Optimal Climate Policy in a Global Economy

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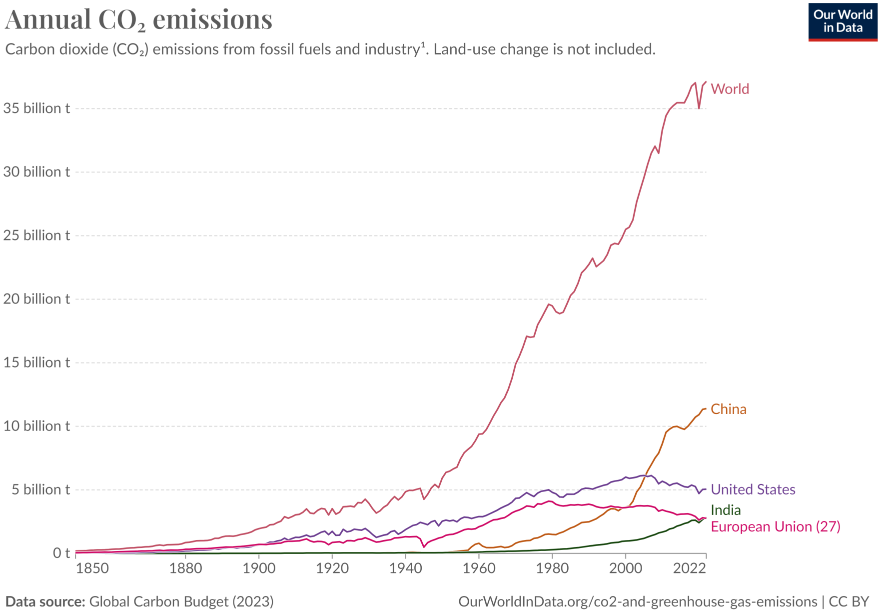
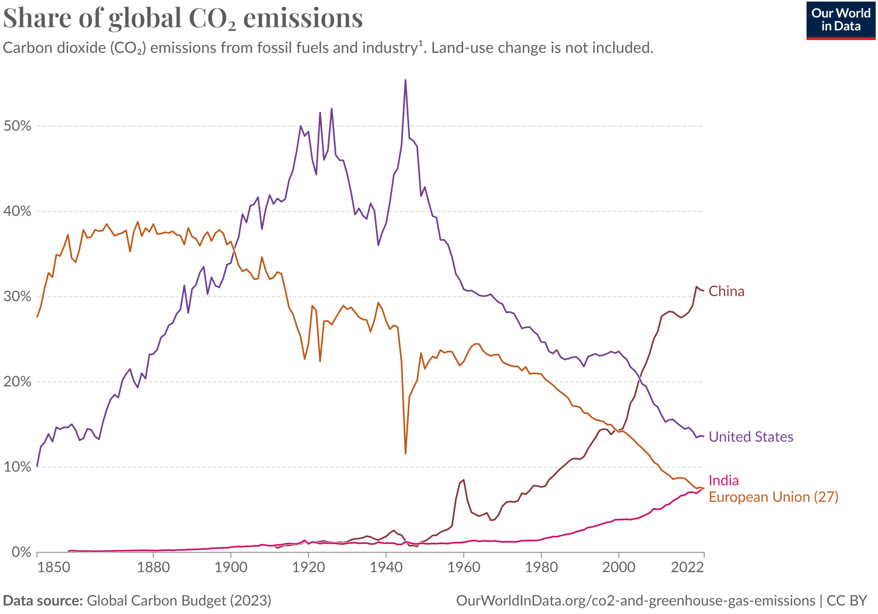
- Optimal unilateral policies?
- *Large* emitters/*large* participants in international capital markets.

Emissions per country



Emissions share per country



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     - If Home grows *faster* than Foreign $\Rightarrow$ use a tax on borrowing, $\tau_t^b > 0$.
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  2. *Domestic* carbon tax τ_t: *above/below* Home's damages
     - Tax *more* carbon if Home is a net *importer* of goods.
     - Tax *less* carbon if Home is a net *exporter* of goods.

