Dynamics of Climate Agreements

Bård Harstad

Meds/Kellogg/Northwestern

5 May 2009
Motivation

[ Insert lots of tables here ]
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[ Add anecdotal evidence here ]
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. **Differential Games**

3. **Applied to Climate Change**
   - Dutta and Radner (2009, JEBO): Compare MPE, SPE, FB. (But no R&D)
   - Dutta and Radner (2006, ET): Allow technological differences. Discuss informally incentives to do R&D.

4. **Contracts, Hold-up and Renegotiation Design**
Outline

1. The Model
2. Business as usual (no agreement)
3. Short-term agreements
4. Long-term agreements
5. Renegotiation Design
6. Generalizations & Robustness
7. Conclusions & Extensions
(1) Model

\begin{center}
\begin{tikzpicture}
\draw (0,0) -- (10,0);
\node at (1.5,0) {invest}; \node at (3,0) {\theta}; \node at (4.5,0) {pollute}; \node at (6,0) {invest}; \node at (7.5,0) {\theta}; \node at (9,0) {pollute}; \node at (10.5,0) {invest};
\end{tikzpicture}
\end{center}
(1) Model
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\[ G = (1 - d_G) G - + \sum g_i + \theta, \ i \in N = \{1, 2, ..., n\} \]
\[ \theta \sim F (0, \sigma^2) \]
\[ R_i = (1 - d_R) R_i - + br_i + e \sum r_j, \ j \in N \setminus i \]
\[ g_i = y_i - R_i \]
\[ u_i = -\frac{c}{2} G^2 - \frac{b}{2} (\bar{y} - y_i)^2 - kr_i \]
\[ U_i = \sum u_i \delta^t \]

- Can contract on \( g_i \) but not \( r_i \)
Look for a MPE (Maskin and Tirole, 2001)

Define continuation values $V_i(G_-, R_-)$ and $W_i(G_-, R)$

Since $k(\cdot)$ linear, $V_i$ linear in $R_-

From foc, $G_- - R$ constant

Thus, $V_i$ linear in $G_-$ as well

... and unique!
(2) Business as Usual
Results:

- If $R_i$ is large, $g_i$ is small, but $g_j$ is large, $j \neq i$
  - Anticipating this, $r_i$ decreases
- If $G_-$ is large, $r_j$ increases
  - Anticipating this, $g_i$ increases
- A dynamic common pool problem that is worse than its static counterpart
(2) Business as Usual

\[
g_i^{bau} = \frac{\bar{v}\bar{y} - V_G - c \left((1 - d_G) G_+ + \theta - \sum_{j \neq i} R_j\right)}{nc + v} \\
\hspace{2cm} - \left(1 - \frac{c}{nc + v}\right) R_i
\]

\[
r_i^{bau} = \frac{(1 - d_G) G_+ - (1 - d_R) R_-}{nB} + \frac{\bar{y} - V_G}{B} - \frac{V_G}{vB} \\
\hspace{2cm} - \frac{(k - V_R) (v + nc)^2}{cnB (v + c)} + \frac{V_G (nc + v)}{cnB}
\]

\[
B \equiv \frac{\partial R}{\partial r_i} = b + (n - 1) e
\]

\[
\frac{\partial V}{\partial G} = -\frac{\delta d_G k [1 - \delta (1 - d_R)]}{Bn}
\]

\[
\frac{\partial V}{\partial R_j} = \frac{\delta (1 - d_R) k}{Bn} \forall j \in \{1, \ldots, n\}.
\]
(3) Short-Term Agreements

```
invest     θ     pollute
```

Negotiate
(3) Short-Term Agreements

- Pollution levels are first best ex post

Proposition

\[ g_i^{st} = g_i^* (r^{st}) < g_i^{bau} \]
(3) Short-Term Agreements

- Pollution levels are first best ex post
- Hold-up problem: If $R_i$ large, $g_i^{st}$ small

**Proposition**

$$g_i^{st} = g_i^* (r_i^{st}) < g_i^{bau}$$
Pollution levels are first best ex post
Hold-up problem: If $R_i$ large, $g_i^{st}$ small
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- $g_i^{st} = g_i^* (r_i^{st}) < g_i^{bau}$
- $r_i^{st} < r_i^{bau}$
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- Pollution levels are first best ex post
- Hold-up problem: If $R_i$ large, $g_i^{st}$ small
- Anticipating this, $r_i$ decreases

