Ambiguity and Strategic Interactions in Global Pollution Problems

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Strategic Interactions in Climate Change

- Consider *changes* in some parameters that affect a country (e.g., degree of ambiguity attitudes, wealth)... How do these changes impact *own*, but also *others'* decisions to pollute (abate)?
  - Theoretical economics literature on strategic climate interactions is rather limited…
  - Gerlagh and Kuik (2014) found strategic complementarity: reduced emissions in some countries might also result into less emissions for others
  - Jørgensen and Nielsen (2022) found that both strategic complementarity and substitutability are possible (in the context of climate taxes)
- In practice, strategic playing in climate policies seems to occur…
  - China, over the past decade, *increased* coal investments domestically and abroad (Ambrose, 2019; Saha, 2019); while coal power generation in the US and Europe steeply *declined*, during 2015-2019
  - Differences among countries' policy makers (in setting climate strategies) may also be driven by differences among their citizens' attitudes (Carlsson et al. (2021) , Schwirplies (2018))

Ambiguity in Climate Change

- Classification of uncertainty by economists (Heal and Kristrom (2002), Quiggin (2008), Heal and Millner (2014)):
  1. Scientific Uncertainty…
  2. Policy Uncertainty…
  3. Impact Uncertainty…
     - How changes in climate regimes may translate into welfare (i.e., human) impacts
     - In the economics literature, climate impact uncertainty is demonstrated through a wide set of estimates for the Social Cost of Carbon:
       - Tol (2009, 2012, 2018): various estimates about Social Cost of Carbon
       - Long time makes discounting critical (Weitzman (2007), Nordhaus (2007))
       - Inconsistent assumptions (Withagen (2022), Bretschger and Pattakou (2019))
       - Possibility of catastrophe non-negligible (Weitzman's "*deep/structural uncertainty*" (2009, 2011), Nordhaus (2011), Pindyck (2011))
- How *changes* in one country's attitudes/perceptions of climate impacts (i.e., becoming more optimistic, or pessimistic) may affect *own* and *others'* decisions to pollute?
  - Large variation across countries' pessimism (Poortinga et al. (2019), Smith et al. (2017))
  - A growing literature (Economics, Sociology and Psychology): what variables drive pessimistic/optimistic attitudes (Tjernström and Tietenberg (2008), Alló and Loureiro (2014), Ziegler (2017), Schleich and Faure (2017)) …

Theoretical Model

- The model builds on pollution model of Andreoni & Levinson (2001):
  - N decision-makers, i ϵ {1,…, N}; with uncertainty…
  - Utility $u_i(c_i, b; \theta) = c_i^{\eta_i} - \theta b, \quad \theta \in \Theta = \left[\theta^l, \theta^h\right]$ "States of Nature"

    Standard utility assumptions…: $\partial u_i / \partial c_i > o$, $\partial^2 u_i / \partial c_i^2 < 0$, $\partial u_i / \partial b < 0$
  - Pollution $b = f(c, e)$; $c = \sum_{i=1}^{N} c_i$ and $e = \sum_{i=1}^{N} e_i$

    Standard assumptions for pollution…: $\partial f / \partial c > 0$, $\partial^2 f / \partial c^2 > 0$,

    $\partial f / \partial e < 0$, $\partial^2 f / \partial e^2 > 0$

    $\partial^2 f / \partial c \partial e < 0$ (f submodular)

    e.g., pollution function $b = f(c, e) = c - c^{\gamma} e^{\lambda}$
  - Budget Constraint: $c_i + e_i = W_i$

Theoretical Model (contd.)

