Sober optimism and the formation of international environmental agreements

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Introduction

Motivation

Literature

Our contribution

Motivation

Paradox of international agreements

In theory:

- the standard non-cooperative-game analysis concludes that **building large and effective IEAs is difficult when the potential gains from cooperation are large** (Hoel, 1992; Carraro and Siniscalco, 1993; Barrett, 1994).

yet in reality (although the record is mixed):

- existing international agreements have attracted many participants and some of them have played an important role (Breitmeier et al., 2006; Young, 2011).

Static models

Large and effective IEAs are possible if we consider:

- trade sanctions or social norms (Barret, 1997; Hoel and Schneider, 1997);
- money transfers (Barrett, 2001; Carraro et al., 2006);
- increasing-return-to-scale technology (Barrett, 2006);
- concave marginal cost function (Karp and Simon, 2013),

suggesting that **IEAs require special circumstances to succeed**.

Literature

Dynamic models

Repeated participation games can also generate large IEAs if

- countries commit to trigger strategies (Barrett, 2003);
- countries can sign a binding long-term agreement to avoid a hold-up problem (Battaglini and Harstad, 2016); or
- deviation causes a costly delay of long-term agreements (Kovac and Schmidt, 2017).

The trigger strategies assume **self-harming out-of-equilibrium behaviors** and the endogneous duration models rely on countries' **commitment ability** or on **costly delay**.

Our contribution

This paper

A dynamic model of international agreements with:

- a general reduced-form payoff function;
- no side payments or sanctions;
- no self-harming punishment, long-term commitment, or costly delay.

which nonetheless explains the paradox:

- **effective agreement with many participants** can emerge;
- yet negotiation may yield **a succession of short-lived ineffective agreements along the way**.

Our contribution

Key observation

Uncertainty due to **multiplicity of equilibria**:

- participants in the negotiation do have a sense of what could possibly emerge at the end of the process;
- but they are unsure about what exactly comes out of it (Benedick, 1998);

indicating that **the same negotiation opportunity may yield different outcomes** (a random variable).

Our contribution

Formalizing the idea

In our model,

- players can review and reject a previously signed international agreement every period;
- abandoning the existing agreement is followed by a new round of negotiation, the result of which is uncertain;
- players share a common belief (prob. distribution) about which equilibrium outcome emerges;
- equilibrium belief must be rationalizable in the sense that an outcome is believed to be possible if and only if it is Nash.

Our contribution

Results

Equilibrium belief is not unique and is **self-fulfilling**:

- believing that a large coalition is (im)possible makes it actually (im)possible to achieve a large coalition, reaffirming the belief;
- a successful IEA requires sober optimism: the understanding that cooperation is possible in the end, but not easy to achieve.

This result emphasizes the important role of communication (on top of the model's primitives) through which players share the sense of what they can achieve.

Model

Reduced form

Static setting

Dynamic setting

Assumptions

Reduced form

Building blocks

The model is described by a list $\langle \delta, N, (u_i)_{i \in N} \rangle$, where

- $\delta \in (0, 1)$ is the discount factor;
- N is the set of players with cardinality $n := |N| \geq 4$;
- $u_i : \mathcal{N} \to \mathbb{R}$ is the payoff of player $i \in N$ where $\mathcal{N}$ is the set of all subsets of N.

The discounted present-value payoff is

$$\sum_{s=t}^{\infty} \delta^{s-t} u_i(M_s),$$

where $M_s \in \mathcal{N}$ is the agreement (coalition) effective at period s.

Reduced form

Example 1

Consider a game with the (non-reduced-form) payoff function

$$-\frac{1}{\gamma}(\bar{g}_i - g_i)^\gamma - c\sum_{j\in N} g_j$$

for some $\gamma > 1$ and $c > 0$, where g_i is a control variable. Assuming that members of a coalition jointly maximize their aggregate payoff, we may write the reduced-form payoff as

$$u_i(M) \propto \begin{cases} |M|^{\frac{\gamma}{\gamma-1}} - |M| + n - \frac{1}{\gamma}|M|^{\frac{\gamma}{\gamma-1}} & \forall i \in M \\ |M|^{\frac{\gamma}{\gamma-1}} - |M| + n - \frac{1}{\gamma} & \forall i \notin M \end{cases}$$

for each $M \in \mathcal{N}$.

Static setting

Review: Stable coalitions

A coalition $M \in \mathcal{N}$ is said to be ***stable*** if

$$i \in M \iff u_i(M \cup \{i\}) \geq u_i(M \setminus \{i\}), \tag{1}$$

where

- $\Rightarrow$ implies that M is ***internally stable***;
- $\Leftarrow$ implies that M is ***externally stable***.

