Pledge-and-Review Bargaining

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Introduction

-The pledge-and-review strategy is completely inadequate.

Christian Gollier and Jean Tirole
The Economist (guest blog)
June 1st, 2015

The 1997 Kyoto Protocol

- 37 committed countries, reducing emissions by 5% (on average)
- "Top-down" negotiations, standard/conditional bargaining, often approximated by the Nash Bargaining Solution:

$$\max_{\{x_i\}} \prod_{j \in N} U_j \left(x_i, \mathbf{x}^*_{-i} \right)$$

- Axiomitized by Nash '50
- *Nash demand game* provides a noncooperative solution (Nash '53, Binmore '87)
- *Alternating offer bargaining* provides another (Rubinstein '82, Binmore et al. '86), even with many parties (Khrishna and Serrano '96, Kawamori '14, Britz et al. '10, Okada '10, Laruelle and Valenciano '08)

The 2015 Paris Agreement

- "Now, instead of setting commitments trough centralized bargaining, the Paris approach sets countries free to make their own commitments." David G. Victor
- §22. Invites Parties to communicate their first nationally determined contribution no later than when the Party submits its respective instrument of ratification, accession, or approval of the Paris Agreement. If a Party has communicated an intended nationally determined contribution prior to joining the Agreement, that Party shall be considered to have satisfied this provision
- “It is the pledge and review system which will become the template for future climate change action.” The Guardian, Nov 23rd, 2015

Introduction

	Kyoto '97	**Paris '15**
(1)	"Top down" Comparable cuts (5%)	"Bottom up" pledges: Nationally determined contributions
(2)	n=37	n=195
(3)	Legally binding	Not legally binding
(4)	Chosen in the 1990s	Chosen in the 2010s
(5)	5y period 2007-2012	5y periods

	Outline	Paris '15
(1)	Pledge bargaining a (general) model	"Bottom up" pledges: Nationally determined contributions
(2)	Participation	n=195
(3)	Self-enforcing?	Not legally binding
(4)	Choice of bargaining game	Chosen in the 2010s
(5)	Commitment period length	5y periods

Literature (incomplete and preliminary)

1. Nash Bargaining Solution (in Nash '50, Kalai '77)
   - Nash demand game provides a noncooperative solution (Nash '53, Binmore '87), also with strategic uncertainty (Carlsson '91, Andersson et al. '17, Abreu and Pearce '15).
   - Alternating offer bargaining provides another (Rubinstein '82, Binmore et al. '86, Kawamori '14)
   - **Here:** Pledge-and-review provides an asymmetric (and inefficient) NBS.
2. Dynamic games with emissions, negotiations, and technology
   - Some early models by Dutta and Radner '04, '06, '09, and my own work (Harstad '12, '15, and Battaglini and Harstad '15) assume efficient negotiations.
   - **This paper** studies the bargaining failure's foundation and consequences.
3. Participation
   - Small coalitions ($n^*=3$) predicted by Hoel '92, Barrett '94, Carraro and Siniscalco '93
   - Battaglini and Harstad '15 predict larger coalitions when the participants can decide on the period length. (This effect is abstracted from here.)
   - **This paper** generalizes results on the trade-off between depth and breadth (f.ex. Finus and Maus '08), provides a foundation for "modesty" in bargaining, and discusses implications for investments and period length.

1. Pledge Bargaining

1. All parties simultaneously pledge to contribute $x_i \in \mathbb{R}_+$.
2. The parties decides whether to accept $\mathbf{x} \equiv \{x_1, ..., x_n\}$.
    - If at least one party declines, the game restarts after delay Δ.
    - If every party accepts, each i receives the payoff $U_i(\mathbf{x})$.

- I assume U_i to be continuously differentiable, concave, and decreasing in x_i.
- With discount factor δ_i^Δ, $\rho_i \equiv \left(1 - \delta_i^\Delta\right)/\Delta$ is the 'discount rate'.
- Restrict attention to stationary SPEs.

