exiting firm eats nondepreciated capital net of adjustments costs of driving capital to zero

$$V_t^X(k_b, k_g) = (1-\delta)(k_b + k_g) - \psi^X(k_b) - \psi^X(k_g)$$

- Continuing firm chooses investment in brown and green capital, subject to adjustment costs

$$V_t^C(z, a, k_b, k_g) = \max_{x_b, x_g} - x_b - x_g - \psi(x_b, k_b) - \psi(x_g, k_g) + \frac{1}{R_t}\mathbb{E}[V_{t+1}(z', a, k_b', k_g')],$$
$$\text{s.t. } k_i' = (1-\delta)k_i + x_i, \quad \text{for } i \in \{b, g\}$$

- Productivity z follows an AR(1) process

$$z' = \rho_z z + \varepsilon; \varepsilon \sim N(0, \sigma_z^2)$$

Firm Entry

- After paying entry cost, entrant observes a, q, decides to exit or make initial investments

$$V_t^E(a,q) = \max\{0, \max_{k_b,k_g} -k_b - k_g + \mathbb{E}_{z|q}[V_t(z,a,k_b,k_g)]\}$$

- Following Clementi and Palazzo (2016),

$$z = \rho_q \log(q) + \epsilon; \epsilon \sim N(0, \sigma_q^2)$$

- Competitive entry of large mass of potential entrants before observing a, q [independent]

$$w_t \kappa \geq \mathbb{E}_{a,q}[V_t^E(a,q)]; q \sim Q_q; a \sim Q_a$$

- Endogenous measure B_t of potential entrants pays the entrance cost $w_t \kappa$

Consumers and Government

- Consumers supply unit of labor, wage w_t, risk-free bond b_t, own shares $\Theta_{i,t}$ in firm i price $p_{i,t}$
- Choose consumption C_t, invest in future shares and bonds, receive transfer T_t & dividends $d_{i,t}$

$$\max_{\{b_{m+1},\vec{\Theta}_{m+1},C_m\}_{m=t}^{\infty}} \sum_{m=t}^{\infty} \beta^m U(C_m)$$

$$\text{s.t. } C_m + \frac{1}{R_m} b_{m+1} + \int p_{i,m}\Theta_{i,m+1} di = w_m + T_m + b_m + \int (p_{i,m} + d_{i,m})\Theta_{i,m} di$$

- Consumer FOC for risk-free asset implies standard Euler condition $U'(C_t) = \beta U'(C_{t+1}) R_t$
- T_t set to clear government budget constraint given any firm taxation scheme
  - Under brown capital tax τ_t, $T_t = \tau_t K_t^b$ where K_t^b is total brown capital in economy

Carbon Cycle

- Aggregate brown capital utilized in production linearly creates emissions $\xi_t = \gamma K_t^b$
- Law of motion of carbon stocks (environmental state variables), given exo. emissions capturing χ_t:

$$\underbrace{S_t^1}_{\text{permanent carbon stock}} = S_{t-1}^1 + \varphi_1 \underbrace{(1-\chi_t)}_{\text{uncaptured}} \underbrace{\gamma K_t^b}_{\text{emissions}}$$

$$\underbrace{S_t^2}_{\text{persistent carbon stock}} = \varphi_3 S_{t-1}^2 + (1-\varphi_1)\varphi_2 \underbrace{(1-\chi_t)}_{\text{uncaptured}} \underbrace{\gamma K_t^b}_{\text{emissions}}$$

- Environmental damage fraction $D(S_t)$ increasing function of total carbon stock $S_t = S_t^1 + S_t^2$
- Without carbon taxes, firms do not internalize their contribution to the carbon stocks S^1, S^2

Equilibrium Definition

Constrained Planning Problem [Ottonello and Winberry (2023)]

- Consider a Social Planner, constrained to the technologies available at the firm-level
- Given firm measure μ, carbon stocks S^1, S^2, max discounted utility stream of rep household

$$\mathcal{W}_t(\mu, S^1, S^2) = \max_{x_b(\cdot), x_g(\cdot), X(\cdot), x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), L^d(\cdot), B, K^b, S^{1\prime}, S^{2\prime}} U(C_t) + \beta \mathcal{W}_{t+1}(\mu', S^{1\prime}, S^{2\prime})$$