Denote $\mathcal{M} \subset \mathcal{N}$ as the set of all stable coalitions, namely,

$$\mathcal{M} := \{M \in \mathcal{N} \mid M \text{ satisfies } (1)\},$$

which in general is not a singleton.

Static setting

Stable coalitions in Example 1

For Example 1, there exists integer $m_* \geq 2$ such that:

- M is stable if and only if $|M| = m_*$;
- the value of m_* is weakly decreasing in γ (a measure of the convexity of the abatement cost function).

In this example, the set $\mathcal{M}$ of stable coalitions contains $C^n_{m_*} := \binom{n}{m_*}$ different outcomes of the game (same size, but different members).

Static setting

Common belief

Provided that $\mathcal{M}$ is not a singleton, **the outcome of negotiation is uncertain**. We describe this uncertainty by a probability distribution $\pi = (\pi_M)_{M \in \mathcal{M}}$ defined over $\mathcal{M}$.

- π may be purely subjective, reflecting a **common belief** (shared in the pre-negotiation phase) about the outcome; or
- π can be viewed as a **randomization device** that players agree to use to promote coordination.

The ex-ante payoff under π (prior to negotiation) is

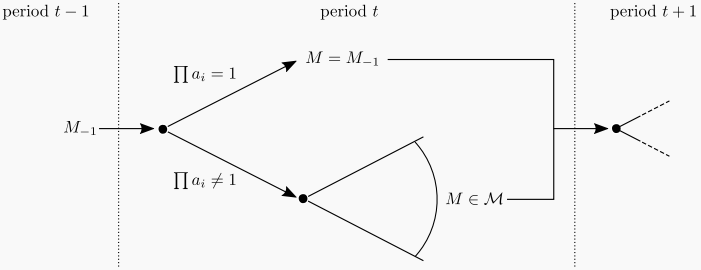
$$\mathbb{E}_\pi \left[u_i(\tilde{M}) \right] := \sum_{M \in \mathcal{M}} u_i(M) \pi_M.$$

Dynamic setting

Extension to a dynamic setting

Each period has two stages:

1. players use a Markovian strategy a_i to determine if they stick with M_{-1} ($a_i(M_{-1}) = 1$) or not ($a_i(M_{-1}) = 0$);
2. if $\prod_{i \in N} a_i(M_{-1}) \neq 1$, they move on to the second stage where they play the standard participation game.



Dynamic setting

Second stage

A coalition $M \in \mathcal{N}$ is a stable outcome of the second-stage participation game if

$$i \in M \iff \begin{array}{c} u_i(M \cup \{i\}) + \delta V_i(M \cup \{i\}) \\ \geq u_i(M \setminus \{i\}) + \delta V_i(M \setminus \{i\}), \end{array} \tag{2}$$

where V_i is the value function. The set of stable coalitions is therefore

$$\mathcal{M} := \{M \in \mathcal{N} \mid M \text{ satisfies (2) given } (V_i)_{i \in N}\}, \tag{3}$$

which is in general not a singleton (can be bigger in the dynamic setting).

Dynamic setting

First stage

Policy functions $(a_i)_{i \in N}$ must satisfy

$$a_i(M_{-1}) \in \underset{a_i \in \{0,1\}}{\operatorname{argmax}} \Big\{ \left[u_i(M_{-1}) + \delta V_i(M_{-1})\right] a_i + \mathbb{E}_\pi \left[u_i(\tilde{M}) + \delta V_i(\tilde{M}) \right] (1 - a_i) \Big\}. \tag{4}$$

Equilibrium

Policies $(a_i)_{i \in N}$ and belief $(\pi_M)_{M \in \mathcal{M}}$ simultaneously determined:

- given $(\pi_M)_{M \in \mathcal{M}}$, policy functions $(a_i)_{i \in N}$ must solve (4);
- given $(a_i)_{i \in N}$, belief $(\pi_M)_{M \in \mathcal{M}}$ must be rationalizable.

Assumptions

Symmetry

To simplify the analysis,

- we assume that the reduced-form payoff functions $(u_i)_{i \in N}$ are symmetric;
- we focus on a class of equilibria where π treats players symmetrically.

Externality

As in the parametric examples, the one-shot game has a unique size m_* of stable coalitions.

