"Optimal Dynamic Carbon Taxes in a Climate-Economy Model with Distortionary Fiscal Policy" by Barrage (2020)

Presenter: Shengyu Li

January 25, 2024

Introduction

- Optimal carbon tax in the first best case is Pigouvian: Social Cost of Carbon, the present value of marginal damages of emission. (Golosov et al., 2014)
- Optimal carbon tax in an IAM model when the government has to raise an amount of revenues using distortionary taxes (i.e. labor income tax & capital income tax).
  1. Second best: optimal distortionary taxes
  2. Third best: distortionary taxes are constrained to some level

Main Results

1. Second best: if the climate change only affects utility, the optimal carbon tax is below Pigouvian level because it exacerbate the deadweight loss of labor income tax; (Bovenberg and Goulder, 1996)
2. Second best: if the climate change only affects production, the optimal carbon tax is exact the Pigovian level if capital tax is optimally set to zero because investment in climate is analogous to investment in physical capital. (Acemoglu et al., 2011; Atkeson et al., 1999)
3. Quantitatively, compared to first best case, the presence of distortionary taxes decrease the optimal carbon tax by 8-24%.

Model: Household

- Golosov et al. (2014) + government faces an extra task of raising revenues to meet a given expenditure requirement using distortionary taxes.
- The representative household's utility

$$U_0 \equiv \sum_{t=0}^{\infty} \beta^t U(C_t, L_t, T_t) = \sum_{t=0}^{\infty} \beta^t \left\{ h(C_t, L_t) + v(T_t) \right\}$$

where T_t is global surface temperature change over pre-industrial levels.

- The household's budget constraint:

$$C_t + K_{t+1} \leq w_t(1 - \tau_{lt})L_t + \{1 + (r_t - \delta)(1 - \tau_{kt})\}K_t + \Pi_t + G_t^T \quad (1)$$

where τ_{lt} and τ_{kt} are labor income tax and capital income tax. Π_t is the profit of the firm.

Model: Firm

- Production

$$Y_t = F(T_t, A_t, L_t, K_t, E_t) = (1 - D(T_t))A_t\tilde{F}(L_t, K_t, E_t) \quad (2)$$

where E_t is emission and $\tilde{F}$ is constant return to scale w.r.t $(L_t, K_t.E_t)$.

- Profit of producer:

$$\Pi_t = Y_t - w_tL_t - r_tK_t - (1 - \mu_t)E_t\tau_{Et} - \Theta_t(\mu_tE_t) \quad (3)$$

where μ_t of the fraction of emissions that are abated and $\Theta_t(\mu_tE_t)$ is the cost of abatement. τ_{Et} is carbon tax.

- Firm's first -order condition w.r.t E_t and μ_t:

$$\frac{\partial Y_t}{\partial E_t} = \tau_{Et}, \quad \tau_{Et} = \Theta_t'(\mu_tE_t) \quad (4)$$

Model: Government & Climate

- Government finances an exogeneously given sequence of public consumption, G_t^C, and household transfer, G_t^T:

$$G_t^C + G_t^T = \tau_{lt} w_t L_t + \tau_{kt}(r_t - \delta)K_t + \tau_{Et} E_t^M \tag{5}$$

where $E_t^M = (1 - \mu_t)E_t$

- Carbon cycle:

$$T_t = \mathbb{F}(\mathbf{S}_0, E_0^M, \cdots, E_t^M, \eta_0, \cdots, \eta_t) \tag{6}$$

where $\mathbf{S}_0$ is the initial conditions, and $\{\eta_s\}_{s=0}^t$ are exogenous shifters.

Model: Government Problem

- Government sets policies $(\tau_{lt}, \tau_{kt}, \tau_{Et}) \Rightarrow$ Take policies as given, agents choose $(C_t, L_t, K_t, E_t, \mu_t, T_t)$ and prices (r_t, w_t) adjust to make market clear $\Rightarrow$ Household's utility $U_0^*(\tau_{lt}, \tau_{kt}, \tau_{Et})$
- The government problem: maximize household's welfare $U_0^*(\tau_{lt}, \tau_{kt}, \tau_{Et})$ subject to competitive equilibrium, for a given set of initial conditions (K_0, S_0).
- Characterize allocations that can be decentralized as a competitive equilibrium (Proposition 1) and Maximize U_0 subject to these allocations (Chari and Kehoe (1999)).