- Subject to: Full Optimization Problem | Implementation Intuition | Unobserved k_b Extension
  - Resource & labor supply constraints, nonnegative entrant mass B, brown capital K^b adding-up
  - Law of motion of firm measure μ' & carbon stocks $S^{1\prime}$, $S^{2\prime}$ are consistent with chosen policies
- **Proposition**: Pigouvian tax on brown capital $\tau_t = \frac{\lambda_t^b}{U'(C_t)}$ implements socially optimal allocation

$$\underbrace{\lambda_t^b}_{\text{shadow cost of brown capital}} = \underbrace{(1-\chi_t)\gamma}_{\text{uncaptured emission rate}} \times \underbrace{\left[\sum_{s=t}^{\infty} \beta^{s-t} U'(C_s) D'(S_s^1 + S_s^2) Y_s [\varphi_1 + (1-\varphi_1)\varphi_2 \varphi_3^{s-t}]\right]}_{\text{future marginal cost of uncaptured emissions}}$$

- Can also implement with carbon credit program - can implement through either price or quantity

Quantification

Emissions Data

- Data: 5-year balanced panel of 389 public firms from 2016-2020 w/ annual frequency
  - Bloomberg: Scope 1 (direct) & Scope 2 GHG emissions (from electricity use) in metric tons CO^2
  - Compustat: Gross property, plants, and equipment ($PPEGT_{i,t}$), GDP-deflated to $ thousands (2015)
- Focus on *emission intensity*: (log) ratio of emission (Scope 1 + 2) to capital

$$y_{i,t} = \log\left(\frac{Emissions_{i,t}}{PPEGT_{i,t}}\right)$$

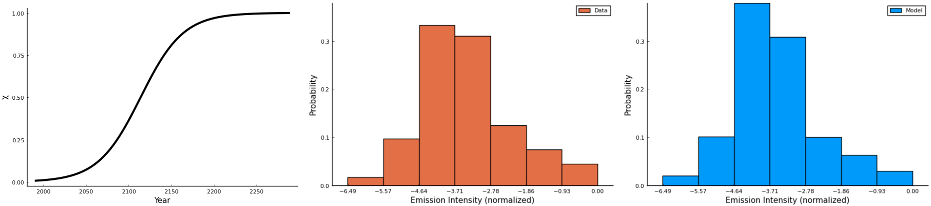
- We run regressions with firm fixed effects to estimate $\alpha_i = \mathbb{E}[y_{i,t}]$ ($R^2 = 0.956$)

$$y_{i,t} = \alpha_i + \varepsilon_{i,t};\ \alpha_i \perp \varepsilon_{i,t}$$

- Empirical distribution of $\hat{\alpha}_i$ maps directly to distribution of a in model
  - Assuming a normalization that dirtiest firm in our dataset operates exclusively using dirty capital

Quantitative Climate Scenario

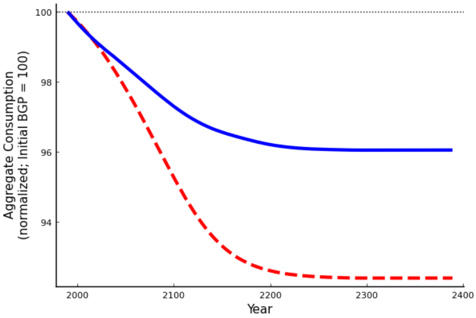
- Start economy on BGP ($\tau_t = 0$, constant $D(S)$) in 1990, calibrate γ to match annual emissions
- Calibrate Q_a to match distribution of $\hat{\alpha}_i$, c_f to match firm exit rates (Decker et al. 2016)
- Assume exogenous improvement in emissions capturing from Krusell and Smith (2022)
- Compute transition dynamics to new BGP under laissez-faire (BAU) and optimal allocations



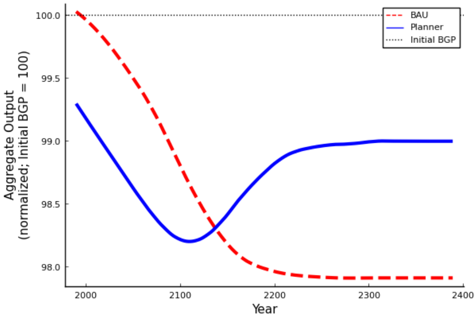
(a) Emissions Capturing (b) Data Histogram (c) Model Histogram

Functional Forms
Full Calibration

Consumption and Output



(a) Aggregate Consumption

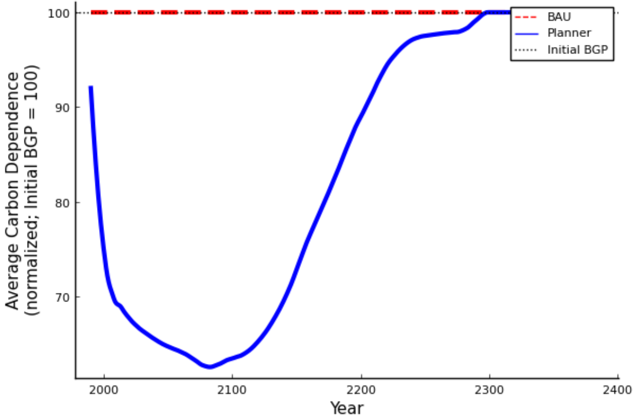


(b) Aggregate Output

- Left: Higher consumption C_t throughout transition (CE = 0.309% of Planner path over BAU)
- Right: Gross production Y_t is smaller under planner in short term, but higher in long term

