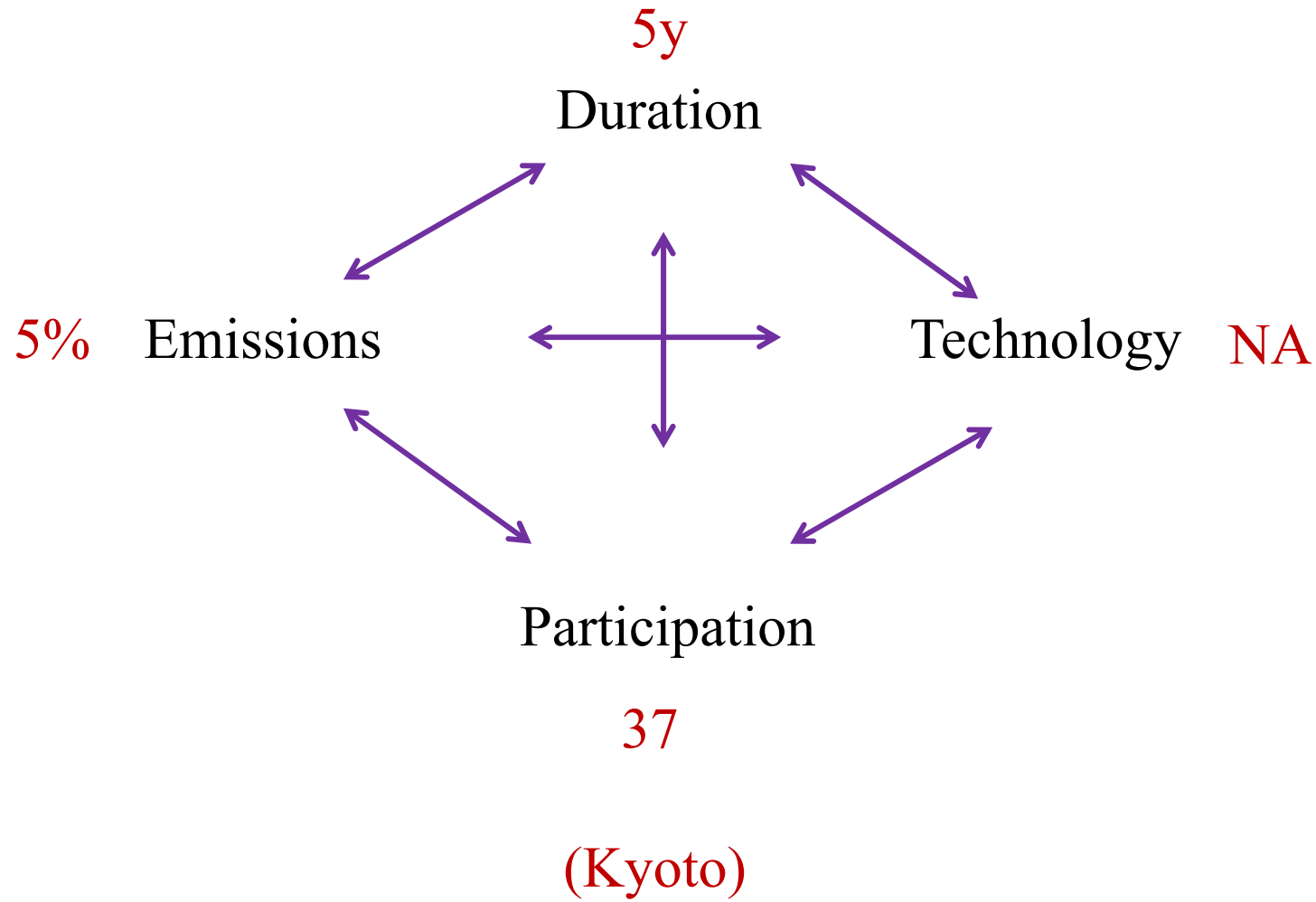


Dynamic Games in Environmental Economics:

LN2: Coalitions - Participation vs. Free Riding

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Relationships



Positive and Normative Questions

1. Why will countries participate, if they can free ride?
2. Can we rationalize observed coalition sizes?
3. What determines the equilibrium coalition size?
4. What types of agreements will motivate participation?

