

Participation and Free Riding

Day 5

PhD minicourse – MIT

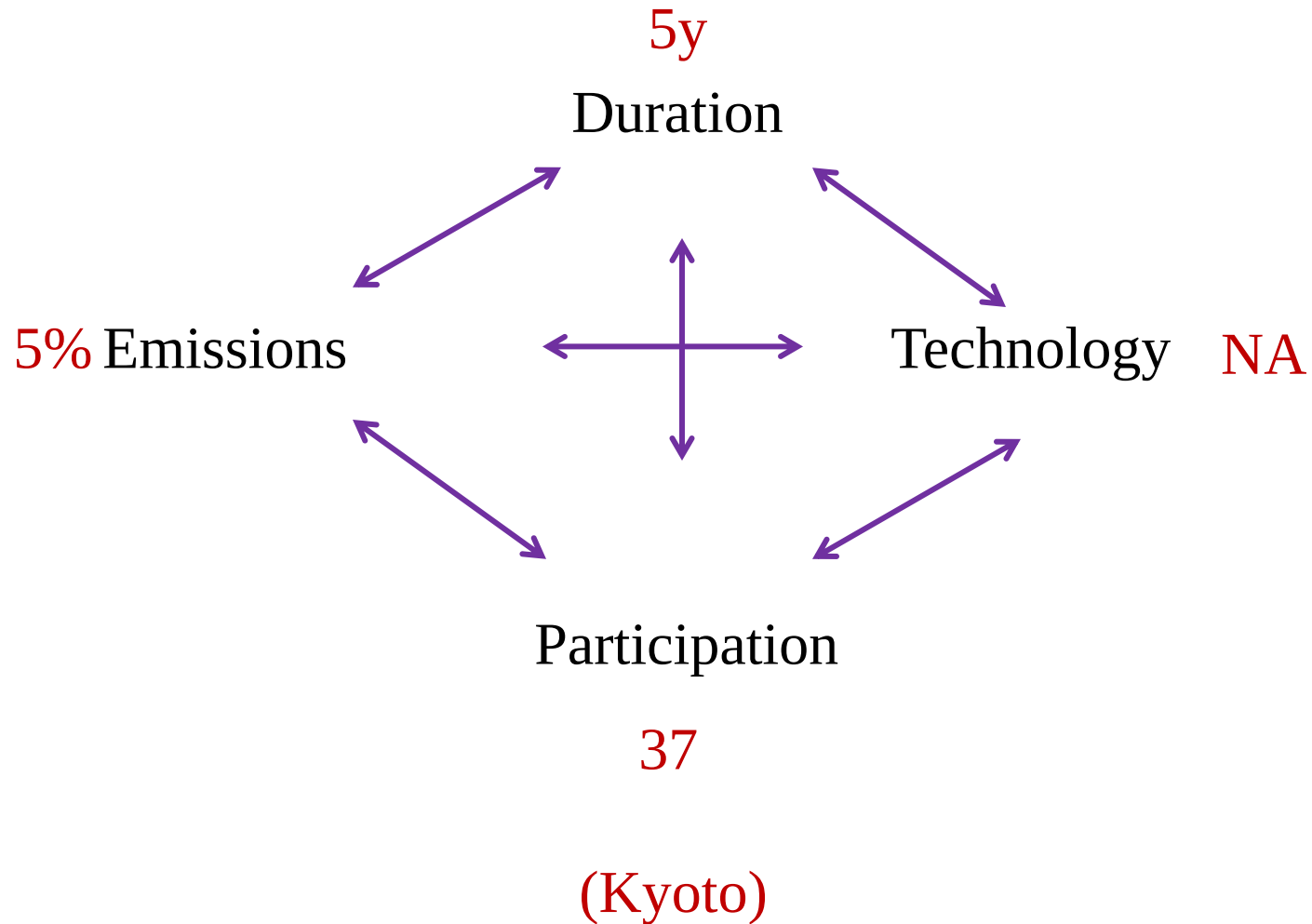
Environmental Economics and Climate Change

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Relationships



Questions – and Possible Answers

1. Is there a trade-off between width, depth, and length?
YES ☹ (Barrett, Finus and Maus, Carraro, trade-literature)
2. Is the equilibrium coalition necessarily small?
YES ☹ (Barrett, Carraro-Siniscalco, Hoel, Dixit-Olson)
3. Should one attempt to contract also on R&D?
YES! (Buchholtz-Konrad, Beccherle-Tirole, Harstad)
4. Is a long-term agreement better than a short-term one?
YES! (Harstad 2012-2014). **NO!** (Karp and Zhao 2010)