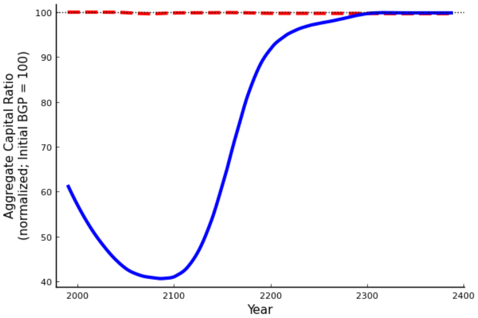
Taxes and Damage Prices Entrant Mass Carbon Stocks

Composition Effect (Extensive Margin)

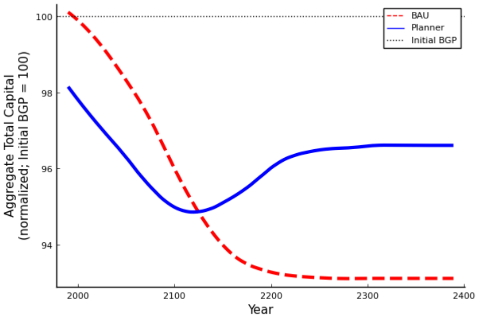


- Average carbon dependence $\bar{a}$ drops under the Planner (*composition effect*)

Substitution Effect and Scale Effect (Intensive Margins)



(a) Aggregate Capital Ratio (Brown over Green)



(b) Aggregate Total Capital (Brown plus Green)

- Left: Brown capital K_t^b drops relative to green capital K_t^g (*substitution effect*)
- Right: Total capital $K_t^b + K_t^g$ is lower in short-term (*scale effect*), then higher in long-term

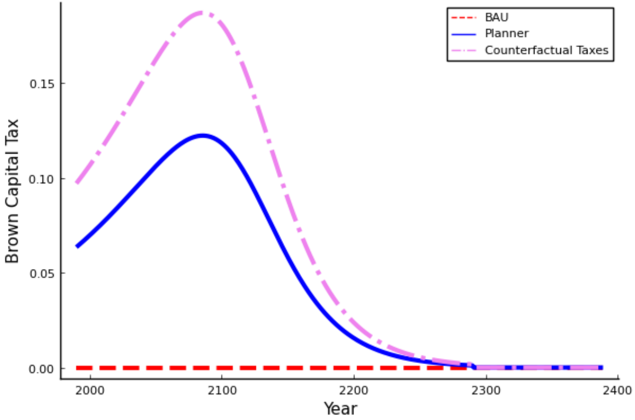
Consequences of Heterogeneity

What Do We Miss Without Heterogeneous Carbon Dependence?

- We eliminate composition effect by collapsing set of carbon dependence a to singleton
    - Match average emissions intensity in data
- Recalibrate the model, again targeting exit rate and initial emissions level to match data
- Compute optimal carbon taxes in this economy, which are larger
    - higher marginal damage of carbon w/o composition change
- *What happens if no-het (higher) optimal carbon taxes are implemented in economy with het in a?*

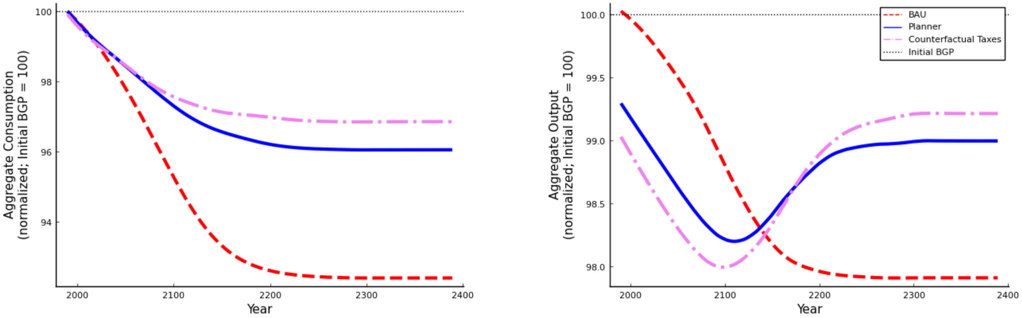
Recalibration

Optimal Brown Capital Taxes w/o Heterogeneity are Higher



- Planner loses composition effect without het. *a*, optimal carbon taxes are higher
- Optimal taxes are on average 52.8 percent higher in no-het relative to baseline