A “Standard” Participation Model

The linear-quadratic model (Barrett '05 for an overview):

Benefit $B(g_{i,t}) = -\frac{b}{2}(\bar{y} - g_{i,t})^2, i \in N = \{1, \dots, n\}$

Costs $u_{i,t} = B(g_{i,t}) - C \sum_{i \in N} g_{i,t}$

Timing: (1) Participate, (2) pollute.

Internal stability: No participation should want to leave.

External stability: No free-rider should want to join.

$$\text{let: } d_{i,t} = \bar{y} - g_{i,t}$$

$$u_{i,t} = -\frac{b}{2} d_{i,t}^2 - Cn\bar{y} + C \sum_{i \in M} d_{i,t} + C \sum_{i \in N \setminus M} d_{i,t}$$

$$d_{i,t} = m \frac{C}{b}$$

Timing: (1) Participate, (2) pollute.

Internal stability: No participation should want to leave.

External stability: No free-rider should want to join.

Equilibrium: $m=3$. (Useful exercise: The third is indifferent, so $m=2$ is also an equilibrium.)

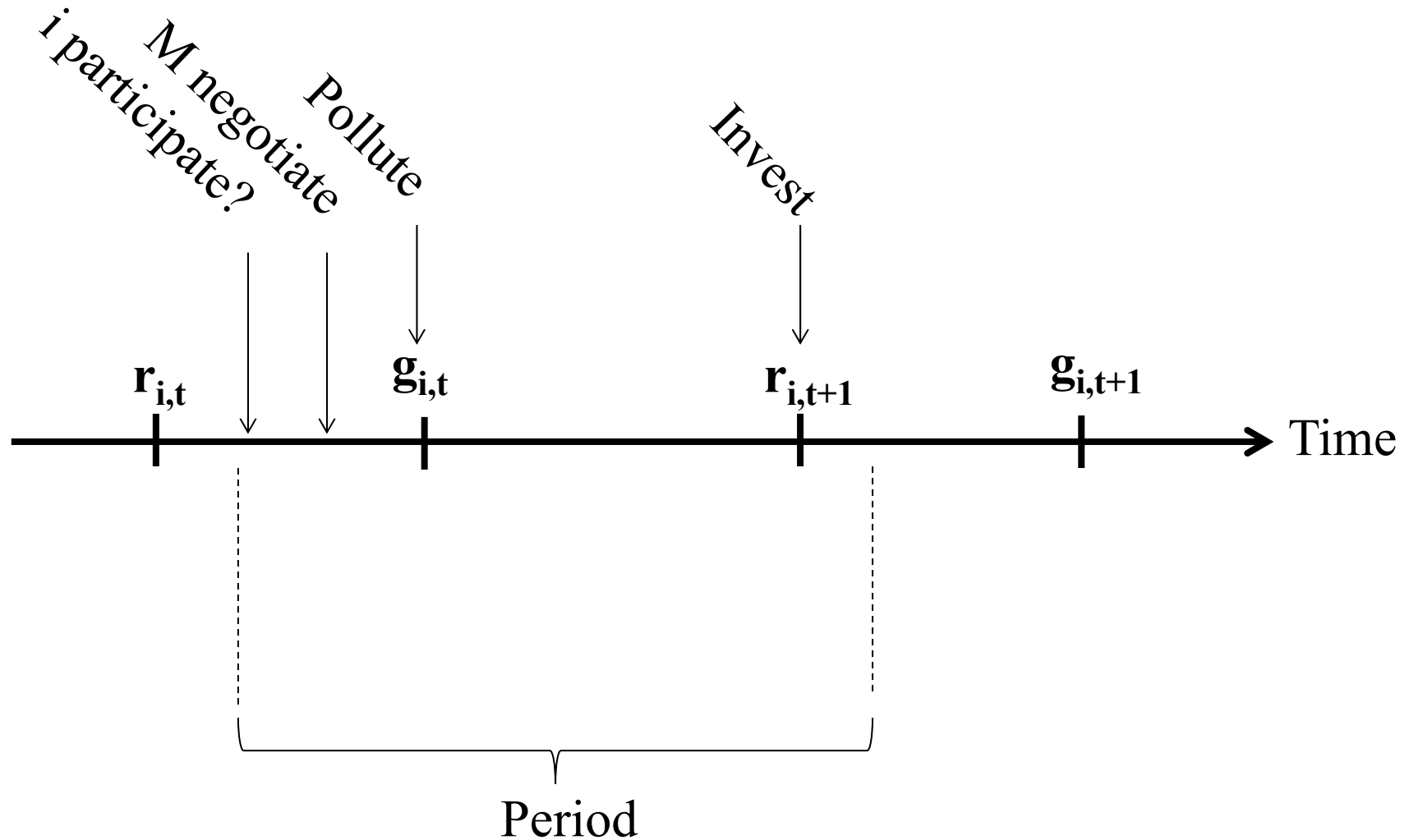
What can explain larger coalitions?

