Dynamics of Climate Agreements

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Figure: A warning!
Questions

1. What is the problem?
2. Are agreements always good?
3. What is the effect on R&D?
4. Subsidize R&D/trade in addition?
5. Short-run or long-run agreements?
6. How ambitious should the agreement be?
7. What is the best possible agreement?
Strands of Literature

1. **Environmental Agreements**

2. **Dynamic Market Competition**

3. **Dynamic Private Provision of Public Goods**

4. **Hold-up and Length of Contract**

5. **Hold-up and Renegotiation design**
1. A dynamic model with R&D and emission
2. Business as usual
3. Short-term agreements
4. Long-term agreements
5. Renegotiation Design
6. Robustness
7. Conclusions & Extensions
(1) Model

invest \quad \theta \quad pollute \quad invest \quad \theta \quad pollute \quad invest
Assumptions

Assumptions I will relax:

- Cannot contract on R&D
- Side payments possible
- Quotas not tradable
- Quadratic/linear utility function
- Homogenous countries
- No role for firms (doing R&D)

Crucial assumptions (won’t be relaxed):

- Countries can commit to pollution levels
- No role for reputation (restrict attention to MPE)
Solution

- Look for a stationary Markov-Perfect Equilibrium
- Solve each period by backwards induction
- Since $g_i = y_i - R_i$:
  - Setting $g_i$ is equivalent to setting $y_i$
  - Thus, $y_i$ is going to be the same across countries
- Since $k(r_i)$ is linear:
  - If $U_i \equiv u_i + \nu(G, R_1, ... R_n)$, $\nu$ is linear
  - State variable is the difference between $G$ and $R$
- Since model is symmetric:
  - No market power exercised in equilibrium
(2) Business as Usual

Proposition

(i) \( g_i \) decreases in \( G_\) and \( R_i \) but increases in \( R_j, j \neq i \).
(ii) \( r_i \) increases in \( G_\) and \( f \) but decreases in \( R_\).
(iii) More pollution and lower utility than in the static model.

- Country \( i \) pollutes more in order to:
  - Induce \( j \) to reduce its pollution
  - Induce \( j \) to invest more in technology

- Country \( i \) invests little as a commitment to pollute more
(2) Business as Usual

Proposition

(i) $g_i$ decreases in $G_-$ and $R_i$ but increases in $R_j$, $j \neq i$.
(ii) $r_i$ increases in $G_-$ but decreases in $R_-$ and $f$.
(iii) More pollution and lower utility than in the static model.

\[
g_i^{bau} = -R_i + \frac{b\bar{y} - v_G - c (G_- + \theta - R)}{nc + b}, \quad R \equiv \sum R_j
\]

\[
r_i^{bau} = \frac{G_- - R_-}{n^2} - \frac{k (b + nc)^2}{bcn^3 (1 - f) (b + c)} + \frac{\bar{y}}{n} + \frac{v_R (b + nc)^2}{bcn^2 (b + c)} + \frac{v_G}{cn^2}
\]

\[
v_R = \frac{\delta k (1 - d_R)}{n^2} \quad \text{and} \quad v_G = \frac{\delta k (1 - d_G) (1 - \delta (1 - d_R))}{n^2}
\]
(3) Short-Term Agreements

![Diagram showing the dynamics of climate agreements with the sequence of actions: invest, 0, pollute, invest, 0, pollute, invest. There is an arrow labeled "Negotiate" indicating a point in the timeline where negotiations are required.](image-url)
Proposition

Proposition 1 survives: (i) $g_i \downarrow$ if $G_- \uparrow$, $R_i \uparrow$, $R_j \downarrow$ and 
(ii) $r_i \uparrow$ if $G_- \uparrow$, $R_- \downarrow$, $f \downarrow$.

(iii) $g_{st}^i = g^*(r_{st}^i) < g_{i}^{bau}$ and $G_{st} < G^{bau}$
(iv) $r_{st}^i < r_{i}^{bau}$

A hold-up problem:

- If $R_i$ is large, $y_i = g_i + R_i$ large even if $g_i$ is small
- Thus, $g_i$ will be small in the bargaining outcome

Anticipating this, $i$ invests less
Proposition

Proposition 1 survives: (i) \( g_i \downarrow \) if \( G_\downarrow, R_i \uparrow, R_j \downarrow \) and

(ii) \( r_i \uparrow \) if \( G_\uparrow, R_\downarrow, f \downarrow \).