- α-MMEU preferences (Ghirardato, Maccheroni and Marinacci; 2004):

$$Z_i(c_i,b;\alpha_i,P_i)=\alpha_i \min_{p(\cdot)\in P_i}\left\{\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,p(\theta)\,d\theta\right\}+(1-\alpha_i)\max_{p(\cdot)\in P_i}\left\{\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,p(\theta)\,d\theta\right\}$$

- Rewrite above by using

$$\overline{p_i}(\cdot)\in\arg\min_{p(\cdot)\in P_i}\left\{\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,p(\theta)\,d\theta\right\} \quad \text{and} \quad \underline{p_i}(\cdot)\in\arg\max_{p(\cdot)\in P_i}\left\{\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,p(\theta)\,d\theta\right\}$$

$$\begin{aligned} Z_i(c_i,b;\alpha_i,P_i) &= \alpha_i\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,\overline{p_i}(\theta)\,d\theta+(1-\alpha_i)\int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\,\underline{p_i}(\theta)\,d\theta \\ &= \int_{\theta^l}^{\theta^h} u_i(c_i,b,\theta)\left[\alpha_i\,\overline{p_i}(\theta)+(1-\alpha_i)\,\underline{p_i}(\theta)\right]d\theta \\ &= c_i^{\eta_i}-b\int_{\theta^l}^{\theta^h}\theta\,\hat{p}_i(\theta;\alpha_i)\,d\theta \end{aligned}$$

or $Z_i(c_i,b;\alpha_i,P_i)=c_i^{\eta_i}-b\left[\alpha_i\overline{\theta_i}+(1-\alpha_i)\underline{\theta_i}\right]$, in which: $\overline{\theta_i}=\int_{\theta^l}^{\theta^h}\theta\,\overline{p_i}(\theta)\,d\theta$

$$\underline{\theta_i}=\int_{\theta^l}^{\theta^h}\theta\,\underline{p_i}(\theta)\,d\theta$$

- Each player i: Max $Z_i(.)$ s.t.
  - Pollution function: b=f (c,e)
  - Budget Constraint: $c_i+e_i=W_i$

Theoretical Model (contd.)

- Use constraints to get:

$$\Psi_i(c_i, \sum_{j\neq i} c_j; \alpha_i, \overline{\theta}_i, \underline{\theta}_i, W_i, \sum_{j\neq i} W_j) = c_i^{\eta_i} - \left[\alpha_i \overline{\theta}_i + (1-\alpha_i)\underline{\theta}_i\right] f\left(\sum_{i=1}^{N} c_i, \sum_{i=1}^{N} (W_i - c_i)\right)$$

- Nash Equilibrium: the system of all FOCs, i.e.,

$$\eta_i c_i^{\eta_i - 1} - \left[\alpha_i \overline{\theta}_i + (1-\alpha_i)\underline{\theta}_i\right]\left(\frac{\partial f}{\partial c} - \frac{\partial f}{\partial e}\right)$$, for all i=1,…,N

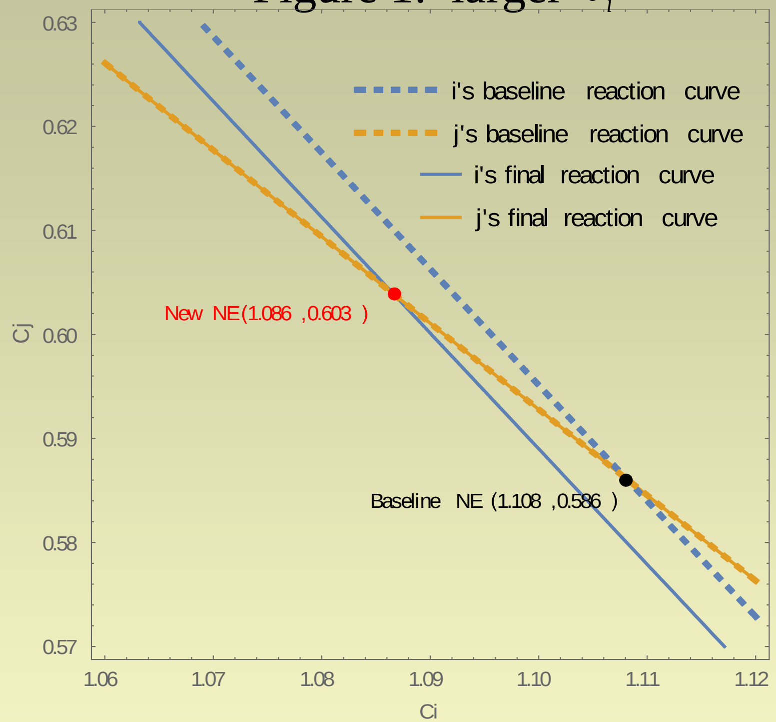
  - Strategic interaction: Aggregative Game (Okuguchi, 1993; Acemoglu and Jensen, 2013).
  - Strategic Substitutes
- Derive comparative statics…
  - Acemoglu and Jensen (2013): ‘idiosyncratic shocks’
  - For non idiosyncratic shocks → Implicit Function Theorem…