1. Non-quadratic functional forms (Karp and Simon, 2013);
Tipping points (Wagener and de Zeeuw)
2. Side transfers (Finus et al., 2006)
3. Linkage to trade clubs (Nordhaus)
4. Heterogeneity...
5. Farsightedness and unravelling
 $m=4$ is not an equilibrium, but therefore $m=5$ might be...
(if, then, one withdraws, the coalition unravels to $m=3$)...

Assumptions

1. Countries are symmetric
2. No technological spillovers
3. Linear climate change cost
4. Quadratic benefit from energy consumption
5. Quadratic investment costs.
6. Technology depreciates after a period, or past technology stock does not influence marginal cost of adding to the stock.

A Dynamic Model: Timing



Model: Equations

Stocks: Climate cost can be cG_t , but let: $C=c/(1-\delta q_G)$

Investment cost: $\underline{k}(r_{i,t+1})^2/2 - q_R \underline{k}(r_{i,t})^2/2$, but let: $k=(1-\delta q_R)\underline{k}$

Then, **no** past action is «payoff relevant»

... **except** whether commitments have been made...

=> Simple to use **Markov-perfect equilibria**

A linear-quadratic model:

$$\text{Benefit} \quad B(y_{i,t}) = -\frac{b}{2}(\bar{y} - y_{i,t})^2, \quad i \in N = \{1, \dots, n\}$$

$$\text{Emission} \quad g_{i,t} = y_{i,t} - r_{i,t}$$

$$\text{Utility} \quad u_{i,t} = B(y_{i,t}) - C \sum_{i \in N} g_{i,t} - \delta \frac{k}{2} r_{i,t+1}^2$$

First Best

Concave&symmetric welfare f.

$$r_{i,t} = n \frac{C}{k}$$

$$d_{i,t} = n \frac{C}{b} \Leftrightarrow$$

$$g_{i,t} = \bar{y} - n \frac{C}{k} - n \frac{C}{b}$$

$$\frac{d_{i,t}}{r_{i,t}} = \frac{k}{b} \equiv x$$

Business as Usual

If nothing is contractible

$$r_{i,t} = \frac{C}{k}$$

$$d_{i,t} = \frac{C}{b} \Leftrightarrow$$

$$g_{i,t} = \bar{y} - \frac{C}{k} - \frac{C}{b}$$

$$\frac{d_{i,t}}{r_{i,t}} = \frac{k}{b} \equiv x$$

Nonparticipants always act this way

Complete Contracts

Depth: *for a given m and T ...*

$$r_{i,t} = m \frac{C}{k}$$

$$d_{i,t} = m \frac{C}{b} \Rightarrow$$

$$g_{i,t} = \bar{y} - m \frac{C}{k} - m \frac{C}{b}$$

$$\frac{d_{i,t}}{r_{i,t}} = \frac{k}{b} \equiv x$$

Length: $T(m) = \infty$ if $m \geq m^*$

$T(m) = 1$ if $m < m^*$

Width: $m^* = \{2,3\}$

Incomplete Contracts

$$r_{i,t} = \frac{b(\bar{y} - g_{i,t})}{b+k}, t \leq T, r_{i,T+1} = \frac{C}{k}$$

