Participation and Duration of Environmental Agreements: Investment lags matter

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Introduction

Motivation

- Climate change (and other environmental problems)
  - Global problem
  - National policies

  $\Rightarrow$ Public good problem
- Without cooperation: Free-riding implies inefficient solution
- No global authority to enforce cooperation
- Cooperation via international environmental agreements (IEA)
  - (Sub)global coalition of countries
  - Cooperation must be self-enforcing
- IEAs are studied since decades
  - Static models: Hoel (1992), Barrett (1994), Hoel & de Zeeuw (2010)
  - Dynamic models: Barrett (1999), Rubio & Casino (2005), Rubio & Ulph (2007)
- Core result: IEAs are either small and deep or large and shallow

Battaglini & Harstad (2016)

- Large IEA can be stable
- Incomplete contract → only emissions, not green investments
- Important assumptions
  - No time lag with respect to emissions
  - Time lag with respect to green investments
- Real world data
  - Climate damages of CO_2 reach maximum 5-10 years after release of emissions
  - Solar and onshore wind: within 2 years
  - Offshore wind: 4 to 13 years
  - Hydroelectric power: 5 to 10 years or more
- Our approach
  - Two kinds of green investments
  - Long investment lag
  - Short investment lag

The Model

Assumptions

- n country model in discrete time with linear-quadratic functions
  - Climate coalition M
  - Fringe $L = N - M$
- Utility of country i in period t depends on sum $y_{i,t}$ of fossil fuel energy $g_{i,t}$ and renewables $R_{i,t} + S_{i,t}$

$$B_i(y_{i,t}) = -\frac{b}{2}\left[\bar{y}_i - g_{i,t} - R_{i,t} - S_{i,t}\right]^2$$

- Climate Damage
  - Climate Damages cG_t depends on CO_2 stock G_t
  - CO_2 accumulates in the atmosphere according to

$$G_t = q_G G_{t-1} + \sum_{j \in N} g_{j,t}$$

Assumptions

- Renewables require production capacities $R_{i,t}$ and $S_{i,t}$
  - Long-lag investments: Capacity investments r_i realize in next period
$$R_{i,t} = q_R R_{i,t-1} + r_{i,t-1}$$
  - Short-lag investments: Capacity investments s_i realize within period
$$S_{i,t} = q_S S_{i,t-1} + s_{i,t}$$
- Investment costs

$$\kappa_R(R_{i,t}, R_{i,t-1}) = \frac{k_R}{2}\left[R_{i,t}^2 - q_R^2 R_{i,t-1}^2\right]$$
$$\kappa_S(S_{i,t}, S_{i,t-1}) = \frac{k_S}{2}\left[S_{i,t}^2 - q_S^2 S_{i,t-1}^2\right]$$

Timing

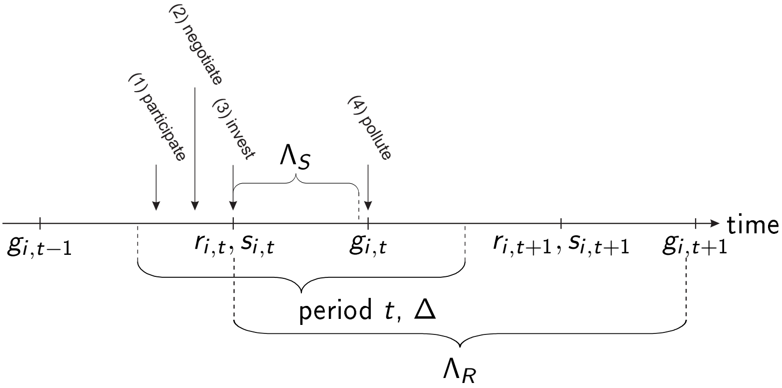

Figure: Timing in the game

Value function and contract types

- Value of Country i given by

$$v_i = \sum_{\tau=t}^{\infty} \delta^{\tau-t} \left[-\frac{b}{2}(\bar{y}_i - g_{i,\tau} - R_{i,\tau} - S_{i,\tau})^2 - C \sum_{j \in N} g_{j,\tau} - \frac{K_S}{2} S_{i,\tau}^2 - \frac{K_R}{2} R_{i,\tau+1}^2 \right]$$

- Complete Contract: Coalition countries coordinate emissions $g_{i,t}$ and capacities (investments) $R_{i,t+1}$, $S_{i,t}$
- Incomplete Contract: Coalition countries only coordinate emissions $g_{i,t}$
- Coalition contract signed for T periods
- Markov-perfect equilibria and stability concept of d'Aspremont et al. (1983)