Proposition 1 (for idiosyncratic shocks)

- An increase in parameter $t_i \in \{\alpha_i, \overline{\theta_i}, \underline{\theta_i}\}$ decreases player i's equilibrium consumption (ci), but *increases* the aggregate of the remaining players' equilibrium consumption levels ($\sum_{j \neq i} c_j$).
  - Changes in t_i constitute negative idiosyncratic shocks (in the context of Acemoglu and Jensen (2013))…
  - Simulations (Mathematica 11) of model with two players (i, j)…

Simulation result for an idiosyncratic shock…

Figure 1: larger $\overline{\theta_i}$



- For idiosyncratic shocks (only one RC shifts): NE consumptions move to *opposite* directions
- Impact of idiosyncratic shocks on pollution: pollution decreases (increases) when aggregate consumption decreases (increases)
- What about non-idiosyncratic shocks (both RC shift)?
  - → Do equilibrium consumptions still move to opposite directions?
  - → Perhaps sometimes only, and when…?

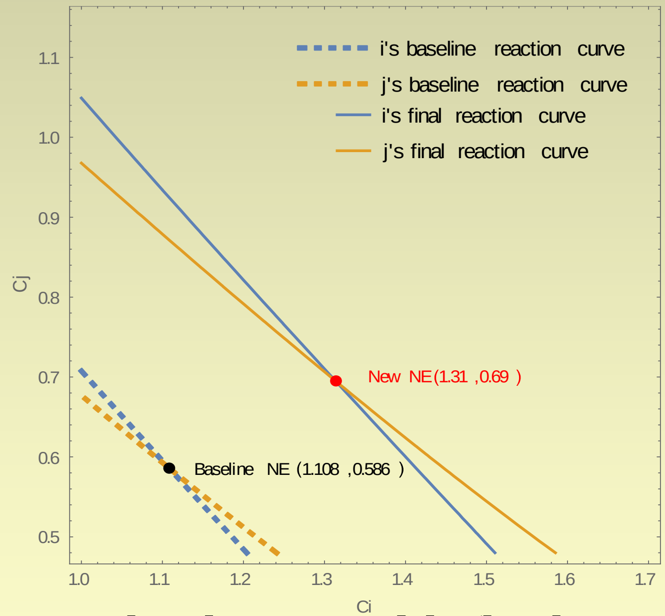
Changes in Wi...

Changes in boundaries of set Θ…

Proposition 2 (for non-idiosyncratic wealth shock)…

- An increase in parameter W_i increases not only player i's equilibrium consumption (ci), but also the aggregate of the remaining players' equilibrium consumption levels ($\sum_{j \neq i} c_j$) . [Proof in Appendix…]

Figure 2: larger Wi



- For the non-idiosyncratic shock on wealth (both RC shift proportionally): NE consumptions move to *same* direction
- Impact of a wealth increase on pollution: in all simulations, pollution decreases…