Deterministic multiple-country economy without capital

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$$\underbrace{Y_t^l}_{\text{net output}} = \overbrace{(1 - D^l(S_t))}^{\text{country-specific damages, } D_S^l > 0} \underbrace{A_t^l F^l(n_t^l, E_t^l)}_{\text{gross output, } \hat{Y}_t^l}, \quad E_t^l = z_t^l f^l(n_{E,t}^l)$$

- One unit of labor allocated between two sectors: $n_t^l + n_{E,t}^l = 1$.

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- Climate variable: *stock* of emissions S_t

$$S_t = H(S_{t-1}, \sum_{l=1}^{N} E_t^l) \quad H_S > 0, H_E > 0$$

- *International* dimension: $E_t^k \uparrow \Rightarrow D^l(S_t) \uparrow, l \neq k$.
- $\Rightarrow S_t$ acts as a *durable, public "bad."*

Global planner

- *Pareto* weights $\eta^l > 0, \sum_{l=1}^N \eta^l = 1$.
- Choose $\{c_t^l, n_t^l, E_t^l, S_t\}_{\forall l,t}$ to maximize

$$\sum_{l=1}^{N} \eta^l \sum_{t=0}^{\infty} \beta^t u^l(c_t^l) \tag{1}$$

subject to

$$\sum_{l}^{N} c_t^l = \sum_{l=0}^{N} (1 - D^l(S_t)) A_t^l F^l(n_t^l, E_t^l) \quad (\equiv Y_t), \forall t \tag{2}$$

$$E_t^l = z_t^l f^l(1 - n_t^l), \forall l, t \tag{3}$$

$$S_t = H(S_{t-1}, \sum_{l}^{N} E_t^l), \forall t \tag{4}$$

with S_{-1} given, and $c_t^l \geq 0, n_t^l \in [0, 1], \forall l, t.$

Optimal cooperative policy

- Consumption efficiency:

$$\frac{u_{c,t}^{l}}{u_{c,t}^{k}} = \frac{\eta^{k}}{\eta^{l}} = \text{constant} \overset{\text{power utility}}{\Rightarrow} c_t^l = \theta^l \cdot Y_t \quad (\textit{constant} \text{ share})$$

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- Shadow value of E^l_t: $\tilde{\mu}^l_t = \underbrace{(1 - D^l_t) A^l_t F^l_{E,t}}_{MP_E^{final} \text{ in } l} \underbrace{- \tilde{\xi}^{global}_t H_{E,t}}_{\text{global externality}}, \forall l.$

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- Shadow cost of S_t:

$$\tilde{\xi}^{global}_t = \underbrace{\sum_{l=1}^{N} D^l_{S,t} \hat{Y}^l_t}_{\text{current global marginal damages}} + \underbrace{\beta \frac{u_{c,t+1}}{u_{c,t}} H_{S,t+1} \tilde{\xi}^{global}_{t+1}}_{\text{future global marginal damages}}$$

Market economy: "Business as Usual" (BAU)

- *Equalize* IMRS across $l = 1, ..., N$:

$$p_t = \beta \frac{u^l_{c,t+1}}{u^l_{c,t}} \forall l.$$

$\Rightarrow$ Consumption *constant* share of global output.

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- Pigouvian tax: *global* unit tax $\tau_t^{\text{global}} \equiv \tilde{\xi}_t^{global} \cdot H_{E,t}$:

$$\pi_t^{l,\text{tax}} = \left[p^l_{E,t} - \tau_t^{global}\right] z^l_t f(n^l_{E,t}) - w^l_t n^l_{E,t}$$

Decentralization of Pareto policy: global carbon tax

- Parametric assumptions: *multiple-country* extension of Golosov et al. (2014)
  1. Permanent and transitory emissions (ϕ_L, ϕ_0, ϕ):

$$S_t = x_t + y_t$$

$$x_t = x_{t-1} + \phi_L \sum_{l=1}^{N} E_t^l, \qquad y_t = (1-\phi)y_{t-1} + (1-\phi_L)\phi_0 \sum_{l=1}^{N} E_t^l$$