1. Pledge Bargaining: Equilibrium Conditions

- Given an equilibrium $\mathbf{x}^*$, j accepts $\mathbf{x}$ if:

$$U_j(\mathbf{x}) \geq \left(1 - \rho_j \Delta\right) U_j(\mathbf{x}^*).$$

- Since i can always find $x_i \neq x_i^*$ and still satisfy this condition, we have the trivial equilibrium $x_i^* = \arg\max U_i\left(x_i, \mathbf{x}_{-i}^*\right) = 0$.
- In reality, it is uncertain what j is willing to accept.
- Assume $\rho_{j,t} = \theta_{j,t}\rho_j$. j accepts if:

$$\begin{aligned} U_j(\mathbf{x}) &\geq \left(1 - \theta_{j,t}\rho_j \Delta\right) U_j(\mathbf{x}^*) \Rightarrow \\ \theta_{j,t} &\geq \frac{U_j(\mathbf{x}^*) - U_j(\mathbf{x})}{\rho_j \Delta U_j(\mathbf{x}^*)}. \end{aligned}$$

- The $\theta_{j,t}$'s are jointly distributed with pdf $f(\boldsymbol{\theta}_t)$ on support $\times_j \left[0, \overline{\theta}_j\right]$ with mean 1 and marginal distribution $f_j(\theta_{j,t}) = \int_{\theta_{-j,t}} f(\boldsymbol{\theta}_t)$.
- With $\theta_{j,t}$, the probability of acceptance is continuous in x_i.

1. Pledge Bargaining: Result 1

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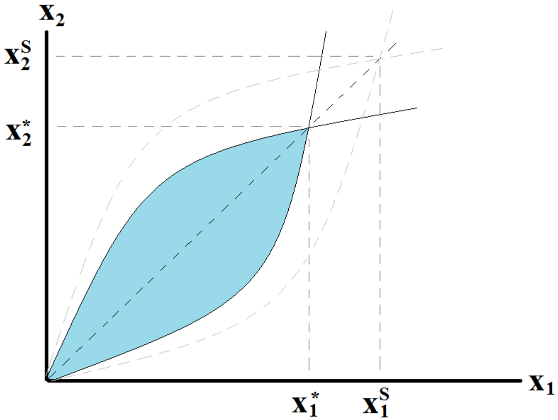
Theorem

- *If x^* is a nontrivial 'perfect' equilibrium, then, for every $i \in N$:*

$$\begin{aligned} x_i^* &= \arg\max_{x_i} \prod_{j \in N} U_j \left(x_i, \mathbf{x}_{-i}^* \right)^{w_j^i} \text{, where} \\ \frac{w_j^i}{w_i^i} &= \frac{\rho_i}{\rho_j} \cdot f_j(0) \cdot E\left(\theta_{i,t} \mid \theta_{j,t} = 0 \right), \, j \neq i. \end{aligned}$$

- Assuming *Small Trembles*: When x is intended, $x + \boldsymbol{\epsilon}_t$ is realized, where $\boldsymbol{\epsilon}_t$ is a vector of n shocks, each i.i.d. over time with mean zero and variance approaching zero.
- Otherwise, the equality should be replaced by $\leq$
- Alternatively: Assume that the support of $\theta_{j,t}$ is $\left[\underline{\theta}_j, \overline{\theta}_j \right]$ where $\underline{\theta}_j < 0$ and $\underline{\theta}_j \uparrow 0 \forall j$.

1. Pledge Bargaining: Result 1



If n=2, colored area describes equilibrium contribution levels, and x^* is unique, given trembles.

1. Pledge Bargaining: Corollaries

- **Corollaries to the Theorem and to the result**

$$
\begin{aligned}
x_i &= \arg\max_{x_i} \prod_{j \in N} U_j \left(x_i, \mathbf{x}^*_{-i} \right)^{w^i_j}, \text{ where} \\
\frac{w^i_j}{w^i_i} &= \frac{\rho_i}{\rho_j} f_j(0) \, \mathrm{E} \left(\theta_{i,t} \mid \theta_{j,t} = 0 \right), \; j \neq i.
\end{aligned}
$$