Proposition 1

- The allocations $C_t, K_t, L_t, E_t, \mu_t, T_t$, along with initial capital K_0, initial capital tax $\overline{\tau_{k0}}$, initial carbon concentrations S_0 in a competitive equilibrium satisfy:

$$F(A_t, T_t, K_t, L_t, E_t) + (1-\delta)K_t \geq C_t + K_{t+1} + G_t^C + \Theta_t(\mu_t E_t) \tag{7}$$

$$T_t \geq \mathbb{F}(\mathbf{S}_0, (1-\mu_0)E_0, \cdots, (1-\mu_t)E_t, \eta_0, \cdots, \eta_t) \tag{8}$$

$$\sum_{t=0}^{\infty} \beta^t \left[U_{ct}C_t + U_{lt}L_t - U_{ct}G_t^T\right] = U_{c0}[K_0 + (F_{k0} - \delta)(1 - \overline{\tau_{k0}})] \tag{9}$$

Concepts

- Pigouvian taxes are defined by

$$\text{Production damages:} \quad \tau_{Et}^{Pigou,Y} \equiv (-1)\sum_{j=0}^{\infty}\beta^j \frac{U_{ct+j}}{U_{ct}}\left[\frac{\partial Y_{t+j}}{\partial T_{t+j}}\frac{\partial T_{t+j}}{\partial E_t^M}\right] \tag{10}$$

$$\text{Utility damages:} \quad \tau_{Et}^{Pigou,U} \equiv (-1)\sum_{j=0}^{\infty}\beta^j \frac{U_{Tt+j}}{U_{ct}}\left[\frac{\partial T_{t+j}}{\partial E_t^M}\right] \tag{11}$$

$$\tau_{Et}^{Pigou,T} \equiv \tau_{Et}^{Pigou,Y} + \tau_{Et}^{Pigou,U} \tag{12}$$

The level of Pigouvian tax in each fiscal scenario is evaluated at the optimal allocation in that particular fiscal scenario.

- The margian cost of public funds (MCF) measures the welfare cost of raising an addition unit of government revenue:

$$\text{MCF}_t \equiv \frac{\lambda_{1t}}{U_{ct}} \tag{13}$$

where λ_{1t} is the Lagrange multiplier on the resource constraint in period t.

Second best: Climate policy with optimized distortionary taxes

- The optimal carbon tax is

$$\tau^*_{Et} = -\left\{ \underbrace{\sum_{j=0}^{\infty} \beta^j \left[\frac{\partial U_{Tt+j}}{\partial U_{ct}} \frac{1}{MCF_t} \right] \left[\frac{\partial T_{t+j}}{\partial E^M_t} \right]}_{\text{Utility}} + \underbrace{\sum_{j=0}^{\infty} \beta^j \left[\frac{\partial Y_{t+j}}{\partial T_{t+j}} \frac{\lambda_{1t+j}}{\lambda_{1t}} \right] \left[\frac{\partial T_{t+j}}{\partial E^M_t} \right]}_{\text{Production}} \right\} \quad (14)$$

Climate change affects only utility

$$\tau_{Et}^{*} = -\sum_{j=0}^{\infty} \beta^{j} \left[\frac{\partial U_{Tt+j}}{\partial U_{ct}} \frac{1}{MCF_t} \right] \left[\frac{\partial T_{t+j}}{\partial E_t^M} \right] = \frac{\tau_{Et}^{Pigou,U}}{\mathrm{MCF}_t} < \tau_{Et}^{Pigou,U} \tag{15}$$

- Climate is consumption good, imposing carbon tax provides no productivity benefits;
- Carbon taxes decrease the real returns to labor and hence decrease employment. $\Rightarrow$ exacerbate the welfare costs of labor income taxes.

Climate change affects only production

$$\tau_{Et}^{*} = -\sum_{j=0}^{\infty} \beta^{j} \left[\frac{\partial Y_{t+j}}{\partial T_{t+j}} \frac{\lambda_{1t+j}}{\lambda_{1t}} \right] \left[\frac{\partial T_{t+j}}{\partial E_{t}^{M}} \right] \tag{16}$$

- How the planner's relative valuation of output ($\frac{\lambda_{1t+1}}{\lambda_{1t}}$) compares to the household's ($\frac{U_{ct+1}}{U_{ct}}$)
- If the government optimally chooses to set capital income taxes to zero, then the optimal carbon tax is the Pigouvian tax.
- Climate is an asset used in production, analogous to physical capital.
- The reason to support that the government leave household's physical capital investments undistorted also apply to environmental investment.