Benchmark

- First best (FB)

$$g^{FB}_{i,t} = \bar{y}_i - n\frac{C}{K_S} - n\frac{C}{b} - R_{i,t}$$

$$S^{FB}_{i,t} = n\frac{C}{K_S}$$

$$R^{FB}_{i,t+1} = n\frac{\delta C}{K_R}$$

- Business as usual (BAU) - Fringe

$$g^{BAU}_{i,t} = \bar{y}_i - \frac{C}{K_S} - \frac{C}{b} - R_{i,t}$$

$$S^{BAU}_{i,t} = \frac{C}{K_S}$$

$$R^{BAU}_{i,t+1} = \frac{\delta C}{K_R}$$

Complete Contract

Policy and Stability

- Coalition's Policy

$$g_{i,t} = \bar{y}_i - m\frac{C}{K_S} - m\frac{C}{b} - R_{i,t}$$
$$S_{i,t} = m\frac{C}{K_S}$$
$$R_{i,t+1} = m\frac{\delta C}{K_R}$$

- Stable coalition of $m^* \in \{2, 3\}$

Incomplete Contract

Timing of Decisions

- Coalition signs T period-contract
- Contract coordinates emissions $g_{j,t}$ for all $j \in M$ and for all $t \in \{1, \dots, T\}$
- Coalition members choose investments $r_{i,t}$ and $s_{i,t}$ at investment-stage (3) in every period $t \in \{1, \dots, T\}$
- Stackelberg game with coalition as leader and members as followers
- Solution via backward induction

Policy

- Emissions and Investments

$$
\begin{aligned}
g_{i,t} &= \bar{y}_i - m\frac{C}{K_S} - m\frac{C}{b} - R_{i,t}, \quad t \in \{1, \ldots, T\} \\
S_{i,t} &= m\frac{C}{K_S}, \quad t \in \{1, \ldots, T\} \\
R_{i,t} &= m\frac{\delta C}{K_R}, \quad t \in \{2, \ldots, T\} \\
R_{i,T+1} &= \frac{\delta C}{K_R}
\end{aligned}
$$

- Hold-up problem in last contract period with respect to long-lag investments
- No hold-up problem with respect to short-lag investments

Contract Length

- Contract holds for
  - $T^* = 1$ period if $m < \hat{m}$
  - $T^* \in \{1, \ldots, \infty\}$ periods if $m = \hat{m}$
  - $T^* = \infty$ periods if $m > \hat{m}$
- Stable coalition signs unlimited contract ($m^* > \hat{m}$)
- Disciplinary constraint: If

$$m^* < m_M = 1 + \frac{1}{1 - \left[\frac{\frac{K_R}{b\delta} + \frac{K_R}{\delta K_S} + \delta}{\frac{K_R}{b\delta} + \frac{K_R}{\delta K_S} + 1} \right]^{0.5}}$$

deviation of one coalition country leads to $T^* = 1$

Stability

- If disciplinary constraint violated, $m^* \in \{2, 3\}$
- If disciplinary constraint satisfied, either $m^* \leq \min\{m_M, n\}$ or $m^* \leq \min\{m_M, m_I, n\}$ with

$$m_I = 3 + \frac{2\delta}{\frac{K_R}{b\delta} + \frac{K_R}{\delta K_S} - \delta}$$

- Mechanism
  - If disciplinary constraint holds, coalition countries credibly threaten to sign short-term contract if one country defects
  - Hold-up problem arises: Long-lag investments reduced
  - Increase of climate damages
  - Incentive to stay in coalition

Stability

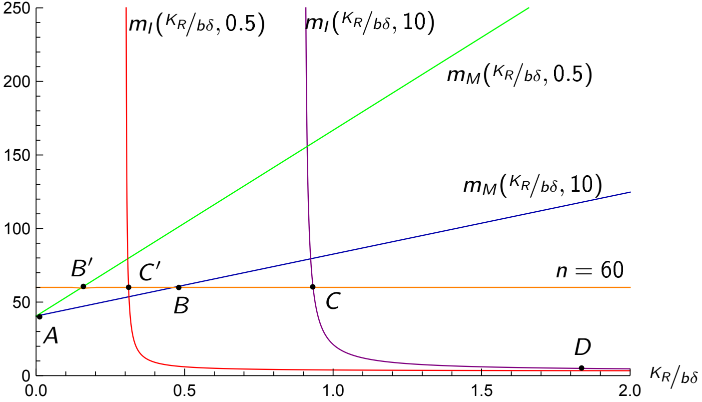

Figure: The size of the stable coalition m^* for $\delta = 0.95$ and $n = 60$

Stability

- Disciplinary constraint is relaxed if short-lag investments become cheaper
- Internal stability constraint is tightened if short-lag investments become cheaper
  - More short-lag investments, long-lag investments unchanged
  - Hold-up problem exists and unchanged
  - Relative strength of hold-up problem reduced due to more energy usage
  - Coalition countries: Disciplinary constraint relaxed
  - Defecting country: Internal stability condition tightened
- Effect of dK_S on internal stability conditions outweighs effect on disciplinary constraint
- Threshold $\bar{K}_S(K_R) = \frac{K_R}{3\delta^2 - \frac{K_R}{b}}$ for $m^* \in \{2, 3\}$

Conclusion

Conclusion

- Capacity with short investment lag in Battaglini and Harstad (2016)
- Incomplete contracts: Stability negatively affected by cheap short-lag investments
- Potential of incomplete climate contracts may be more limited than expected

Thank You

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