  2. Exponential country-specific damages:

$$D^l(S_t) = 1 - \exp\left(-\gamma^l (S_t - \bar{S})\right),$$

  3. Power utility: $u^l(c) = (c^{1-\rho} - 1)/(1-\rho), \forall l.$

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- *Global carbon tax:*
$$\frac{\tau_t^{\text{global}}}{Y_t} = \sum_{i=0}^{\infty} \beta^i \left(\frac{Y_{t+i}}{Y_t}\right)^{1-\rho} \underbrace{(1-d_i)}_{\text{depreciation of emissions}} \sum_{l=1}^{N} \gamma^l s_{t+i}^l,$$
where $s_t^l \equiv \frac{Y_t^l}{Y_t}$: output *share* of l in global output,
$1 - d_i \equiv \phi_L + (1-\phi_L)\phi_0(1-\phi)^i$.
- $\sum_{l=1}^{N} \gamma^l s_{t+i}^l$: *output-weighted* global marginal damages.

Beyond cooperation

- Country-specific policymaker: maximizes utility of household in l.
- *Large* emitter $\Rightarrow$ understands the effect of energy use on S_t and damages.
- *Large* participant in international capital markets.
- $\Rightarrow$ Understands how equilibrium interest rates are formed.
- $\Rightarrow$ Tries to *affect* prices to maximize domestic welfare.
- Incentives for price manipulation *intertwined* with carbon taxation.

Prelude: Large emitter but price-taker in international markets

- *Given* $E_t^j, j \neq l$ and *prices* p_t, the policymaker in l maximizes

$$\sum_{t=0}^{\infty} \beta^t u^l(c_t^l) \tag{5}$$

subject to

$$c_t^l + p_t b_{t+1}^l = (1 - D^l(S_t)) A_t^l F^l(n_t^l, E_t^l) + b_t^l$$
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- Country-specific carbon tax:

$$\frac{\tau_t^l}{Y_t} = \sum_{i=0}^{\infty} \beta^i \left(\frac{Y_{t+i}}{Y_t}\right)^{1-\rho} (1 - d_i) \gamma^l s_{t+i}^l$$

- The policymaker in l cares *only* for the marginal damages in l.

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- World interest rates: $p_t = \beta \frac{u^2_{c,t+1}}{u^2_{c,t}}, R_t \equiv 1/p_t \Rightarrow q_t = \beta^t \frac{u^2_{c,t}}{u^2_{c,0}}$.
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- Zero initial net foreign asset position, $b^1_0 = b^2_0 = 0$.
- Two *instruments* to decentralize the allocation:
  1. A domestic *carbon tax* τ_t on energy producers to affect the intersectoral allocation of labor.
  2. A *tax on borrowing/saving* τ^b_t to manipulate world interest rates ⇒ *Capital controls*!

Problem of H

- Policymaker in H chooses $\{c_t^1 \geq 0, n_t^1 \in [0,1], E_t^1, c_t^2 \geq 0, S_t\}$ to max

$$\sum_{t=0}^{\infty} \beta^t u^1(c_t^1)$$

subject to

$$\begin{aligned}
c_t^1 + c_t^2 &= (1 - D^1(S_t))A_t^1 F^1(n_t^1, E_t^1) + (1 - D^2(S_t))\hat{Y}_t^2 \\
E_t^1 &= z_t^1 f^1(1 - n_t^1) \\
S_t &= H(S_{t-1}, E_t^1 + E_t^2) \\
\sum_{t=0}^{\infty} \beta^t \underbrace{u_c^2(c_t^2)}_{q_t} &\left[c_t^2 - (1 - D^2(S_t))\hat{Y}_t^2\right] = 0, \quad \text{(IBC of F)}
\end{aligned}$$

- $(E_t^2, \hat{Y}_t^2)$ functions of $(A_t^2, z_t^2) \Rightarrow$ *outside* of control of H.
- Prices $q_t = \beta^t \frac{u_{c,t}^2}{u_{c,0}^2}$: *controlled* by H subject to IBC.
- Setup similar to a *monopolist* that faces a *competitive fringe*.