1. Given x^*_{-i}, x^*_i maximizes an Asymmetric Nash Product.
2. w^i_j varies with i, so the set $\mathbf{x}^*$ is not Pareto optimal.
3. Symmetric: $x^*_i = \arg\max \; U_i + \sum_{j \setminus i} wU_j$, $w = f(0)\mathrm{E}(\theta_{i,t} \mid \theta_{j,t} = 0)$.
4. Example E: $U_i = \alpha \sum_{j \neq i} x_j - \beta x_i^2 / 2 \Rightarrow x^*_i = w(n-1)\alpha/\beta$.
5. With symmetry and i.i.d. shocks, $w = f_j(0) < 1/2$.
6. If uncertainty vanishes, then $f_j(0) \to 0 \Rightarrow w \to 0$.

A Dynamic Game

- Article 4-9: "*Each Party shall communicate a nationally determined contribution every five years*"
- New technology/renewables can make earlier pledges undemanding
- But will the parties have *incentives* to develop such technologies?
- Assume utility is linear in emissions, quadratic in energy consumption from fossils ($g_{i,t}$) + renewables ($\widetilde{Y}_{i,t}$), and quadratic investment cost:

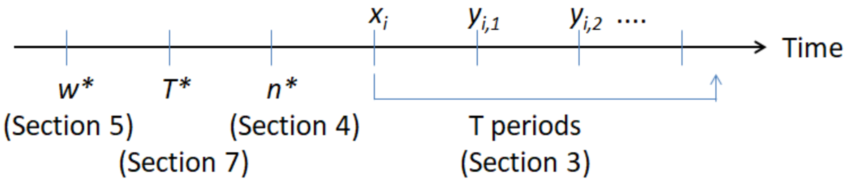
$$\begin{aligned}\widetilde{u}_{i,t} &= -c\sum_{j} g_{i,t} - \frac{b}{2}\left(E_i^* - E_{i,t}\right)^2 - \frac{k}{2}\widetilde{y}_{i,t}^2, \text{ where} \\ E_i &= g_{i,t} + \widetilde{Y}_{i,t} \text{ and } \widetilde{Y}_{i,t+1} = \widetilde{Y}_{i,t} + \widetilde{y}_{i,t}.\end{aligned}$$

- The "business as usual" (MPE) is

$$g_{i,t}^{BAU} = E_i^* - \widetilde{Y}_{i,t} - \frac{c}{b} \text{ and } \widetilde{y}_{i,t}^{BAU} = \frac{\delta c}{(1-\delta)\,k}.$$

- The pledge $x_i \equiv g_{i,t}^{BAU} - g_{i,t}$ commits i for T periods.
- Increase investments by $y_{i,t}$? An optimal control problem...

A Dynamic Game: Timing



A Dynamic Game: Investments

Lemma

In equilibrium, the stock $Y_{i,t}$ and the investment $y_{i,t}$ are both linear in x_i:

$$\begin{aligned}
Y_{i,t} &= x_i\left(1 - C_1 L_1^t - C_2 L_2^t\right), \text{ and, therefore,} \\
y_{i,t} &= x_i\left[C_1 L_1^t\left(1 - L_1\right) - C_2 L_2^t\left(L_2 - 1\right)\right], \text{ where} \\
L_1 &\equiv \frac{1 + 1/d + b/k}{2} - \sqrt{\left(\frac{1 + 1/d + b/k}{2}\right)^2 - \frac{1}{d}} \in (0,1) \\
L_2 &\equiv \frac{1 + 1/d + b/k}{2} + \sqrt{\left(\frac{1 + 1/d + b/k}{2}\right)^2 - \frac{1}{d}} > 1, \\
C_1 &\equiv \frac{L_2^{T-1}\left(L_2 - 1\right)}{L_2^{T-1}\left(L_2 - 1\right) + L_1^{T-1}\left(1 - L_1\right)} \in (0,1), \\
C_2 &\equiv \frac{L_1^{T-1}\left(1 - L_1\right)}{L_2^{T-1}\left(L_2 - 1\right) + L_1^{T-1}\left(1 - L_1\right)} = 1 - C_1 \in (0,1).
\end{aligned}$$