Results

Equilibrium with a single coalition size

Equilibrium with multiple coalition sizes

Extension with a stock variable

Conclusions

Equilibrium with a single coalition size

Proposition 3.1

The Markovian policy function defined by

$$a_i(M_{-1}) = \begin{cases} 1 & \text{if } |M_{-1}| \geq l^* \geq m_* \text{ and } i \in M_{-1} \\ 1 & \text{if } |M_{-1}| \geq m_* \text{ and } i \notin M_{-1} \\ 0 & \text{otherwise} \end{cases}$$

together with the common belief given by

$$\pi_M = 1/C^n_{m_*} \quad \forall M \in \mathcal{M} := \{M \in \mathcal{N} \mid |M| = m_*\}$$

constitutes an equilibrium if and only if the discount factor δ is smaller than a threshold value.

Equilibrium with multiple coalition sizes

Proposition 3.2

For each $m^* > m_*$, the following are equivalent:

a) there exists a symmetric belief $(\pi_M)_{M \in \mathcal{M}}$ with

$$\mathcal{M} = \{M \in \mathcal{N} \mid |M| \in \{m_*, m^*\}\}$$

such that the policy functions

$$a_i(M_{-1}) = \begin{cases} 1 & \text{if } |M_{-1}| \geq m^* \text{ and } i \in M_{-1} \\ 1 & \text{if } |M_{-1}| \geq k^* \in [m_*, m^*] \text{ and } i \notin M_{-1} \\ 0 & \text{otherwise} \end{cases}$$

constitutes an equilibrium;

b) the discount factor δ is greater than a threshold value δ_{m^*}.

Equilibrium with multiple coalition sizes

Equilibrium beliefs: sober optimism

Probability of reaching a larger agreement (of size m^*) must be:

- not too small (players cannot be too pessimistic) in order for a large coalition to be signed (otherwise they cannot set the bar high enough);
- not too large (players cannot be too optimistic) in order for the coalition to be used thereafter.

A successful agreement requires **sober optimism**: the understanding that cooperation is possible but not easy to achieve.

Equilibrium with multiple coalition sizes

Proposition 3.3

The support of any symmetric equilibrium belief contains coalitions with at most two distinct sizes.

Extension with a stock variable

Structural models

We also consider the extended model with a stock variable G, for which the equation of motion is

$$G_t = F(\boldsymbol{g}_t, G_{t-1})$$

for some function F. The discounted present-value payoff of player i at period t is

$$\sum_{s=t} \delta^{s-t} \Phi_i(\boldsymbol{g}_s, G_s).$$

Extension with a stock variable

Propositions 4.1 & 4.2: Isomorphism

Under a set of assumptions, **the structural models (with a stock variable) are isomorphic to the reduced-form models**.

Linear-in-state model

The key assumption is **linearity in state**:

- the per-period payoff function is

$$\Phi_i(\boldsymbol{g}_t, G_t) = \phi_i(\boldsymbol{g}_t) - cG_t$$

- the equation of motion for G is

$$F(\boldsymbol{g}_t, G_{t-1}) = f(\boldsymbol{g}_t) + \sigma G_{t-1}$$

Extension with a stock variable

Example 2: Stylized climate-economy model

A simplified version of Battaglini and Harstad (2016):

$$\Phi_i(\boldsymbol{g}, G) = -\frac{1}{2}(\bar{g}_i - g_i)^2 - cG$$

and

$$F(\boldsymbol{g}, G_{-1}) = \sum_{i \in N} g_i + \sigma G_{-1}.$$

This model, after being transformed into the associated reduced-form model, coincides with Example 1 with $\gamma = 2$.

Extension with a stock variable

Example 3: DSGE-type integrated assessment model

A variant of Golosov et al. (2014) and Traeger (2015):

$$\sum_{s=t}^{\infty} \delta^{s-t} \ln(C_{i,t}),$$

$$K_{i,t} = Y_{i,t} - C_{i,t},$$

$$Y_{i,t} = e^{-cG_t} A_{i,t-1} K_{i,t-1}^{\kappa} H_i(N_{i,t}^1, \ldots, N_{i,t}^L),$$

$$g_{i,t} = E_i(N_{i,t}^1, \ldots, N_{i,t}^L),$$

for some functions $H_i(\cdot)$ and $E_i(\cdot)$. This model can be transformed into a linear-in-state model.

Conclusions

International agreements with sober optimism

Contrary to the commonly held pessimistic view (which may be self-fulfilling), countries can cooperate in the presence of a free-rider problem:

- no explicit sanctions or money transfers required;
- no long-term commitment ability assumed;
- based on a general reduced-form model;
- applicable to structural models with stock variables,

which **casts doubt on the conventional wisdom that special circumstances are needed for IEAs to succeed**. Beliefs are important, and communication matters.