$$g_{i,t} = \bar{y} - m \frac{C}{k} - m \frac{C}{b} \Rightarrow$$

$$r_{i,t} = m \frac{C}{k} > r_{i,T+1} = \frac{C}{k} \Rightarrow$$

$$d_{i,t} = m \frac{C}{b}$$

$$\frac{d_{i,t}}{r_{i,t}} = \frac{k}{b} \equiv x$$

$T(m) = \infty$ if $m \geq \hat{m} < m^*$

$T(m) = 1$ if $m \leq \hat{m} < m^*$

Larger; $m^*=n$ possible

Intuition

Participate? $m = m^* \Rightarrow T = \infty \Rightarrow r = m(C/k)$

$$\Rightarrow \quad \textcolor{red}{IFF} \quad m^* \leq \bar{m}_I \equiv \begin{cases} 3 + \frac{2\delta}{x-\delta} \text{ if } x > \delta \\ \infty \text{ if } x \leq \delta \end{cases}$$

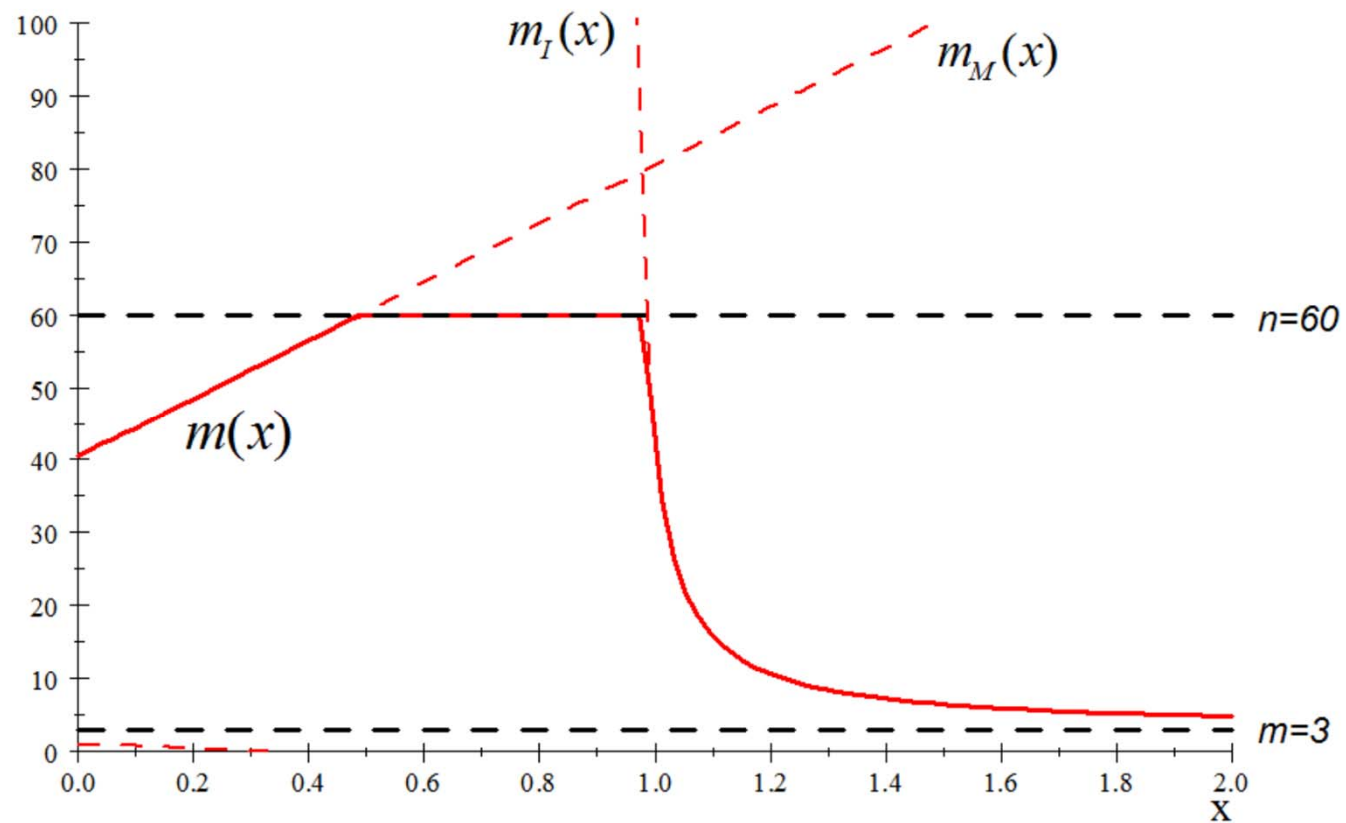
Deviate? $m = m^*-1 \Rightarrow T = 1 \Rightarrow r = C/k$