A Dynamic Game: Equilibrium

Lemma

Since every $y_{i,t}$ is linear in x_i, i's continuation value, relative to BAU, can be written as in Example E:

$$U_i(\mathbf{x}) = \sum_{t=0}^{\infty} \delta^t u_{i,t} = \alpha \sum_{j \neq i} x_j - \frac{\beta}{2} x_i^2, \tag{E}$$

where α and β are defined as

$$\alpha \equiv \frac{c}{1-\delta}\left[1 + \delta^T \left(1 - C_1 L_1^T - C_2 L_2^T\right)\right],$$

$$\beta \equiv \sum_{t=0}^{T-1} \delta^t \Big[\frac{b}{2}\left(C_1 L_1^t + C_2 L_2^t\right)^2 + \frac{k}{2}\left(C_1 L_1^t \left[1 - L_1\right] - C_2 L_2^t \left[L_2 - 1\right]\right)^2\Big]$$

- From the corollary, $x_i^* = w\,(n-1)\,\alpha / \beta$.

A Dynamic Game: Equilibrium

Proposition

- *A smaller w reduces contributions, investments, and welfare.*

- Payoffs are maximized when $w = 1$:

$$U_i = \frac{\alpha^2}{\beta} (n-1)^2 w \left(1 - \frac{w}{2}\right)$$

2. Participation and Free Riding

- The participation stage is standard (d'Aspremont et al., 1983, Hoel '92, Carraro and Siniscalco '93, Barrett '94):
  - Each $i \in \{1, ..., \overline{n}\}$ decides simultaneously whether to participate.
  - The participants continue by playing the game above.
  - The nonparticipating parties find it optimal to contribute $x_i = 0$.
- Every pure-strategy equilibrium is characterized by the same number n^* of participating parties.
  - The 'standard' result is $n^* \leq 3$ (when $w = 1$)
  - Exceptions (Finus and Maus '08, de Zeeuw '08, Karp and Simon '12, Battaglini and Harstad '15)

2. Participation and Free Riding: Result 2

Proposition

- *The equilibrium coalition size is larger if w is small:*

$$n(w) = \lfloor 1 + 2/w \rfloor \approx 1 + 2/w$$

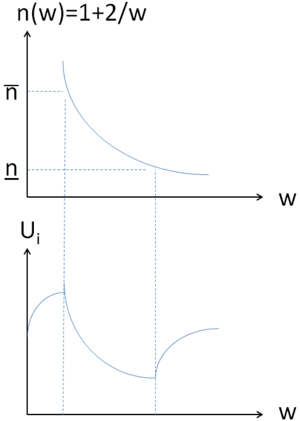
- *Proposition 1 is reversed: A smaller w increases aggregate contributions, investments, and welfare.*

- Payoffs decrease in w: $U_i = 4\frac{\alpha^2}{\beta}\left(\frac{1}{w} - \frac{1}{2}\right)$.

4. Institutional Choice and Development

- The level of w depends on the bargaining game.
- With an exogenous n, it is optimal with $w = 1$.
- With an endogenous n, it is optimal with a small w
- There is a trade-off between broad-but-shallow and narrow-but-deep if
  - There are relatively few countries: $\overline{n} < n(w) = \overline{n}$, or
  - There is a large number $\underline{n}$ of 'committed' parties (or minimum participation requirement)

4. Institutional Choice and Development: Result 4



- *If $\underline{n}$ is small and $\overline{n}$ large, then it is better with $\underline{w} < \overline{w}$ (so, pledge-and-review is better than top-down negotiations)*

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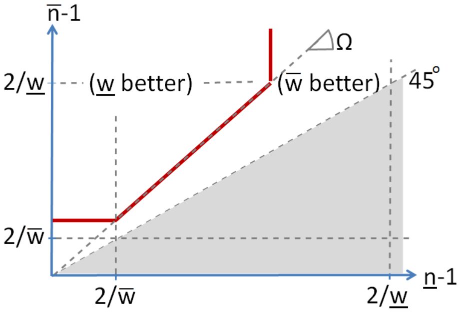

$$\Omega \equiv \sqrt{\frac{\overline{w}\,(1-\overline{w}/2)}{\underline{w}\,(1-\underline{w}/2)}} \in \left(1, \frac{\overline{w}}{\underline{w}}\right)$$