Consumption allocation

- Optimal choice of c_t^2 (Φ multiplier on IBC of F):

$$\underbrace{u^1_{c,t}}_{\text{MC of increasing } c_t^2} = \Phi \overbrace{\left[u^2_{c,t} - u^2_{cc,t} \underbrace{\cdot (c_t^1 - Y_t^1)}_{\text{net } \textit{buyer} \text{ (+)/} \textit{seller} \text{ (-)}} \right]}^{\text{MB of increasing } c_t^2}$$

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- A *reduction* in q_t is:
  - *Beneficial* if H is a net *buyer* of goods, $c_t^1 > Y_t^1$ ($nx_t^1 < 0$).
  - *Harmful* if H is a net *seller* of goods, $c_t^1 < Y_t^1$ ($nx_t^1 > 0$).

Consumption shares, price wedge and τ_t^b

- Price wedge: $\chi_t \equiv \frac{u^1_{c,t}}{\Phi u^2_{c,t}} - 1$

- Ratio of marginal utilities:

$$\frac{u^1_{c,t}}{u^2_{c,t}} = \Phi(1+\chi_t), \quad \chi_t = \epsilon^2_{cc,t}\frac{c^1_t - Y^1_t}{c^2_t}$$

where $\epsilon^2_{cc} = -\frac{u^2_{cc}}{u^2_c}c^2$: *elasticity* of MU of F.

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- Power utility: $\theta^1_t \equiv c^1_t/Y_t, s^1_t \equiv Y^1_t/Y_t$.

$$\left(\frac{\theta^1_t}{1-\theta^1_t}\right)^{-\rho} = \Phi\big(1 + \rho\frac{\theta^1_t - s^1_t}{1-\theta^1_t}\big)$$

  $\Rightarrow$ *time-varying* consumption share (due to *market power*), $\theta^1_t = \theta^1(s^1_t)$!

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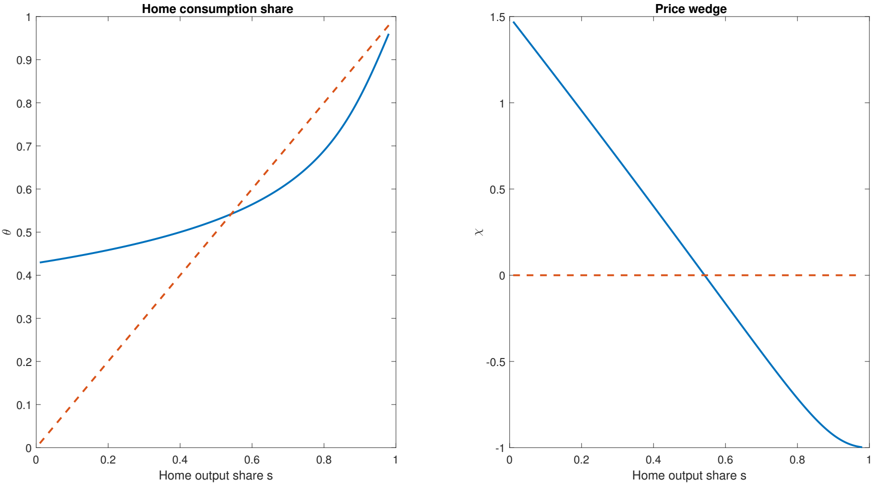
- $\frac{\partial \theta^1_t}{\partial s^1_t} > 0$, $\frac{\partial \chi_t}{\partial s^1_t} < 0$.

Consumption share θ and price wedge χ



- $\rho = 2, \Phi = 0.7141.$
- At the Pareto-optimal allocation θ is *constant!*

Tax on borrowing/saving τ^b_{t+1}

- Wedge in IMRS as long as χ_t *varies*!