Welfare Impacts of No-Het Carbon Taxes in Economy with Het



(a) Aggregate Consumption (b) Aggregate Output

- CE = 0.28% for no-heterogeneity tax path over BAU (90.7% of CE for Planner over BAU)
- Lower consumption in short-term, but higher in long-term

Comparison of Carbon Taxes to Literature

- Translate proportional brown taxes into USD per metric ton of CO2 emissions (MtE)
- Our estimate are on average \$15.07 per MtE in first 100 years (min = \$12.75; max = \$17.34)
- Similar to low end of estimates from literature

Paper	Carbon Tax Estimate (\$/MtE)
Nordhaus (2008)	15
Stern (2007)	127
Golosov et al. (2014)	29-252

- Model ingredients differ between papers (discount rate, moral concern for future generations, etc.)
- Most similar methodology to ours is [bottom of range of] Golosov et al. (2014)
- Without *a* heterogeneity, taxes average \$22.91 per MtE; same ballpark as Golosov et al. (2014)

Conclusion

Conclusion

- We develop a GE climate-macro model with heterogeneous firm carbon dependence
- We calibrate our model to match the distribution of carbon dependence in the data
- We compute the BAU and socially optimal green transitions & carbon tax sequence
- We demonstrate that optimal carbon taxes in economies that ignore het can be too large
- We find the welfare consequences of ignoring het are much lower than ignoring climate change

Appendix

Firm Distribution

- Given incumbent firm distribution μ, entrant mass, and firm policies, operating firm distribution is

$$\Phi(\mu, B, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot))(s) \equiv \mu(s) + B \int Q_q(q) Q_a(a)[1 - X^E(a,q)] \mathbb{1}_{k_b = x_{b,t}^E(a,q)} \mathbb{1}_{k_g = x_{g,t}^E(a,q)} p_q(z - \rho_q \log(q)) dq$$

and incumbent firm distribution tomorrow is

$$T^*(\mu, B, x_b(\cdot), x_g(\cdot), X(\cdot), k_b^E(\cdot), k_g^E(\cdot), X^E(\cdot))(s') = \int (1-\lambda)[1 - X(s)] \mathbb{1}_{k_b' = (1-\delta)k_b + x_b(s)} \mathbb{1}_{k_g' = (1-\delta)k_g + x_g(s)} \times \mathbb{1}_{a'=a} Q_z(z'|z) d\Phi(\mu, B, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot))(s)$$

Back to labor
Back to full planner problem

Equilibrium Definition

A **Carbon-Cycle Competitive Equilibrium** is a set of allocations $\{k^E_{b,\iota}(a,q), k^E_{g,\iota}(a,q), x_{b,\iota}(s), x_{g,\iota}(s), L^d_\iota(s), S^1_\iota, S^2_\iota, K^b_\iota, \mu_\iota, \Theta_{i,\iota}, b_\iota\}_{\iota=t}^\infty$, prices $\{w_\iota, R_\iota\}_{\iota=t}^\infty$, taxes $\{T_\iota, \tau_\iota\}_{\iota=t}^\infty$, continuation rules $\{X_\iota(s), X^E_\iota(a,q)\}_{\iota=t}^\infty$, and mass of entrants $\{B_\iota\}_{\iota=t}^\infty$ such that

- Firm decisions solve their optimization problems
- Household decisions solve their problem
- Government budget constraint holds
- Free entry condition holds
- Markets clear in labor, risk-free asset, and stock market
- Adding-up holds for K^b_ι
- Carbon stocks evolve according to their law of motion

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Planner Problem

The planner solves

$$\mathcal{W}_t(\mu, S^1, S^2) = \max_{x_b(\cdot),x_g(\cdot),X(\cdot),x_b^E(\cdot),x_g^E(\cdot),X^E(\cdot),L^d(\cdot),B,K^b,S^{1\prime},S^{2\prime}} U(C_t) + \beta \mathcal{W}_{t+1}(\mu', S^{1\prime}, S^{2\prime})$$