$$\textcolor{red}{IFF} \quad m^* - 1 \leq \hat{m} \Leftrightarrow m^* \leq \bar{m}_M, \text{ where}$$

$$\bar{m}_M \equiv 1 + \frac{1}{1 - \sqrt{\frac{x+\delta}{x+1}}}.$$

Proposition: m^* is an equilibrium iff:

$$m^* \leq \min\{\bar{m}_I, \bar{m}_M, n\} = n \rightarrow \textcolor{red}{FB} \text{ iff } \delta \uparrow \text{ and } x \text{ moderate}$$



The key variable is: $x=k/b$

Bottom line

The hold-up problem can be beneficial!

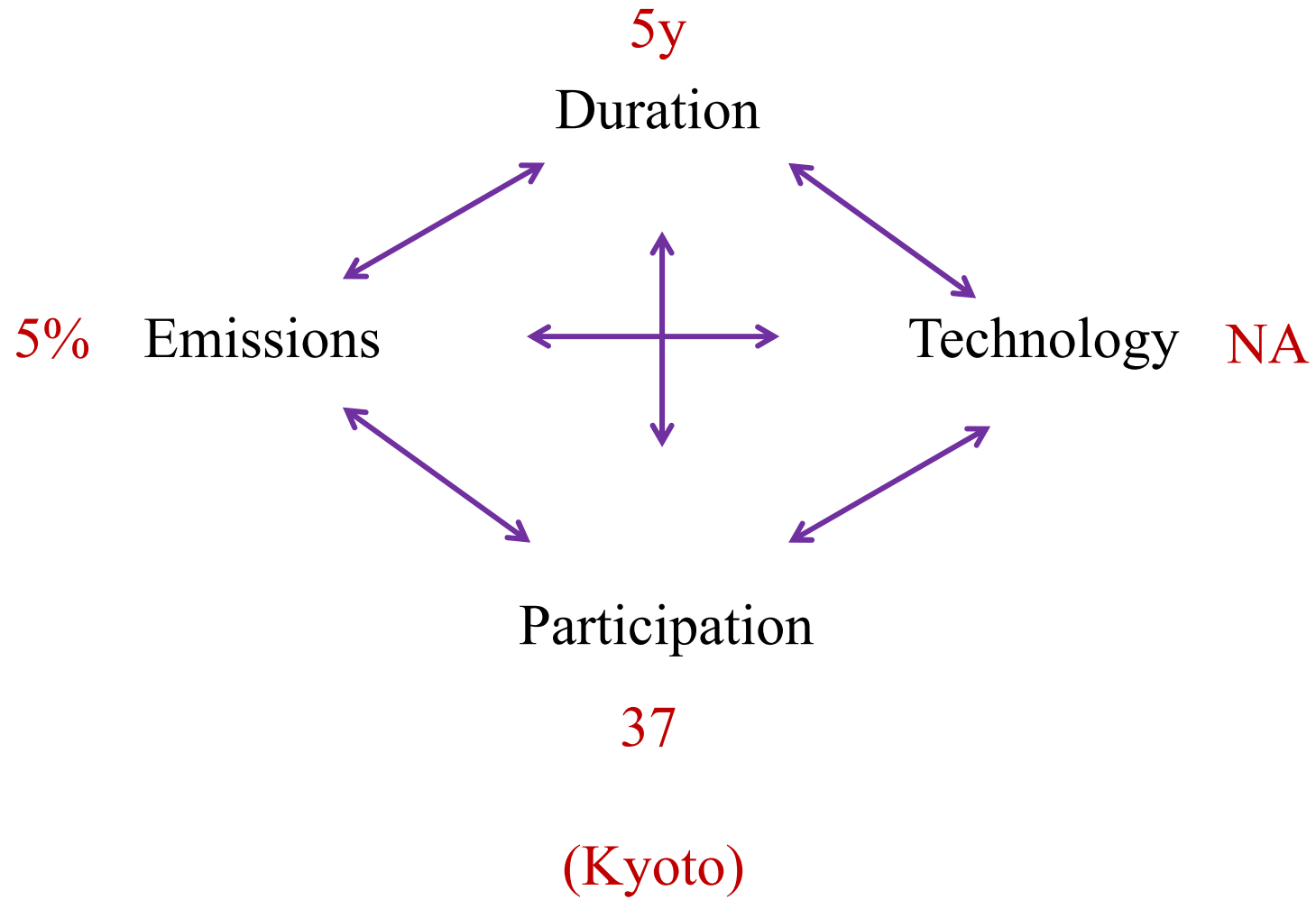
Because:

- *Investments are low if T is small.*
- *T is small if m is small.*
- *Thus, it is more costly to free ride.*
- *In other words, an agreement that only focuses on emission, and not on investments, can lead to larger coalitions.*

Participation: Lessons from the lecture

1. If countries can opt out, there is a strong incentive to free-ride
2. In static linear-quadratic models, only 3 (!) countries want to participate in equilibrium
3. This conclusion continues to hold even if we add:
 - a) Green technology or
 - b) Many periods
4. But the coalition can be much larger if:
 - a) Contracts are incomplete *and*
 - b) Duration is endogenous
5. The hold-up problem can then be *beneficial*: It leads to under-investments *if* the agreement is short-term, and it is short-term *if* few countries participate. Thus, many may participate.
6. There may be **good reasons** for why treaties countries negotiate emissions, but not investments.

Relationships



Dynamic Games in Environmental Economics

Emissions $\leftrightarrow$ Investments

1. Real-world treaties focus on emissions; not R&D.
2. Theories on repeated games, dynamic games, and contract theory can be used to analyze such agreements.
3. With “**business as usual**,” countries may invest strategically little, to motivate others to invest more and pollute less later..
4. With **legally binding agreements**, investments will be strategically small before bargaining.
5. This hold-up problem can make short-term agreements costly.
6. Only a large **coalition** prefers to lock in for the long run.
7. This *can* motivate free-riders to participate.
8. Findings can rationalize larger coalitions, and incomplete contracts.

Further Readings: What can explain larger coalitions?

1. Non-quadratic functional forms (Karp and Simon, 2013);
Tipping points (Wagener and de Zeeuw)
2. Side transfers (Finus et al., 2006)
3. Linkage to trade clubs (Nordhaus, 2015)
4. Heterogeneity (Botteon and Carraro, 1997)
5. Farsightedness and unravelling (Ray and Vohra, 2015)
 $m=4$ is not an equilibrium, but therefore $m=5$ might be...
(if, then, one withdraws, the coalition unravels to $m=3$)...
6. “Modesty may pay” (Finus and Maus, 2008)