Self-enforcing climate coalitions for farsighted countries: integrated analysis of heterogeneous countries

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Introduction

- Global warming and three decades of climate negotiations
- Signatories commit to maximising payoffs of all coalition members in choosing their emission reduction levels.
- Different levels of ambition in emission reduction by different climate coalitions
- We model negotiations of countries to form climate coalitions.
- We capture broad incentives of policymakers of countries.
- Our policymakers are **farsighted**.
- We allow for **heterogeneity** across countries.

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Contribution

- The problem of coalition formation of heterogeneous countries can be **decoupled**:

    1. number of coalitions and number of signatories
    2. composition of signatories in each coalition

- About numbers: In climate coalition formation + Integrated Assessment Model (IAM), we offer a simple algorithm to **fully characterise** the equilibrium number of climate coalitions and their number of signatories.

- About composition:

  we identify the most emission-**efficient** coalitional setting,

  the countries prefer to give rise to efficient coalitions.

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- The algorithm relies on Tribonacci numbers

$$\{1, 2, 4, 7, 13, 24, ...\}$$

- The **policy** message:
  - allow multiple climate coalitions!
  - large coalitions can be stable.

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Introduction

Model

- The economy
- Climate coalition formation

Analysis

- Action stage
- Membership decision

Conclusion

Setup

- Country $i \in I$, and set of countries is $I \equiv \{1, 2, ..., N\}$
- Time is discrete and infinite, $t = 0, 1, 2, ...$
- Each country has a planner, who represents it in climate negotiations and can implement desired outcomes in a decentralised economy
- Open membership and binding

Timeline

- Two-stage climate coalition formation
  - Beginning of period *t*: **membership stage**
  - From end of period *t* onward: **action stage**

    → emission reduction decisions within coalitions
    → country-level decisions

- At the end of each period emissions are observed and payoffs are realised.

The economy of each country i

- Planner of i maximises the lifetime utility of a representative household: $U(C_{it})$
- Energy is sources from exhaustible fossil fuels, R_{it}.
- Total emissions, E_t, linearly increase global temperature, which negatively affects TFP of production of final output.
- Heterogeneity with respect to TFP, K_{i0}, R_{i0}.

Golosov et al. (2014, ECTA)

Climate coalition formation

- **Coalition structure** is a partition of set I into coalitions, $\mathbb{M} \equiv \{M_1, M_2, ..., M_k\}$.
- m is number of signatories of M.
- **Numerical coalition structure**, $\mathcal{M} \equiv \{m_1, m_2, ..., m_k\}$.
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Solution concept

- Pure strategy Markov Perfect equilibrium

  current state: the formed coalitions (if any); identity (and number) of those negotiating (if any); proposal (if ongoing or signed); cumulative emissions; K_{it}; and μ_{it}.

- Strategies of country i: as P; as R; action stage strategies: $\{E_{it+\tau}(M, \mathbb{M}), C_{it+\tau}(M, \mathbb{M}), K_{it+\tau+1}(M, \mathbb{M}), R_{it+\tau+1}(M, \mathbb{M})\}_{\tau=0}^{\infty}$

- Farsightedness (Ray and Vohra, 1997)

Action stage

$\hat{\Lambda}(m) \equiv \frac{\xi \gamma m}{1-\beta}$ is per-unit SCC

μ_{it}: per-unit scarcity rent

The m member of coalition M maximise,

$$\sum_{i \in M} \sum_{\tau=0}^{\infty} \beta^t \{U(C_{it+\tau})\}$$

subject to: resource constraint and feasibility constraint

Proposition

- Optimal unique emission of $i \in M$, $E_{it}(m)$ negatively depends on $\hat{\Lambda}(m)$, and μ_{it}.
- Emission strategies are **dominant** against what other coalitions choose.