(iii) \( g_{i}^{st} = g^* (r_{i}^{st}) < g_{i}^{bau} \) and \( G^{st} < G^{bau} \)

(iv) \( r_{i}^{st} < r_{i}^{bau} \)

- Negotiating \( \{g_i\} \) equivalent to negotiating \( \{y_i\} \) \( \Rightarrow \) \( y_i = y_j \forall i, j \in N \)

\[
\begin{align*}
  g_{i}^{st} &= -R_i + \frac{b\bar{y} - n\nu_G - nc (G_\downarrow + \theta - R)}{n^2c + b} \\
  r_{i}^{st} &= \frac{G_\downarrow - R_\downarrow}{n^2} - \frac{k (b + n^2c)}{fn^3 bc} + \frac{\bar{y}}{n} + \frac{\nu_R (b + n^2c)}{bcn^2} + \frac{\nu_G}{cn^2}
\end{align*}
\]

- \( \nu_G \) and \( \nu_R \) same as under no agreement \( \Rightarrow \) can compare directly
(3) Short-Term Agreements

Intuition:

- Hold-up problem as bad as the dynamic common pool problem
  
  \[ g_i + R_i \] same for all \( i \) (independent of \( R_i \) for fixed \( R \))

- Pollution is going to be less with an agreement

- Less urgent to solve problem now by R&D

- R&D decrease

- \( \Rightarrow \) Can welfare decrease?
(3) Agree to the Worse?

**Proposition**

\[ U^{st} < U^{bau} \text{ if } f \text{ and } \delta (1 - d_E) \text{ are large} \]

\[
\left( \frac{n}{1 + (1 - f)(1 - 1/n) - 1} \right)^2 - \left[ 1 - \delta (1 - d_R) \right]^2 > \frac{\sigma^2}{k^2} \frac{n^4 (b + c) (bc)^2}{(n^2 c + b) (nc + b)^2}
\]

- **Intuition:**
  - Anticipating negotiations reduces R&D
  - Underinvestements severe if \( \delta (1 - d_E) \) and \( f \) are large

- **Examples:**
  - If \( \delta (1 - d_R) \approx 1, \sigma \approx 0 \), agreements always bad!
  - If \( \delta (1 - d_R) \approx 0, \sigma \approx 0, n \geq 4 \), agreements bad if \( f \leq 4/3 \).

- **Go home?**
(4) Long-Term Agreements

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Negotiate
(4) Long-Term Agreements

- Set $g$ before $r$? No adverse effect of $r_i$ on $g_i$.

- $r_i$ decreases in $g_i^{lt}$

**Proposition**

(i) Set $g^{lt} = Eg^{*}(r^{lt})$? Yes iff $\delta(1 - d_R) = 0$ and $f = 0$, then $r = r^{*}$.

(ii) Otherwise, $g^{lt} < g^{*}(r^{lt})$.

(iii) Agreement should be more ambitious if $f$ and $\delta(1 - d_R)$ large

(iv) If $f$ is large, long-term better than short-term agreements.

- By letting $g^{lt} < g^{*}(r^{lt})$, R&D increases

- But not optimal ex post
(4) Long-Term Agreements

- Set $g$ before $r$? No adverse effect of $r_i$ on $g_i$.
- $r_i$ decreases in $g_i^{lt}$

**Proposition**

(i) Set $g^{lt} = Eg^* \left( r^{lt} \right)$? Yes iff $\delta (1 - d_R) = 0$ and $f = 0$, then $r = r^*$. 
(ii) Otherwise, $g^{lt} < g^* \left( r^{lt} \right)$.
(iii) Agreement should be more ambitious if $f$ and $\delta (1 - d_R)$ large
(iv) If $f$ is large, long-term better than short-term agreements.

$$R_i^{lt} = \bar{y} - g_i - \frac{k - v_R (n + (1 - f) (n - 1))}{b + (1 - f) b (n - 1)}$$

$$g^{lt} = Eg^* \left( r^{lt} \right) - \frac{k (n - 1)}{n (n^2 c + b)} \left( \frac{1 - (1 - f) (1 - \delta (1 - d_R) (1 - 1/n))}{1 + (n - 1) (1 - f)} \right)$$
(5) Long-Term Agreements with Renegotiation

The diagram illustrates the dynamics of climate agreements over time.

- The timeline is divided into segments labeled 'invest', '0', 'pollute', 'invest', '0', 'pollute', and 'invest'.
- At the points labeled 'invest', there are arrows indicating 'Negotiate' and 'Renegotiate'.
- The segments between 'invest' and '0' represent the opportunity to change agreements, with 'pollute' indicating an option that may lead to renegotiation.