- *If $\underline{n}$ is small and $\overline{n}$ large, then it is better with $\underline{w} < \overline{w}$ (so, pledge-and-review is better than top-down negotiations)*

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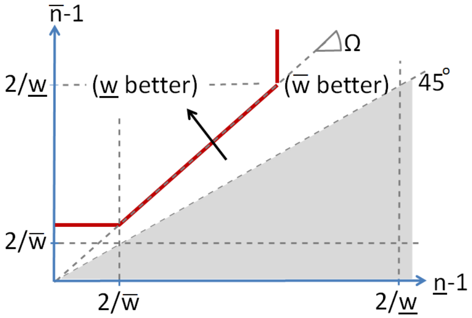
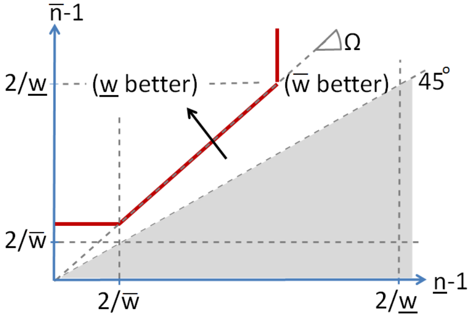


- Emerging economies are now more relevant for climate policy, so $\overline{n} \uparrow$
- Several signatories of Kyoto declined to participate in its second commitment period (Belarus, Ukraine, Japan, New Zealand, Russia, Canada, USA), so $\underline{n} \downarrow$

4. Institutional Choice and Development: Result 4



$$n(\underline{w}) \approx 195 \Leftrightarrow \underline{w} \approx \frac{1}{97}$$

$$\text{P\&R} \succ \text{NBS} \Leftrightarrow \underline{n} \leq 28$$

3. Compliance and Enforcement

- Since there is no world government, the treaty must be self-enforcing
- Suppose that if one party "defects", cooperation breaks down from next period on
- If w is small:
  - the cost of contributing is small, and so is the temptation to defect
  - the incentive constraint is more likely to hold:

$$w \leq 2 - 2\left[1 - \delta\left(C_1 L_1 + C_2 L_2\right)\right] \frac{a\left(1 - \delta^T\right)}{\alpha\left(1 - \delta\right)}$$

  - it may not be necessary to raise the cost of defection by requiring the treaty to be "legally binding"
- The reasoning holds whether or not n is endogenous

5. Contract Theory: Length of the Commitment Period

- The optimal **period length** solves the following trade-off:

1. With a **larger** T, pledges will not reflect recent advancements in technology (Harris and Holmstrom '87).
2. With a **smaller** T, investments are low because of the next approaching hold-up problem (Buchholtz and Konrad '94, Harstad '16)

- Trade-off independent of w and n
- The optimal T^* is independent of w and n:

$$T^* = \arg\max_T \frac{\alpha^2}{\beta\left(1-\delta^T\right)}.$$

Conclusion

	Kyoto '97	**Paris '15**	**Results**
(1)	"Top down" Comparable cuts	"Bottom up" pledges: Nationally determined	Asymmetric NBS with weights $w=f(0)<\frac{1}{2}$
(2)	n=37	n=195	$n'(w)<0$, so $x'(w)<0$, $y'(w)<0$
(3)	Legally binding	Not legally binding	Self-enforcing if $w \downarrow$
(4)	Chosen in the 1990s	Chosen in the 2010s	Due to development?
(5)	5y period 2007-2012	5y periods	$T'(n)=T'(w)=0$

Robustness

1. Pledging to invest (T^* becomes irrelevant)
2. Pledging on emission taxes
3. Pledging both investments and emission taxes
4. Pledging investments and contributions
5. Pledging a path of contributions ($T^* = \infty$)
6. Firms may invest ($T^* = 1$)
7. The timing of T can be after/in between
8. Multiple participation stages
9. Multiple bargaining choice stages
10. Limited punishments