Simulation results for non-idiosyncratic shock on Θ

- A decrease in lower boundary of set $\Theta = \left[\theta^l, \theta^h\right]$ (common for all players)
  - Several players i (for i=1,2,...,N) decrease their $\underline{\theta_i} = \int_{\theta^l}^{\theta^h} \theta \, \underline{p_i}(\theta) d\theta$
  - Reaction curves shift upwards, but not necessarily by same magnitude…

Figure 3:
Proportionate shifts

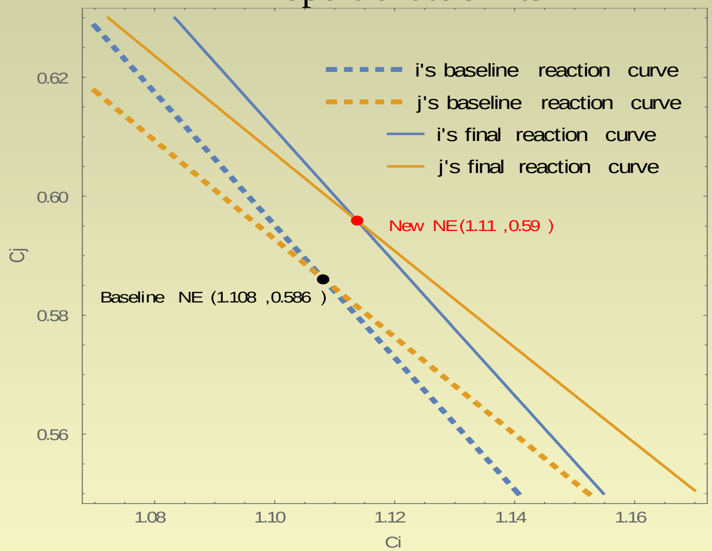
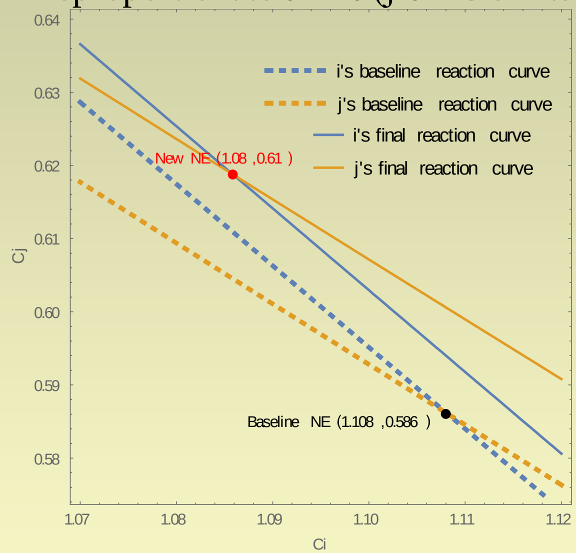


Figure 4:
Disproportionate shifts (j's RC shifts more)



  - Increasing ambiguity in terms of expanding the set $\Theta = \left[\theta^l, \theta^h\right]$ moves equilibrium consumptions to *same* direction when reaction curves shift proportionally; and to opposite directions when reaction curves shift *disproportionally*.
    - A reflection of Roy and Sabarwal (2010)…
  - Impact of expanding the boundaries of set Θ on pollution: pollution increases (decreases) when aggregate consumption increases (decreases)

Conclusions…

- Purpose was to explore, from a theoretical perspective, the possible strategic interactions in a Climate Change Game
  - Model builds on the deterministic pollution framework of Andreoni and Levinson (2001)
  - Attitudes toward uncertainty (ambiguity) are represented in terms of the α-MMEU of Ghirardato et al. (2004)
- Comparative Statics Findings…
  - For idiosyncratic shocks: equilibrium consumptions always move to *opposite* directions
  - For non idiosyncratic wealth shock: equilibrium consumptions always move to *same* direction
  - For non-idiosyncratic shock of expanding set Θ: "uncertain" about our prediction…
  - Results are a reflection of those for Aggregative Games with Strategic Substitutes (Acemoglu and Jensen (2013), Roy and Sabarwal (2010))

Thank you