subject to

$$\begin{aligned}
C_t &= (1 - D(S^{1\prime} + S^{2\prime}))Y_t - I_t - \Psi_t \\
1 &= \int (L^d(s) + c_f)\Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds + B\kappa \\
K^b &= \int k_b \Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds \\
S^{1\prime} &= S^1 + (1 - \chi_t)\varphi_1 \gamma K^b \\
S^{2\prime} &= \varphi_3 S^2 + (1 - \chi_t)(1 - \varphi_1)\varphi_2 \gamma K^b \\
B &\geq 0 \\
\mu' &= T^*(\mu, x_b(\cdot), x_g(\cdot), X(\cdot), x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)
\end{aligned}$$

where

$$\begin{aligned}
Y_t &= \int \exp(z) A_t^{1-\alpha} [a^{1-\rho} k_b^{\rho} + (1-a)^{1-\rho} k_g^{\rho}]^{\frac{\alpha}{\rho}} \\
&\qquad \times (L^d(s))^{\mu} \Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds \\
I_t &= \int (x_g(s) + x_b(s))(1 - \lambda)\Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds \\
&\quad + \int (-(1-\delta)k_b - (1-\delta)k_g)\lambda \Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds \\
&\quad + \int \int (x_g^E(a,q) + x_b^E(a,q))[1 - X^E(a)]BQ_a(a)Q_q(q)dadq \\
\Psi_t &= \int (\psi[x_g(s), k_g] + \psi[x_b(s), k_b])(1-\lambda)\Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds \\
&\quad + \int [\psi^X(k_g) + \psi^X(k_b)]\lambda \Phi(\mu, x_b^E(\cdot), x_g^E(\cdot), X^E(\cdot), B)(s)ds
\end{aligned}$$

and measure of productive firms $\Phi(\cdot)$ and measure operator $T^*(\cdot)$ are defined here

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Implementation Intuition

- Only inefficiency in CE: firms do not internalize their contribution to carbon stocks
- Planner internalizes this damage
- Consider implementing a Pigouvian tax where firms internalize their contribution to carbon stocks
- When $w_t =$ Planner's MPL, R_t equals that implied by Planner's SDF, B_t equals Planner's B_t $\forall t$:
  - Optimality conditions for firms align with those of the Planner for all firm-level choices
  - Optimality conditions hold for household problem - RFA and stock market clearing hold
  - Planner FOC w.r.t. B implies free entry condition holds
  - Labor supply constraint in Planner problem implies labor market clearing
  - Climate-related constraints for Planner implies they also hold
  - Lump-sum transfer to HH ensures GBC holds
- Therefore, definition of equilibrium is satisfied. See Appendix B for mathematical proof Back

Decentralization under Emissions Tax: Unobserved k_b

- Suppose k_b is unobserved by the taxation authority, but noisy emissions are observable:

$$\xi_{j,t} = \eta_{j,t}\gamma k_{b,j,t};\ \eta_{j,t} \sim_{iid} F; \mathbb{E}[\eta_{j,t}] = 1\ \eta_{j,t} \geq 0\ a.s.$$

For example, $\log(\eta_{j,t}) \sim_{iid} N\left(-\frac{\sigma_E^2}{2}, \sigma_E^2\right)$

- From the Planner's perspective, mean preserving spread integrates out; first-best unchanged

- Consider new emissions tax, $-\tau_t^E \xi_{j,t}$ in firm's problem in place of tax on brown capital
  - Specifically, consider $\tau_t^E = \frac{\tau_t}{\gamma}$

- We show that both ex-ante value & ex-post policies match that of original decentralized problem

- Hence, the set of prices and taxes $\{\tau_t^E, \hat{w}_t, \frac{1}{\hat{R}_t}\}_{t=0}^{\infty}$ implements the Planner allocation in a CE

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Functional Forms

- $D(S) = 1 - \exp(-\Delta(S - \bar{S}))$
  - Golosov et al. (2014)
- $\chi_t = \begin{cases} 1 - \left(1 + \exp\left(\log\left(\frac{0.01}{0.99}\right)\right)\frac{t - t_{\chi=0.5}}{t_{\chi=0.01} - t_{\chi=0.5}}\right)^{-1}, & \text{if } t < t_{\chi=1} \\ 1, & \text{if } t \geq t_{\chi=1} \end{cases}$
  - Krussell and Smith (2022)
- $\psi(x, k) = \hat{\psi}(x/k)^2 k$
  - Corbae and D'Erasmo (2021)
- $U(C) = \log(C)$
  - Golosov et al. (2014); Krusell and Smith (2022)
- Q_q: Pareto$(\bar{q}, \Xi)$