The “Standard” Participation Model

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

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

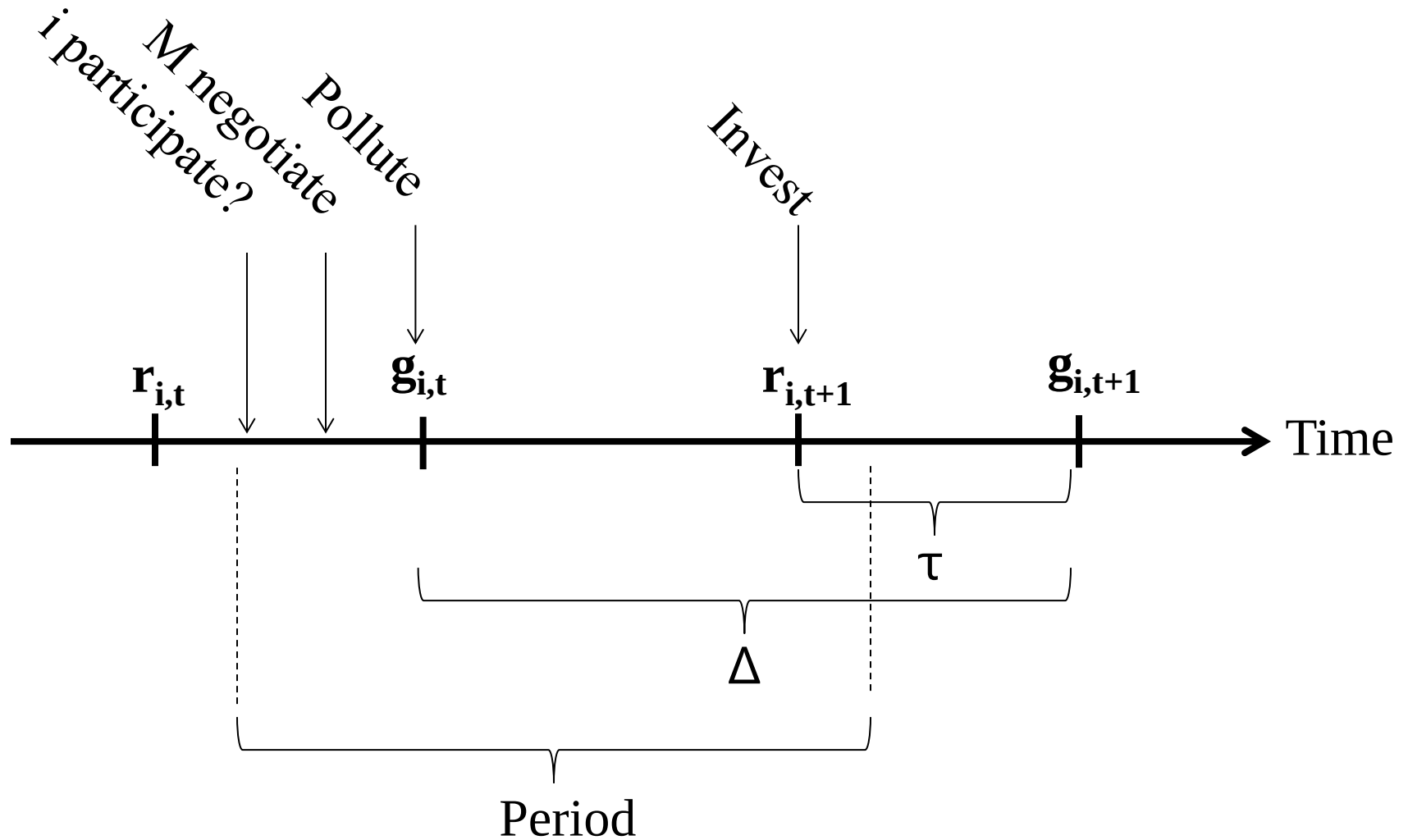
Costs $u_{i,t} = B(g_{i,t}) - C \sum_{i \in N} g_{i,t}$

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

Internal stability: No participation should want to leave

External stability: No free-rider should want to join

A Dynamic Model: Timing



Model: Equations

A linear-quadratic model:

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

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

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

$$\delta \equiv e^{-\rho \Delta}$$

$$k \equiv e^{\rho \tau} \bar{k} \Rightarrow \delta k = e^{-\rho(\Delta - \tau)} \bar{k}$$

Equilibria: Markov-perfect

Preliminaries

Preferences rewritten. If:

$$d_{i,t} \equiv \bar{y} - y_{i,t} \Leftrightarrow g_{i,t} = \bar{y} - d_{i,t} - r_{i,t}$$

$$v_{i,1} \equiv \sum_{t=1}^{\infty} \delta^{t-1} \hat{u}_{i,t}, \text{ where}$$

$$\hat{u}_{i,t} = -\frac{b}{2} d_{i,t}^2 - C \sum_{j \in N} (\bar{y} - d_{j,t} - \delta r_{j,t+1}) - \delta \frac{k}{2} r_{i,t+1}^2$$

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

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

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

Assumptions

(can be relaxed)

1. Countries are symmetric
2. Pollution is flow (stock depreciates after a period)
3. Technology depreciates after a period
4. Permits are non-tradable
5. Linear-quadratic utility functions

