First-mover advantage of defecting coalitions in international climate negotiations

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Some definitions

- A *cooperative game* (N, v) consists of a set of players N and a *characteristic function* $v : 2^N \to \mathbb{R}$.
- $v(S)$ is called the *value* of coalition $S \subseteq N$.
- An allocation is a vector $x \in \mathbb{R}^n$ with $\sum_{i \in N} x_i = v(N)$.
- The *core* of the game is the set of all allocations from which no coalition has an incentive to deviate.

$$\mathcal{C}(N, v) = \{x \in \mathbb{R}^n \mid \sum_{i \in S} x_i \geq v(S) \; \forall S \subsetneq N\}$$

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Basic model

Our setup is based on the model of transfrontier pollution by Chander and Tulkens (1997):

- set of players $N = \{1, .., n\}$
- emissions E_i
- production function $P_i(E_i)$, depending on a country's own emissions. It is assumed to be monotonically increasing up to a baseline emission level E_i^0 and concave.
- benefit function $B_i(E_N)$, depending on total emissions E_N. It describes the virtues of a reduction in total emissions and is assumed to be monotonically decreasing and concave.

Basic model II

- Assume some set of countries $S \subset N$ forms a coalition.
- Countries determine their emissions by maximizing utility, the sum of production function and benefit function.
- Coalition members maximize joint utility of the coalition, while non-members maximize individual utility.

$$\max_{(E_i)_{i \in S}} \sum_{i \in S} [P_i(E_i) + B_i(E_N)]$$

$$\max_{E_j} P_j(E_j) + B_j(E_N) \quad \forall j \notin S$$

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Basic model III

This behaviour of non-members is the γ-assumption by Hart and Kurz (1983). The characteristic function of the associated game is defined by

$$v^{\gamma}(S) := \max_{(E_i)_{i \in S}} \sum_{i \in S} [P_i(E_i) + B_i(E_N)].$$

The core of this game (the γ-core) is shown to be non-empty for certain classes of games by Chander and Tulkens (1997). This result is extended to standard convexity assumptions by Helm (2001).

First-mover advantage

We changed the optimization problem slightly:

$$\max_{(E_i)_{i\in S}} \sum_{i\in S}[P_i(E_i) + B_i(E_N)]$$

$$s.t. \;\; E_j = \arg\max_{E_j} \;\; P_j(E_j) + B_j(E_N) \;\; \forall j \notin S$$

- When calculating its optimal emission vector, the coalition no longer takes the emissions of non-members as given, but takes their best-reply functions into account.
- Non-members take the emissions of the coalition as given.
- In the economic model of Stackelberg competition, S is the leader and non-members are followers.
- The associated characteristic function was called v^{ϕ} by Marini and Currarini (2003).

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Theoretical results

As the coalition is in a better position in the Stackelberg model, we have

$$v^{\phi}(S) \geq v^{\gamma}(S) \quad \forall S \subset N.$$

Let $\mathcal{C}^{\phi}$ and $\mathcal{C}^{\gamma}$ be the cores of the corresponding games. Then we have

$$\mathcal{C}^{\phi} \subset \mathcal{C}^{\gamma}.$$

Marini and Currarini (2003) showed that the inclusion is strict and that the ϕ-core can be empty for certain parameters.

Quadratic analysis

For our analysis, we use quadratic and symmetric functions

$$P_i(E_i) = P^0 - \mu(E^0 - E_i)^2$$
$$B_i(E_N) = B^{max} - \pi E_N^2,$$

with

- Baseline production P^0 (in monetary units).
- Baseline emissions E^0.
- Abatement cost parameter $\mu > 0$ (in $\frac{\text{money}}{\text{emissions}^2}$).
- Maximal environmental benefits B^{max} (in monetary units). This level is reached for zero global emissions.
- Vulnerability parameter $\pi > 0$ (in $\frac{\text{money}}{\text{emissions}^2}$).

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Quadratic analysis II

We check if the symmetric allocation lies in the core, i.e.

$$v^{\phi}(S) \leq \frac{s}{n} v^{\phi}(N) \quad \forall s = 1, .., n-1$$

This leads to

$$\frac{\pi}{\mu} \leq \frac{n+s-2}{n-s}.$$

This quotient is monotonically increasing in s, so $s = 1$ is the only relevant case. Therefore, this is necessary and sufficient condition for non-emptiness of the core.

Quadratic analysis III

In the case of $s = 1$, the condition simplifies to

$$\pi \leq \mu.$$

This means that higher damage costs lead to „less cooperation".

Interpretation:

- If damages are high enough, countries will abate enough by themselves, so no cooperation is needed.
- The members of the Stackelberg leader coalition have the advantage of forcing non-members to emit less, by emitting more themselves. This mechanism works even better when damages are high.

Conclusion

- Standard Chander / Tulkens γ-game has non-empty core.
- Introducing first-mover advantage for the coalition can cause an empty core for certain parameter combinations.
- In this situation a high damage cost parameter leads to "less cooperation".
- In numerical simulations, this carries over to the non-symmetric case.

Thank you!