This diagram visualizes the strategic decisions and potential for renegotiation in long-term agreements.
Since long-term agreement sub-optimal ex post, why not renegotiate?
- If default then is *business as usual*, equivalent to short-term agreement
- But suppose default is the *ex ante* agreement

Let $g^{ea}$ be the *ex ante* agreement

At abatement stage, renegotiate optimally to $g^* (r^{ea})$

The role of $g^{ea}$ is only to provide incentives to invest:
- The smaller is $g^{ea}$, the larger is R&D
(5) Long-Term Agreements with Renegotiation

Proposition

(i) All $g_i$ and $r_i$ are first-best under the ea-agreement below
(ii) If $f = \delta = 0$, $g_{ea} = Eg^*(r_{ea})$ is first-best
(iii) The larger is $f$ and $\delta (1 - d_R)$, the more ambitious the agreement should be

$$g_{ea} = Eg^*(r_{ea}) - \frac{k}{b} \left( \frac{f}{(1 - f)(n - 1)} + \delta (1 - d_R) \right)$$

Intuition:

- After renegotiation, $g$ is set at its first best level
- If $g_{ea}$ is small, countries renegotiate to a less ambitious deal
- A small $R_i$ makes $i$ "desperate" and it will have to "pay" more
- To avoid this, $i$ invests to increase $R_i$ and thus its bargaining power.
(5) Long-Term Agreements with Renegotiation

Compared to the case without renegotiation (lt), the agreement should now be more ambitious

\[ g^{ea} = g^{lt} - \frac{k}{b} \left( \frac{1-f}{(n-1)f} + \delta (1-d_R) \right) \]
\[ < g^{lt} < g^{*} (r^{lt}) \]

**Intuition:**

- The long-term agreement sets \( g^{lt} \) as a *compromise* between what is optimal ex post (\( g^{*} (r^{lt}) > g^{lt} \)) and a smaller \( g \) to provide incentives.
- After renegotiation, \( g = g^{st} \) anyway, so there is no need to compromise.
- Thus, reduce \( g^{ea} \) further until incentives first best.
(6) Robustness: R&D Subsidises

- If $s$ measures the other countries subsidy when $i$ and $j$ trade, simply replace $(1 - f)$ by $(1 - f)(1 + s)$
- If $s$ is small:
  - $U^{st} < U^{bau}$ likely
  - Long-term agreement is better
  - $g^{lt}$ should decrease
- Optimally, $s$ should increase in $f$ and $\delta (1 - d_R)$
- Investments are first-best if

\[
\begin{align*}
    s^{lt} &= \frac{n}{(1 - f)[n - \delta (1 - d_R)(n - 1)]} - 1 \\
    s^{st} &= \frac{n}{1 - f} - 1.
\end{align*}
\]

- But $g^{lt}$ never first-best because of $\theta$
(6) Robustness

- Suppose there are transaction costs associated with transfers: Identical results
- Suppose permits are tradable: Similar results
  - If Pigou taxes, similar results:
    \[
    t^{ea} = \mathbb{E}t^* + k \left( \frac{f}{(1-f)(n-1)} + \delta (1-d_R) \right), \text{ compared to }
    \]
    \[
    g^{ea} = \mathbb{E}g^* - \frac{k}{b} \left( \frac{f}{(1-f)(n-1)} + \delta (1-d_R) \right) \text{ from above.}
    \]
- Suppose \( b(.) \), \( c(.) \) and \( k(.) \) are general functions:
  \[
  u_i = b( y_i ) - g(G) - k(r)
  \]
- The main result holds and can be rewritten
  \[
  b' \left( g_i^{ea} + R_i^* \right) - \mathbb{E}b' \left( g_i^* + R_i^* \right) = k' \left( \frac{f}{(1-f)(n-1)} + \delta (1-d_R) \right)
  \]
Questions - And Conclusions

1. What is the problem?
   - A dynamic common pool / hold-up problem

2. Are agreements always good?
   - No: Short-term agreements may be bad

3. What's the effect on R&D?
   - R&D ↓ (↑) under short-term (long-term) agreement

4. Subsidize R&D/trade in addition?
   - Yes, particularly under short-term agreements

5. Short-term or long-term agreements?
   - Long-term better if patents and subsidises weak

6. How ambitious should the agreement be?
   - More ambitious if short-term and weak patent system

7. What is the best possible agreement?
   - First-best possible by ambitious agreement with renegotiation.
8. What happens with heterogeneity?
   - If $k_i$ varies, only $i$ s.t. $k_i = k$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate

9. What if countries can adapt to the new climate?
   - Countries adapt *too much* to gain bargaining power
   - Under over-ambitious agreement: Adapt *too little*

10. What if $n$ is endogenous?
    - If few show up, they prefer short-term agreement and strategic status-quo
    - Anticipating this, participation may increase