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Calibration

Parameter	Value	Source	Description
		Preferences	
β	0.971	$R^{BGP} = 1.04$	Time preference
ι	0.01	Krusell and Smith (2022)	Economy growth rate
		Production	
α	0.3	Standard parameter	Capital share
ν	0.65	Standard parameter	Labor share
λ	0.025	Decker et al. (2016)	Exogenous Exit Rate
$\hat{\psi}$	0.297	Corbae and D'Erasmo (2021)	Capital adjustment cost
δ	0.12	Standard parameter	Depreciation rate
ρ	-0.058	Stern (2012)	Substitutability between capital types
ρ_z, ρ_q	0.659	Khan and Thomas (2013)	Idiosyncratic productivity persistence
σ_z, σ_q	0.118	Khan and Thomas (2013)	Idiosyncratic productivity volatility
Ξ	2.69	Clementi and Palazzo (2016)	Pareto tail of entrant productivity signal
κ	0.0071	Consistent with unit wage	Entry cost
		Climate	
Δ	0.000053	Golosov et al. (2014)	Damage function parameter
φ_1	0.2	Krusell and Smith (2022)	Fraction of permanent emissions
φ_2	0.398	Krusell and Smith (2022)	Fraction of dissipated persistent emissions
φ_3	1.0	Krusell and Smith (2022) [0.998]	Persistence of persistent emission stock
$\bar{S}$	581	Golosov et al. (2014)	Pre-industrial level of emissions
$S_{9,1}$	684	Krusell and Smith (2022)	Stock of persistent emission in 1999
$S_{9,2}$	118	Krusell and Smith (2022)	Stock of permanent emission in 1999
E_9	8.741	Krusell and Smith (2022)	Emissions in 1999
$t_{\chi=0.01}$	10	Krusell and Smith (2022)	Years until one percent of emissions are captured
$t_{\chi=0.5}$	125	Krusell and Smith (2022)	Years until half emissions are captured
$t_{\chi=1}$	301	Krusell and Smith (2022)	Years until all emissions are captured
γ	47.505	Consistent with total emissions in 1990	Emissions per unit of brown capital

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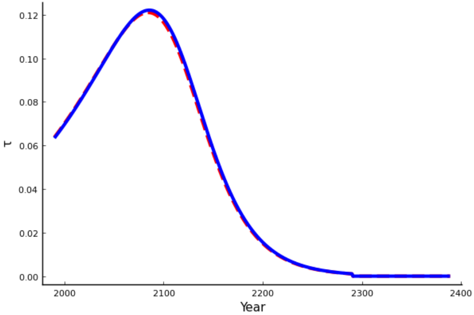
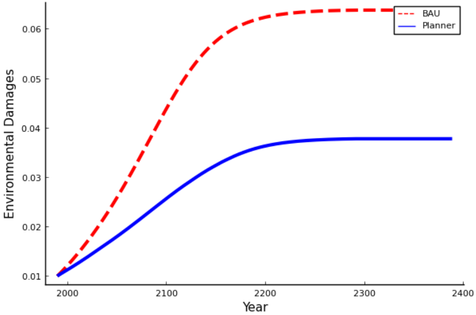
Planner Multiplier and Environmental Damage



(a) Shadow Cost of Brown Capital in Consumption Units



(b) Environmental Damage

- Left: $\tau_t = \frac{\lambda_t^k}{U'(C_t)}$ evaluated under the BAU and Planner scenarios
- Right: $D(S_t)$ evaluated under the BAU and Planner scenarios

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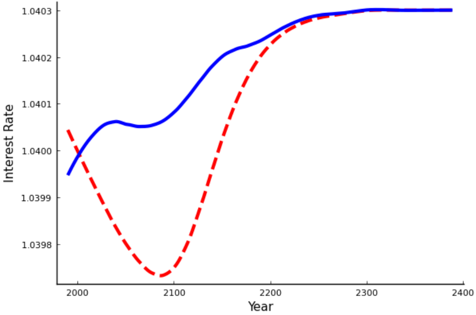
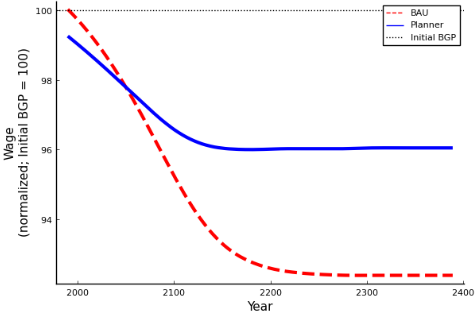
Equilibrium Prices



(a) Interest Rate



(b) Wage

- Left: Planner avoids large drop in consumption in BAU $\Longrightarrow$ flatter interest rate
- Right: Capital level $\downarrow \Rightarrow$ marginal product of labor $\downarrow$