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 ...*

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

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

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

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

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

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

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

Incomplete Contracts

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

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

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

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

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

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

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

Larger; $m^*=n$ possible

Intuition

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

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

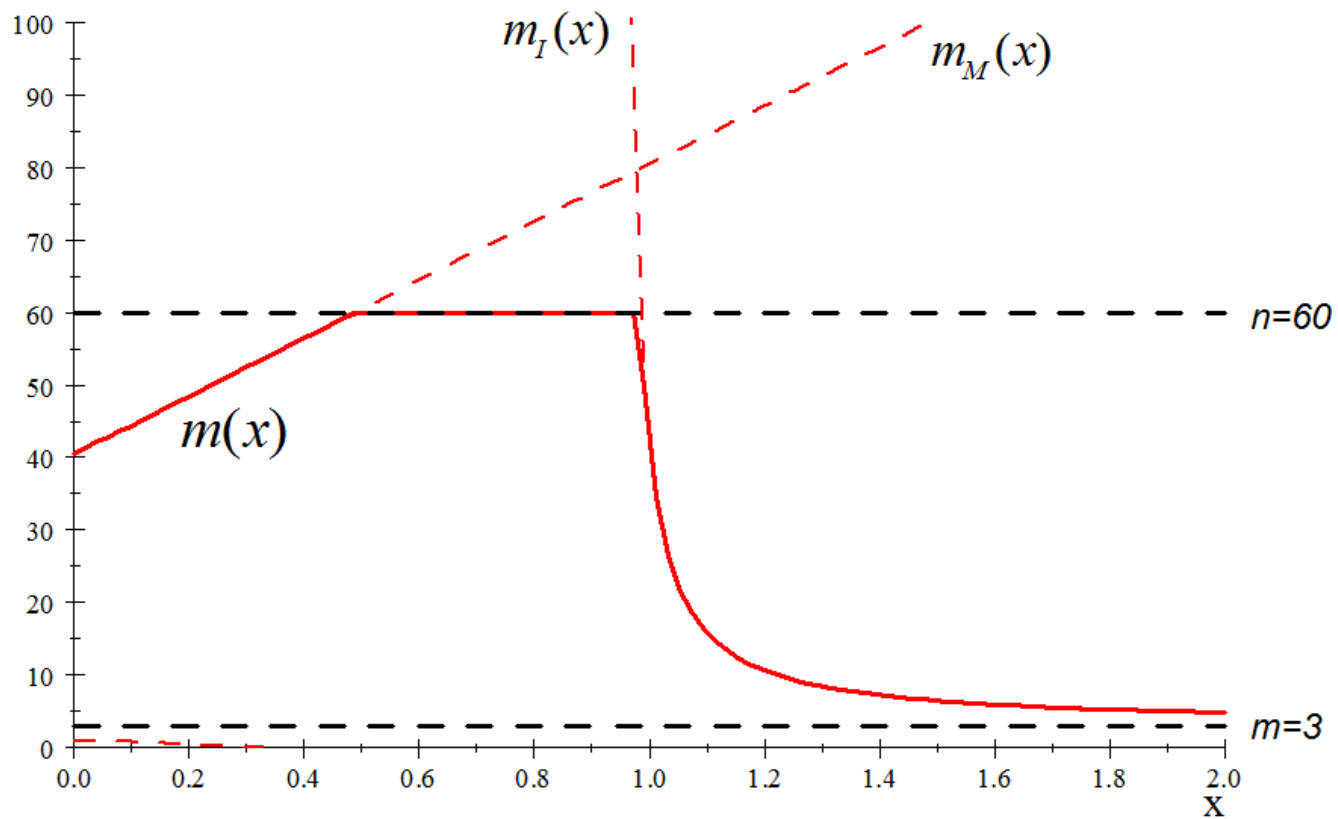
Deviate? $m = m^*-1 \Rightarrow T = 1 \Rightarrow r = C/k$

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

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

Proposition: m^* is an equilibrium iff:

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



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

Bottom line

The hold-up problem can be beneficial and a credible out-of-equilibrium threat, materialized if a participant deviates, investments are noncontractible, and T is endogenous

Participation: Lessons

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 is materialized only if few countries participate, since only a large coalition prefers to lock in the participants, and this (credible) threat can motivate many more countries to participate.
6. There are thus also good equilibria in Kyoto-style games where countries negotiate emissions, but not investments.

Dynamic Games in Environmental Economics

Lessons

Emissions $\leftrightarrow$ Investments

1. Recent theory on repeated games, dynamic games, and contract theory can be used to analyze environmental issues.
2. In business as usual, countries may invest strategically little, to motivate others to invest more and pollute less later.
3. In repeated games, countries may want to require over-investments in technology to ensure compliance.
4. With commitments, emission quotas should be small to motivate investments.
5. Investments will be strategically small before bargaining
6. This can make short-term agreements costly.
7. Only a large coalition prefers to lock in for the long run.
8. This *can* motivate free-riders to participate.