**Proposition**

- $g_i^{st} = g_i^*(r_i^{st}) < g_i^{bau}$
- $r_i^{st} < r_i^{bau}$
- $u_i^{st} < u_i^{bau}$ if $\delta$ large, $\sigma$ small, $n$ large
(3) Short-Term Agreements

\[
\left(1 - \frac{1}{n}\right)^2 - \left(\frac{1 - \delta (1 - d_R)}{n}\right)^2 < u^{st} < u^{bau} \text{ if }
\]

\[
\frac{(v + c)(\sigma vcB / k)^2}{(n^2 c + v)(nc + v)^2}
\]

ie, \textit{always if}

\[
\delta (1 - d_R) \rightarrow 1 \quad \sigma \rightarrow 0.
\]
(4) Long-Term Agreements
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- Fix $g_i$ before $r_i$? No adverse effect of $r_i$ on $g_i$.
- $r_i$ decreases in $g_i$

Proposition

- $g_{lt} < g^* (r_{lt})$ and agreement should be more ambitious if $e$ and $\delta$ are large

The agreement should be more ambitious if it is "short-lasting" and externalities are large

\[
  g_{lt}^1 = Eg_{lt}^* (r_{lt}) - \frac{k(n-1)}{B(n^2c + v)} \left( \frac{e}{b} + \frac{\delta(1 - d_R)}{n} \left( 1 - \frac{e}{b} \right) \right)
\]
(4) Long-Term Agreements: Multiple Periods

invest $\theta$ pollute invest $\theta$ pollute invest

Negotiate
Suppose $g_i$ fixed for time $1, 2, \ldots, T$.

**Proposition**
- Optimally, $g_i$ should increase over time
- $g_i$ should be smaller if $e$ is large (just as before)
- $T$ should be larger if $e$ is large (2OC holds)
Long-Term Agreements with Renegotiation
(5) Long-Term Agreements with Renegotiation
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Proposition

- First best possible: $g^{de} < E g^* (r^{de})$ and initial agreement should be more ambitious if $\delta$ and $e$ are large

Intuition:
- After renegotiation, $g$ is set at its first best level
- If $g^{de} < E g^* (r^*)$, 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.
- To exploit this effect, set:

$$g_{i}^{de} = E g_{i}^* (r^{de}) - \frac{k}{Bv} \left[ \delta (1 - d_R) + \frac{en}{b - e} \right]$$
(6) Robustness

- Patents: Suppose $j$ can pay $i$ to get the full value of $R_i$
  - Large $e$ means poor patent protection
  - Let $s$ measure external subsidy on R&D-trade

\[ g_i^{de} = E g_i - \frac{k}{bnv} \left[ \delta (1 - d_R) + \frac{n(1 - z)}{z(n - 1)} \right], \text{ where} \]
\[ z \equiv (1 + s) (1 - e / (b - e)). \]

- $s$ should be larger if $g_i$ is small, $e$ large, $\delta$ large
- Side transfers possible or not: Identical results
- Permits tradable or not: Identical results
- If Pigou taxes instead:

\[ t_i^{de} = Et_i - \frac{k}{bn} \left[ \delta (1 - d_R) + \frac{n(1 - z)}{z(n - 1)} \right] \]

- If $u_i = v(y_i) - c(G) - kr_i$:

\[ V_i^{de} - Ev_i = \frac{k}{bn} \left[ \delta (1 - d_R) + \frac{n(1 - z)}{z(n - 1)} \right] \]
Questions - And Conclusions
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1. What is the problem?

A dynamic common pool / hold-up problem

2. Are agreements always good?

No!

3. What’s the effect on R&D?

R&D under short-term (ambitious 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 if weak patent system and no R&D subsidises

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 initial agreement with renegotiation.
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2. **Are agreements always good?**

3. **What's the effect on R&D?**
   - Under short-term agreements, R&D is less likely to occur under ambitious long-term agreements.
   - Subsidize R&D/trade in addition, particularly under short-term agreements.

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- May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
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    • Under over-ambitious agreement: Adapt *too little*