Membership decision

- **Optimum-value function** of $i \in M$ is $V_i(M, \mathbb{M})$

Farsighted countries

- $\mathbb{M}^*$ is immune to unilateral and multilateral deviations by
  - the deviating group
  - the active players in the negotiation room
- The equilibrium $\mathbb{M}^*$ needs to be found **recursively**:
  if $N = 2$, then $\mathbb{M}^* =?$. Then if $N = 3$, $\mathbb{M}^* =?$. Then, if ... . [if symmetric: $\mathcal{M}^*$]
- We check for which group of countries, a grand coalition forms in equilibrium.

- In a stage of recursion, suppose j is initial P and compares $M \in \{M_1, M_2, ..., M_k\}$ versus $\{I\}$:

$$\sum_{i=1}^{m} V_i^j(M, \mathbb{M}) - \sum_{i=1}^{m} V_i^j(I)$$

- This is independent of any stocks and TFP.

  $\Rightarrow$ membership decisions are independent of heterogeneity w.r.t. K_{i0} and TFP.
- This linearly depends on **emissions** only.
- membership decisions are independent of heterogeneity w.r.t. μ_{it} if $\beta \to 1$

  $\Rightarrow$ the comparison reduces to

$$V_i^j(m, \mathcal{M}) - V_i^j(N)$$

- This is as if they were symmetric.
  1. focus on equilibrium numerical coalition structure
  2. composition and efficiency

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  1. focus on equilibrium numerical coalition structure
  2. composition and efficiency

- $\mathcal{T}^*$ is the set of N for which a grand coalition forms in equilibrium.

- $D(N) = \{m_1, m_2, ..., m_k\}$ is **decomposition** of N, such that m_k is the largest integer in $\mathcal{T}^*$ that is strictly smaller than N. Then any other element is the largest integer that is no greater than $N - \sum_{j=i+1}^{k} m_j$.

- Example: if $N = 3$, and $\mathcal{T}^* = \{1, 2\}$, in equilibrium $\{3\}$ forms or $\{2, 1\}$ or $\{1, 1, 1\}$?
  - Because $D(3) = \{1, 2\}$, then ~~$\{1, 1, 1\}$~~

Lemma

Let $D(N) = \{m_1, m_2, ..., m_k\}$, such that m_1 is the smallest element of $D(N)$. If $\beta \to 1$, then independent of source of heterogeneity, a grand coalition forms in equilibrium if

$$\frac{N}{m_1} < e^{(k-1)}$$

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Proposition

If $\beta \to 1$, for any number of heterogeneous countries, a grand coalition occurs in equilibrium if N is an element of

$$\mathcal{T}^* = \{1, 2, 4, 7, 13, 24, 44, 81, 149, 274, ...\} \tag{1}$$

which is the Tribonacci sequence.

- if $N \in \mathcal{T}^*$, then $\mathcal{M}^* = \{N\}$
- if $N \notin \mathcal{T}^*$, then $\mathcal{M}^* = D(N)$

The equilibrium number of signatory, m^*, in any coalition is a Tribonacci number.

Example. If $N = 195$ then $\mathcal{M}^* = \{149, 44, 2\}$.

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Composition of countries in coalitions

- Assume countries are heterogeneous w.r.t. μ_{it}
- Equilibrium payoffs and global temperature depend on identity of P and the composition of countries in coalition.

Example. $I = \{1, 2, 3, 4, 5, 6\}$ and $\mu_{it} > \mu_{i+1t}$
The most efficient $\mathbb{M}^* = \{\{1, 2\}\{3, 4, 5, 6\}\}$

Proposition. Assume that the grand coalition is not stable, and the initial proposers make acceptable offers with probability one. Then for any β, countries prefer coalitions with lowest global emissions among all possible coalition structures with the same numerical coalition structure.

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Conclusion

- Decoupling result: characterising $\mathcal{M}^*$ independent of composition
- Capturing various aspects of climate negotiations:

  farsightedness $+$ heterogeneity $+$ economic growth $+$ general equilibrium $+$ climate dynamics
- A simple algorithm to fully characterise $\mathcal{M}^*$ in climate coalition $+$ IAM
- Climate coalitions with Tribonacci number of signatories in equilibrium
- Suggesting a more ambitious architecture for climate treaties