Proposition 2

- If preferences are of either commonly used constant elasticity form,

$$U(C_t, L_t, T_t) = \frac{C_t^{1-\sigma}}{1-\sigma} + \vartheta(L_t) + v(T_t) \tag{17}$$

$$U(C_t, L_t, T_t) = \frac{(C_t L_t^{-\gamma})^{1-\sigma}}{1-\sigma} + v(T_t) \tag{18}$$

and direct government transfers to households ar either zero or account for a constant fraction of consumption, then

1. the optimal carbon income tax is zero: $\tau^*_{kt+1} = 0$;
2. The optimal carbon tax is

$$\tau^*_{Et} = \frac{\tau_{Et}^{Pigou,U}}{\mathsf{MCF}_t} + \tau_{Et}^{Pigou,Y} \tag{19}$$

Third best: climate policy with constrained distortionary taxes

- If the government is constrained to maintain capital income taxes at $\overline{\tau_k} > 0$, the government faces another constraint

$$\frac{U_{ct}}{\beta U_{ct+1}} = 1 + (1 - \overline{\tau_k})(F_{kt+1} - \delta) \tag{20}$$

a wedge between the household's intertemporal marginal rate of substitution $(\frac{U_{ct}}{\beta U_{ct+1}})$, and the marginal rate of transformation $(1 + F_{kt+1} - \delta)$.

- $\overline{\tau_l} > 0$, another constraint

$$-\frac{U_{lt}}{U_{ct}} = (1 - \overline{\tau_l})F_{lt} \tag{21}$$

Third best: climate policy with constrained distortionary taxes

Corollary 1 *If the government is constrained to maintain capital income taxes at* $\overline{\tau_k}$ $\forall t > 0$:

$$\frac{U_{ct}}{\beta U_{ct+1}} = 1 + (1 - \overline{\tau_k})(F_{1kt+1} - \delta) \tag{3.12}$$

then, letting Ψ_t *denote the planner's Lagrange multiplier on (3.12) in period* t, *the optimal carbon tax for* $t > 0$ *is implicitly defined by:*

$$\tau_{Et}^{*} = (-1)\left[\underbrace{\sum_{j=0}^{\infty} \beta^j \frac{U_{Tt+j}}{U_{ct}} \frac{1}{MCF_t} + \frac{\lambda_{1t+j}}{\lambda_{1t}} \frac{\partial Y_{t+j}}{\partial T_{t+j}}}_{\text{Utility + Production impacts}} + \underbrace{\frac{\Psi_{t-1+j}}{\lambda_{1t}} \frac{1}{\beta} \frac{\partial F_{1kt+j}}{\partial T_{t+j}} (1 - \overline{\tau_k})}_{\text{Fiscal constraint interaction}}\right] \left[\frac{\partial T_{t+j}}{\partial E_t^M}\right], \tag{3.13}$$

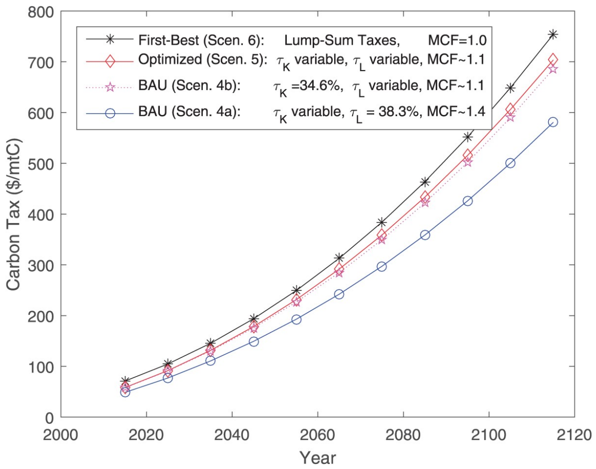
where the government's discounting of output damages for $t \geq 0$ *is defined by:*

$$\frac{\beta \lambda_{1t+1}}{\lambda_{1t}} = \left[F_{1kt+1} + (1 - \delta) + \frac{\Psi_t}{\lambda_{1t+1}} \frac{1}{\beta} \frac{\partial F_{1kt+1}}{\partial K_{1t+1}} (1 - \overline{\tau_k})\right]^{-1}. \tag{3.14}$$