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  - $s^1_{t+1} > s^1_t \Rightarrow \frac{Y^1_{t+1}}{Y^1_t} > \frac{Y^2_{t+1}}{Y^2_t} \Rightarrow \theta^1_{t+1} > \theta^1_t \Rightarrow \tau^b_{t+1} > 0 \Rightarrow$ *tax on borrowing.*
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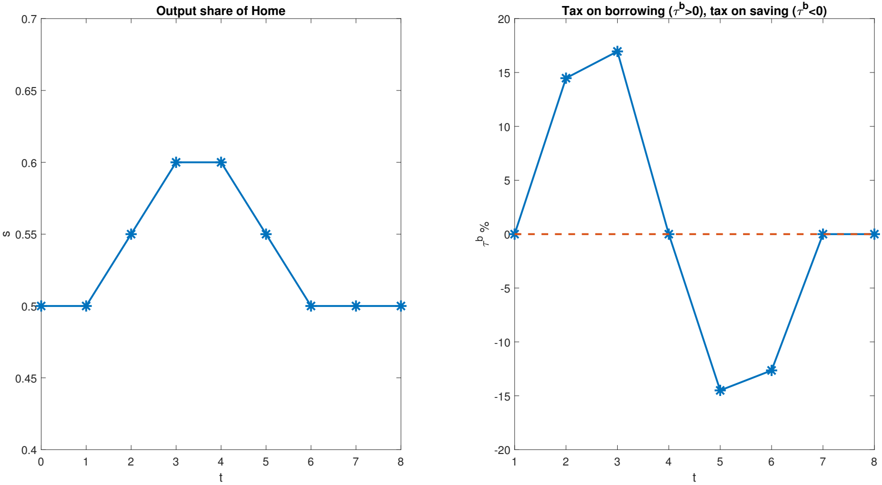
  - $s^1_{t+1} = s^1_t \Rightarrow \theta^1_{t+1} = \theta^1_t \Rightarrow \tau^b_{t+1} = 0$. Same at the BGP.

Indicative path of τ_t^b



- $\rho = 2, \Phi = 0.7141.$
- $\tau_{t+1}^b = \frac{\chi_t - \chi_{t+1}}{1+\chi_{t+1}}.$

Social cost of carbon and carbon taxes $\tau_t^M \equiv \tilde{\xi}_t^M \cdot H_{E,t}$

- Shadow cost of emissions

$$\tilde{\xi}_t^M = \underbrace{D_{S,t}^1 \hat{Y}_t^1}_{\text{damages of H}} + \underbrace{\frac{\chi_t}{1+\chi_t} D_{S,t}^2 \hat{Y}_t^2}_{\text{price wedge (+/-)} \times \text{ damages of F}} + \beta \underbrace{\frac{u_{c,t+1}^1}{u_{c,t}^1}}_{\neq p_t} \tilde{\xi}_{t+1}^M H_{S,t+1}$$

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- *Parametric* example:

$$\frac{\tau_t^M}{Y_t} = \sum_{i=0}^{\infty} \beta^i \left(\frac{\theta_{t+i}^1}{\theta_t^1}\right)^{-\rho} \left(\frac{Y_{t+i}}{Y_t}\right)^{1-\rho} (1-d_i)\left[\gamma^1 s_{t+i}^1 + \gamma^2 (1 - s_{t+i}^1)\frac{\chi_{t+i}}{1+\chi_{t+i}}\right]$$

- BGP: $\frac{\tau_t^M}{Y_t} = (\gamma^1 s^1 + \gamma^2(1-s^1)\frac{\chi}{1+\chi}) \sum_{i=0}^{\infty} \tilde{\beta}^i (1-d_i)$, $\tilde{\beta} \equiv \beta(1+g)^{1-\rho}$.

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- What if the policymaker in H were *"altruistic"* and maximized the weighted utility of H and F?
- *Qualitatively*, similar mechanisms would emerge.
- Carbon tax and capital control wars?
- H chooses $(\tau_t^1, \tau_t^{b,1})$, F chooses $(\tau_t^2, \tau_t^{b,2})$ and play *Nash* against each other.

THANK YOU!

Choi, Jason, Rishabh Kirpalani, and Diego J. Perez. 2024. US Public Debt and Safe Asset Market Power. *Journal of Political Economy* Forthcoming.

Costinot, Arnaud, Guido Lorenzoni, and Ivan Werning. 2014. A Theory of Capital Controls as Dynamic Terms-of-Trade Manipulation. *Journal of Political Economy* 122 (1):77–128.

Golosov, Mikhail, John Hassler, Per Krusell, and Aleh Tsyvinski. 2014. Optimal taxes on fossil fuel in general equilibrium. *Econometrica* 82 (1):41–88.