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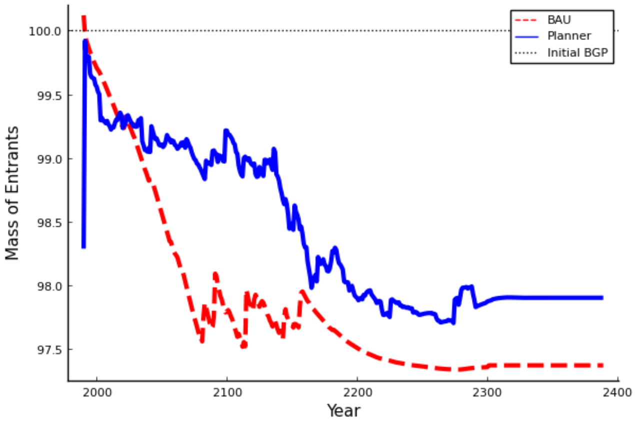
Mass of Entrants



- Less entrants in short-term; more entrants in long-term

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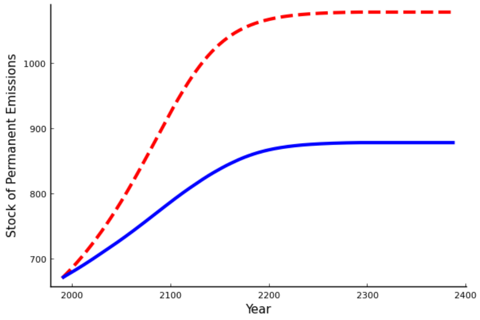
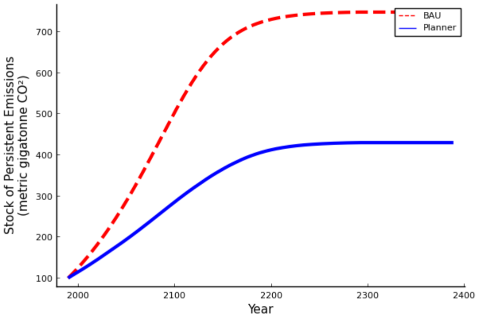
Climate Evolution



(a) Permanent Stock of Emissions



(b) "Persistent" Stock of Emissions

- Lower brown capital $\Longrightarrow$ fewer emissions $\Longrightarrow$ smaller stocks of carbon emissions

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Recalibration

Parameter	Description	Target	Baseline	Counterfactual
κ	Entry Cost	Unit wage in initial BGP	0.0071	0.0071
γ	Emissions per unit of brown capital	Total emissions in 1990	47.5056	72.409
c_f	Fixed cost of production	Exit rate $=$ 9%	0.02118	0.02198

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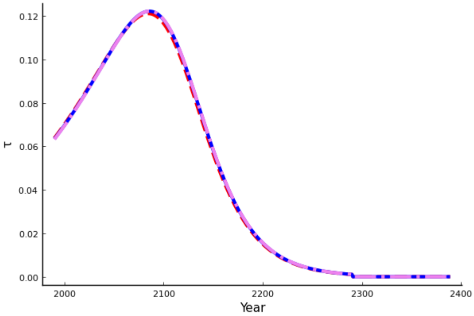
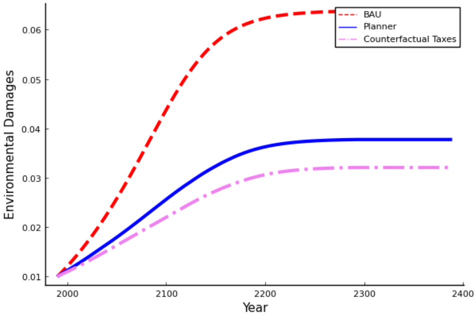
Planner Multiplier and Environmental Damage (Counterfactual)



(a) Shadow Cost of Brown Capital in Consumption Units



(b) Environmental Damage

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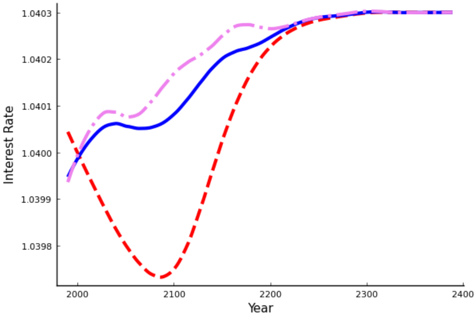
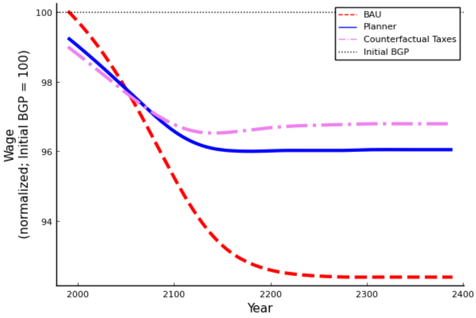
Equilibrium Prices (Counterfactual)