Scenarios

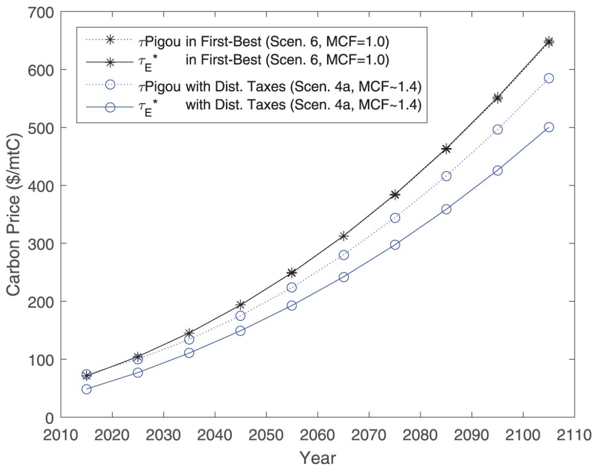
1. First-best: (1) Optimal carbon tax; (2) Lump-sum Taxation
2. Second-best: (1) Optimal carbon tax; (2) Distortionary but optimal taxation
3. Third-best: (1) Optimal carbon tax; (2) Distortionary and constrained taxation; (a.$\overline{\tau_l}$; b.$\overline{\tau_k}$)
4. (1) "Wrong" first-best carbon tax; (2) Distortionary and constrained taxation; (a.$\overline{\tau_l}$; b.$\overline{\tau_k}$)
5. BAU: (1) No carbon tax; (2) Distortionary and constrained taxation; (a.$\overline{\tau_l}$; b.$\overline{\tau_k}$)

Main Results



- Alongside distortionary taxes, optimal carbon taxes are 8-24% lower than the first-best case.

Main Results

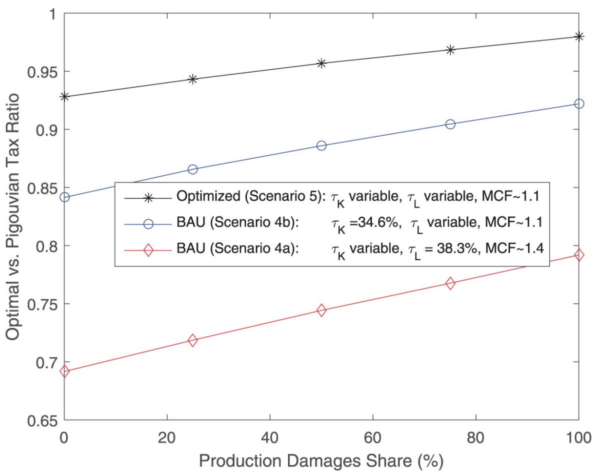


- Allocation: economic size is smaller ⇒ SCC is lower
- Formula: Optimal tax is not Pigouvian

Main Results

- The welfare gains of adopting carbon taxes is large: 0.78-0.95% permanent consumption increase.
- Compared to "wrongly" implementing fist-best carbon tax, adjusting carbon tax to the fiscal setting create welfare improvement: 0.05% or 0.02% permanent consumption increase;

Main Results



- The ratio of the carbon price relative to the Pigouvian levy is increasing in the share of climate damages affecting production;
- Abstracting from the effect of climate change in production leads to an underestimate of the optimal carbon price.

Conclusion

- Compared to the first-best setting, commonly considered in the IAM literature, the optimal carbon taxes are 8-24% lower when levied alongside distortionary taxes;
- The optimal carbon tax may not be as low as suggected by prior studies that focused on climate policy interactions with pre-existing taxes: they assume climate change only affects utility;
- The governments seeking to reduce intertemporal distortions should be concerned not only with capital income tax reform, but also with climate policy: if the government optimally sets capital income taxes to zero, then carbon taxes to internalize production losses from climate change should be set at Pigouvian rates.

References

Acemoglu, D., Golosov, M., and Tsyvinski, A. (2011). Political economy of ramsey taxation. *Journal of Public Economics*, 95(7-8):467–475.

Atkeson, A., Chari, V. V., Kehoe, P. J., et al. (1999). Taxing capital income: a bad idea. *Federal Reserve Bank of Minneapolis Quarterly Review*, 23:3–18.

Barrage, L. (2020). Optimal dynamic carbon taxes in a climate–economy model with distortionary fiscal policy. *The Review of Economic Studies*, 87(1):1–39.

Bovenberg, A. L. and Goulder, L. H. (1996). Optimal environmental taxation in the presence of other taxes: general-equilibrium analyses. *The American Economic Review*, 86(4):985–1000.

Chari, V. V. and Kehoe, P. J. (1999). Optimal fiscal and monetary policy. *Handbook of macroeconomics*, 1:1671–1745.

Golosov, M., Hassler, J., Krusell, P., and Tsyvinski, A. (2014). Optimal taxes on fossil fuel in general equilibrium. *Econometrica*, 82(1):41–88.