Dynamics of Climate Agreements

Bård Harstad

Meds/Kellogg/Northwestern

5 May 2009

Motivation

[Insert lots of tables here]

Motivation

[Add anecdotal evidence here]

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?

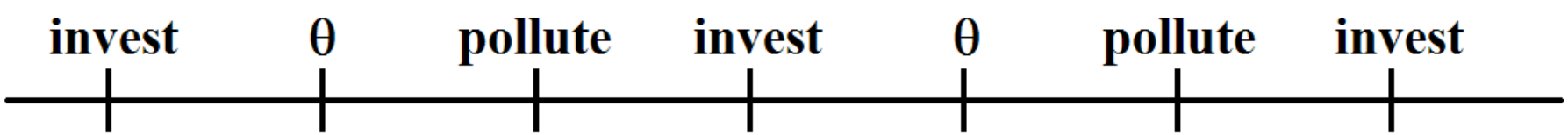
Strands of Literature

1. *Environmental Agreements*
   - Aldy and Stavins (2005, 2007), Frankel (2008), Barrett (2005), Karp and Zhao (2008), Golombek and Hoel (2005,2006)
2. *Differential Games*
   - Friedman (1974), Dockner et al. (2000), Dutta and Sundaram (1993)
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.
   - Dutta and Radner (2004, 2006, AME): Allow R&D, but "bang-bang" since costs linear (and no contracts).
4. *Contracts, Hold-up and Renegotiation Design*
   - Hart and Moore (1988), Harris and Holmstrom (1987)
   - Aghion, Dewatripont and Rey (1994), Guriev and Kvasov (2002), Edlin and Hermalin (2000), Che and Hausch (1999)

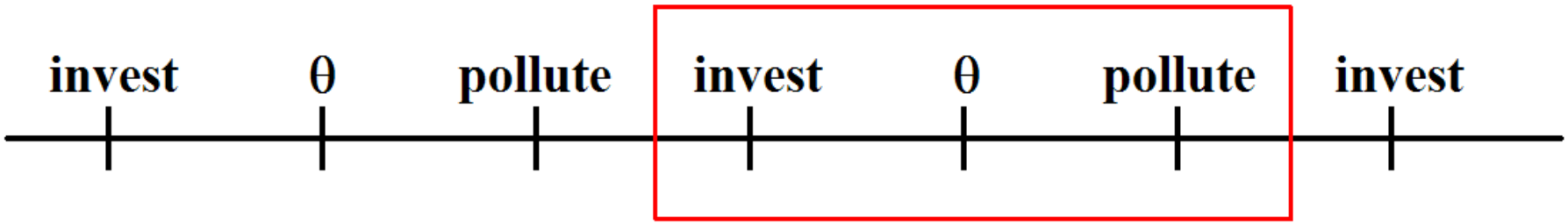
Outline

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



(1) Model



(1) Model

$$
\begin{aligned}
G &= (1-d_G)\,G_- + \sum g_i + \theta,\ \ i \in N = \{1,2,...,n\} \\
\theta &\sim F\left(0,\sigma^2\right) \\
R_i &= (1-d_R)\,R_{i,-} + br_i + e\sum r_j,\ \ j \in N \backslash i \\
g_i &= y_i - R_i \\
u_i &= -\frac{c}{2}G^2 - \frac{b}{2}\left(\overline{y} - y_i\right)^2 - kr_i \\
U_i &= \sum u_i \delta^t
\end{aligned}
$$

- Can contract on g_i but not r_i

(1) Solution Concept and Method

- Look for a MPE (Maskin and Tirole, 2001)
- Define continuation values $V_i(G_-, R_-)$ and $W_i(G_-, R)$
- Since $k(.)$ 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

(2) Business as Usual

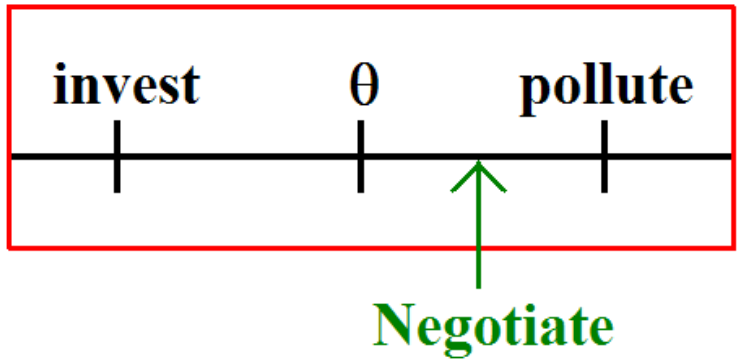
Results:

- 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

$$
\begin{aligned}
g_i^{bau} &= \frac{v\overline{y} - V_G - c\left(\left(1-d_G\right)G_- + \theta - \sum_{j\neq i} R_j\right)}{nc+v} \\
&\quad - \left(1 - \frac{c}{nc+v}\right) R_i \\
r_i^{bau} &= \frac{\left(1-d_G\right)G_- - \left(1-d_R\right)R_-}{nB} + \frac{\overline{y}}{B} - \frac{V_G}{vB} \\
&\quad - \frac{\left(k-V_R\right)\left(v+nc\right)^2}{cvnB\left(v+c\right)} + \frac{V_G\left(nc+v\right)}{cvnB} \\
B &\equiv \partial R/\partial r_i = b + \left(n-1\right)e \\
\partial V/\partial G &= -\frac{\delta d_G k\left[1-\delta\left(1-d_R\right)\right]}{Bn} \\
\partial V/\partial R_j &= \frac{\delta\left(1-d_R\right)k}{Bn} \forall j \in \{1,...n\}.
\end{aligned}
$$

(3) Short-Term Agreements



(3) Short-Term Agreements

- Pollution levels are first best ex post

Proposition

- $g_i^{st} = g_i^* \left(r^{st} \right) < g_i^{bau}$

(3) Short-Term Agreements

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

Proposition

- $g_i^{st} = g_i^* \left(r^{st} \right) < g_i^{bau}$

(3) Short-Term Agreements

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

Proposition

- $g_i^{st} = g_i^* \left(r^{st} \right) < g_i^{bau}$

(3) Short-Term Agreements

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

Proposition

- $g_i^{st} = g_i^* \left(r^{st} \right) < g_i^{bau}$
- $r_i^{st} < r_i^{bau}$

(3) Short-Term Agreements

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

Proposition

- $g_i^{st} = g_i^* \left(r^{st} \right) < g_i^{bau}$
- $r_i^{st} < r_i^{bau}$
- $u^{st} < u^{bau}$ *if* δ *large,* σ *small, n large*

(3) Short-Term Agreements

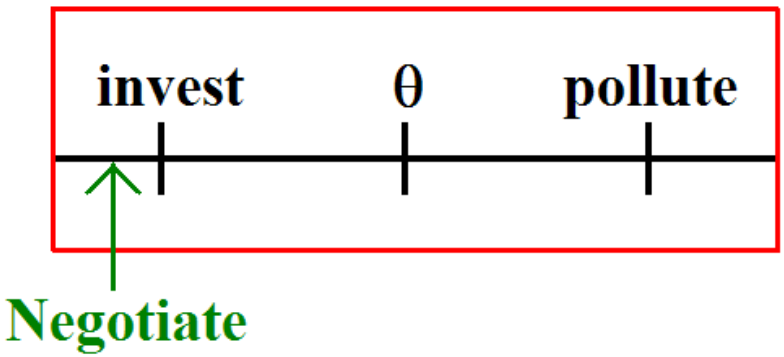
$$
\begin{array}{rcl}
u^{st} & < & u^{bau} \text{ if} \\
\left(1-\frac{1}{n}\right)^2 - \left(\frac{1-\delta\left(1-d_R\right)}{n}\right)^2 & > & \frac{\left(v+c\right)\left(\sigma vcB/k\right)^2}{\left(n^2c+v\right)\left(nc+v\right)^2}
\end{array}
$$

ie, *always* if

$$
\begin{array}{rcl}
\delta\left(1-d_R\right) & \rightarrow & 1 \\
\sigma & \rightarrow & 0.
\end{array}
$$

(4) Long-Term Agreements

(4) Long-Term Agreements



(4) Long-Term Agreements

- Fix g_i before r_i ? No adverse effect of r_i on g_i.
- r_i decreases in g_i

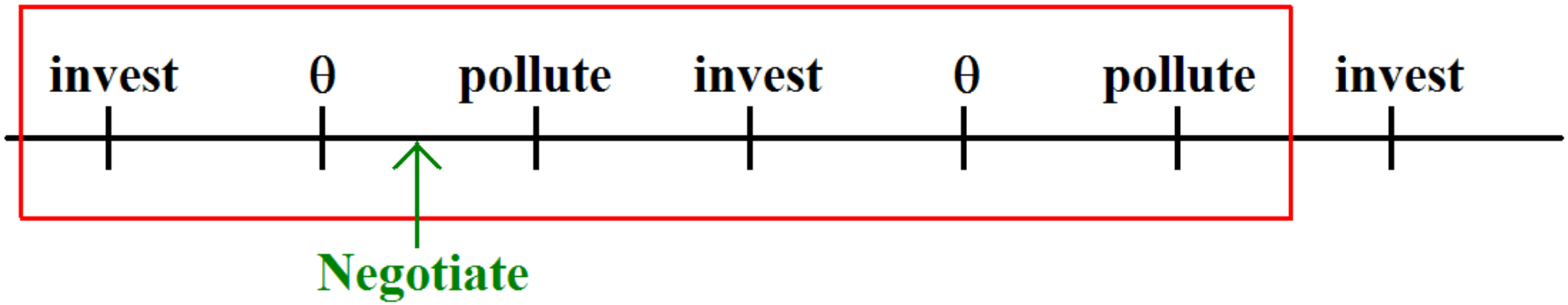
Proposition

- *$g^{lt} < g^*\left(r^{lt}\right)$ and agreement should be more ambitious if e and δ are large*