(a) Interest Rate



(b) Wage

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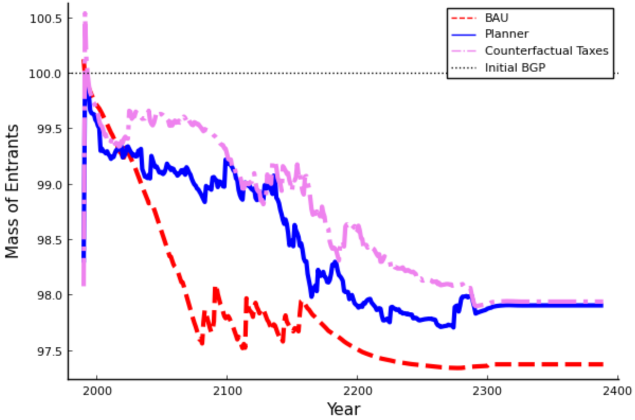
Mass of Entrants (Counterfactual)



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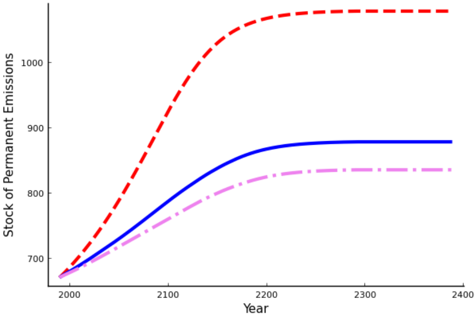
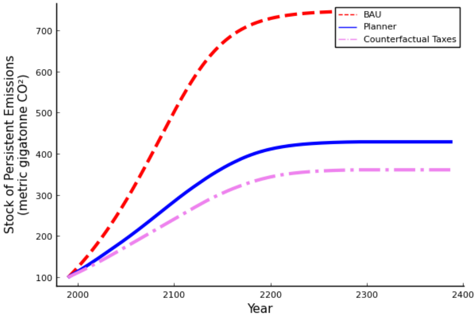
Climate Evolution (Counterfactual)



(a) Permanent Stock of Emissions



(b) "Persistent" Stock of Emissions

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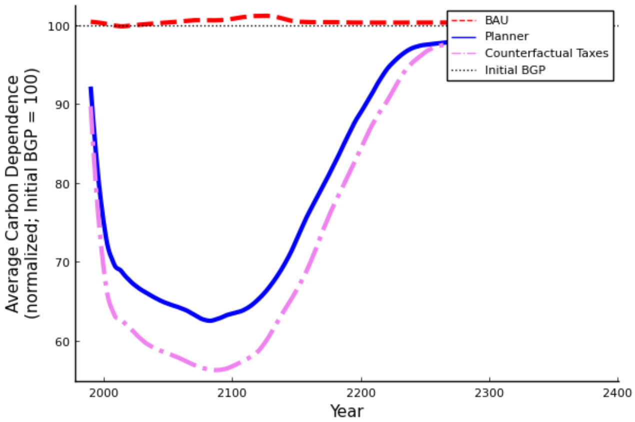
Composition Effect (Extensive Margin) (Counterfactual)



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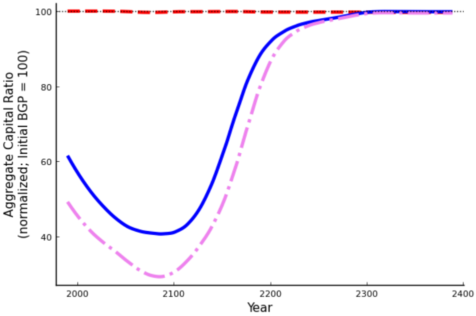
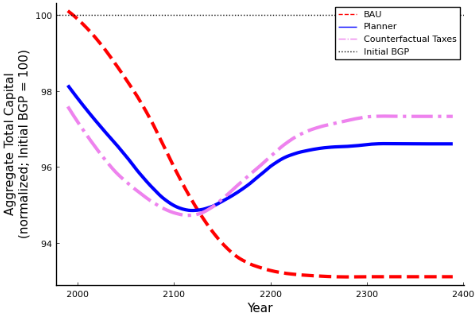
Substitution Effect and Scale Effect (Intensive Margins) (Counterfactual)



(a) Aggregate Capital Ratio (Brown over Green)



(b) Aggregate Total Capital (Brown plus Green)

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