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

$$g_i^{lt} = \mathrm{E}g_i^*\left(r^{lt}\right) - \frac{k\left(n-1\right)}{B\left(n^2c+v\right)}\left(\frac{e}{b} + \frac{\delta\left(1-d_R\right)}{n}\left(1-\frac{e}{b}\right)\right)$$

(4) Long-Term Agreements: Multiple Periods



(4) Long-Term Agreements: Multiple Periods

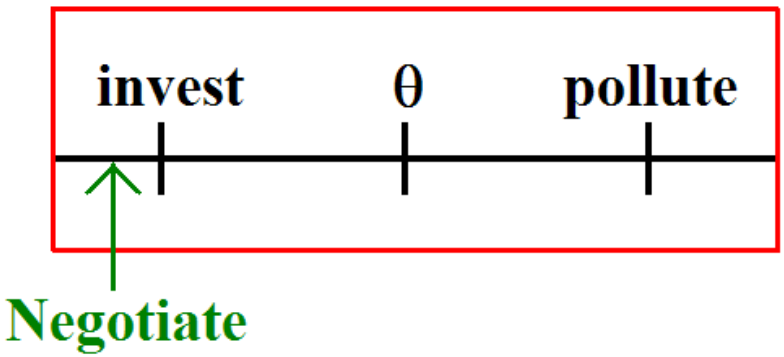
- Suppose g_i fixed for time $1, 2, \ldots T$.

Proposition

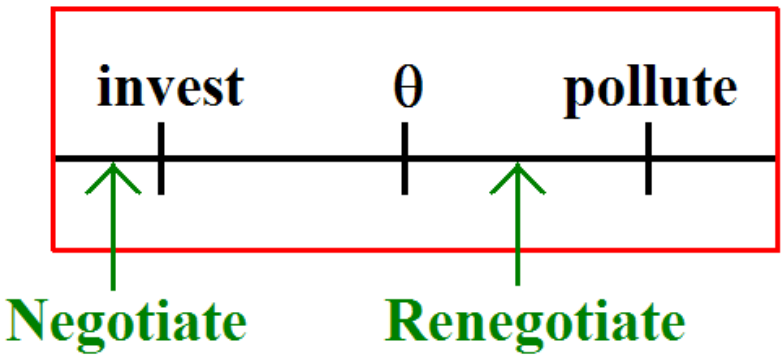
- *Optimally, g_i should increase over time*
- *g_i should be smaller if e is large (just as before)*
- *T should be larger if e is large (2OC holds)*

(5) Long-Term Agreements with Renegotiation

(5) Long-Term Agreements with Renegotiation



(5) Long-Term Agreements with Renegotiation



(5) Long-Term Agreements with Renegotiation

Proposition

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

- Intuition:
  - After renegotiation, g is set at its *first best* level
  - If $g^{de} < \mathrm{E}g^*(r^*)$, countries renegotiate to a *less* ambitious deal
  - A small R_i makes i "desparate" 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:

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

(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

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

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

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

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

$$v'_{de} - \mathrm{E}v'_* = \frac{k}{bn}\left[\delta\left(1-d_R\right)+\frac{n\left(1-z\right)}{z\left(n-1\right)}\right]$$

Questions - And Conclusions

Questions - And Conclusions

1. What is the problem?

Questions - And Conclusions

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

Questions - And Conclusions

1. What is the problem?
   - A dynamic common pool / hold-up problem
2. Are agreements always good?

Questions - And Conclusions

1. What is the problem?
   - A dynamic common pool / hold-up problem
2. Are agreements always good?
   - No!

Questions - And Conclusions

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?

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) under short-term (ambitious long-term) agreement

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) under short-term (ambitious long-term) agreement
4. Subsidize R&D/trade in addition?

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) under short-term (ambitious long-term) agreement
4. Subsidize R&D/trade in addition?
   - Yes, particularly under short-term agreements

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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?

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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?

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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?

Questions - And Conclusions

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 $\downarrow$ ($\uparrow$) 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.

Questions - Continued

8. What happens with heterogeneity?

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?
   - If few show up, they prefer short-term agreement and strategic status-quo

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?
   - If few show up, they prefer short-term agreement and strategic status-quo
   - Anticipating this, participation may increase

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?
   - If few show up, they prefer short-term agreement and strategic status-quo
   - Anticipating this, participation may increase
10. What if countries can adapt to the new climate?

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?
   - If few show up, they prefer short-term agreement and strategic status-quo
   - Anticipating this, participation may increase
10. What if countries can adapt to the new climate?
   - Countries adapt *too much* to gain bargaining power

Questions - Continued

8. What happens with heterogeneity?
   - If k_i varies, only i s.t. $k_i = \underline{k}$ (should) innovate
   - May want to require $g_i < g_j$ if $k_i < k_j$, but renegotiate
9. What if n is endogenous?
   - If few show up, they prefer short-term agreement and strategic status-quo
   - Anticipating this, participation may increase
10. What if countries can adapt to the new climate?
    - Countries adapt *too much* to gain bargaining power
    - Under over-ambitious agreement: Adapt *too little*