

Effect of technological development on stability of Int. Env. Agreements

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Int. Env. Agreements

- Theoretical issue
 - size of the stable coalition
 - different strands of game theory
- Political issue
 - abatement targets (Kyoto Protocol)
 - technology agreement (USA c.s.)
- Internal/external stability concept

Technological development

- R&D cooperation
 - extra positive externality (share fixed costs)
 - Buchner and Carraro (2004), Bargiacchi and de Zeeuw (2005)
- “Breakthrough” technology
 - adopt new green technology at a cost
 - Barrett (2006)
 - increasing returns to adoption

Green technology

- Green capital k lowers abatements costs
- However, size of stable coalition still small

$$0.5e^{-k_i} a_i^2$$

$$0.5(a_i - k_i)^2$$

Model

- Quadratic model
- $P(m,k)$, $Q(m,k)$ functions of total k
- Note: maximal and equal for $k=\beta$

$$\beta a - 0.5a^2 - 0.5\alpha(a_i - k_i)^2, a = \sum_{i=1}^n a_i, i = 1, 2, \dots, n$$

Example

- Parameters: $n=4$, $\beta=5$, $\alpha=20$
- $Q(2,k) > P(3,k)$
 - size 3 is not internally stable
- $Q(2,k(2)) < P(3,k(3))$ for $k(3)$ large enough
- Larger coalition invests more in green capital, total green capital increases, but outsiders may again free-ride on that

Investment stage

- Quadratic investment costs
- Coalition members expect $P(m,k)$ and outsiders expect $Q(m,k)$ in the next stage
- $k(3) > k(2)$
- $Q(2,k(2)) < P(3,k(3))$
- However, if investment costs are included, internal stability does not hold!

Sharing investment costs

- Coalition members have lower investment costs by sharing fixed costs d
- Buchner and Carraro (2004): “technology coalitions”
- Internal stability possible
- Minimum d to increase the coalition
- Minimum d to get the full coalition

Result

- For a high value of the cost parameter α , only a small positive externality is needed to enlarge the coalition
- Similarly for a large number of countries n
- More work needed
- Asymmetric countries?
- Dynamic aspects?

Barrett's model

- R&D
- Either “old” abatement or erase emissions E at adoption cost c_1

$$\max[\max(\sum_{j=1}^n a_j - 0.5c_0 a_i^2), \sum_{j \neq i}^n a_j + E - c_1]$$

Result

- The “old” abatement options will be used but can be ignored for the basic result
- If benefits per country are normalized to 1 , stable size k close to adoption cost c
- Pessimistic result: stable size is small if potential net benefits are large
- Increasing returns to adoption: large size

Focus on R&D phase

- Hoel and de Zeeuw (2008)
- Benefit of new green technology is 1 and adoption cost is c
- Individually rational to adopt: $c < 1$
- Collectively rational to adopt: $c < k$
- Total R&D denoted by M
- Adoption cost: $c(M)$, $c' < 0$, $c'' > 0$

Model

- Assumption: $c(m) + m > 1$, so one country will not invest and adopt by itself
- Stages of the game:
 - membership or not
 - (break up again or not)
 - R&D choice
 - adoption or not

Social optimum

- Suppose $V(N) > 0$, so it is socially optimal to develop and adopt the new technology
- Note: optimal $M^*(N)$ increasing in N , because $c'' > 0$

$$V(N) = N - \min\left[c(M) + \frac{M}{N}\right]$$

Non-cooperative equilibrium

- Suppose $c(M) = 1$ for $M = M'$
- Suppose $V' = N - 1 - M'/N > 0$
- Nash equilibrium: each country chooses R&D equal to M'/N and adopts
- Difference with the social optimum will typically be large if large “overinvestment” $M' - M^*(N)$ is needed

Case 1

- Non-cooperative equilibrium with full adoption does not exist
- Outsiders will not invest in R&D and will not adopt
- Payoff to a coalition member:

$$k - \min\left[c(M) + \frac{M}{k} \right]$$

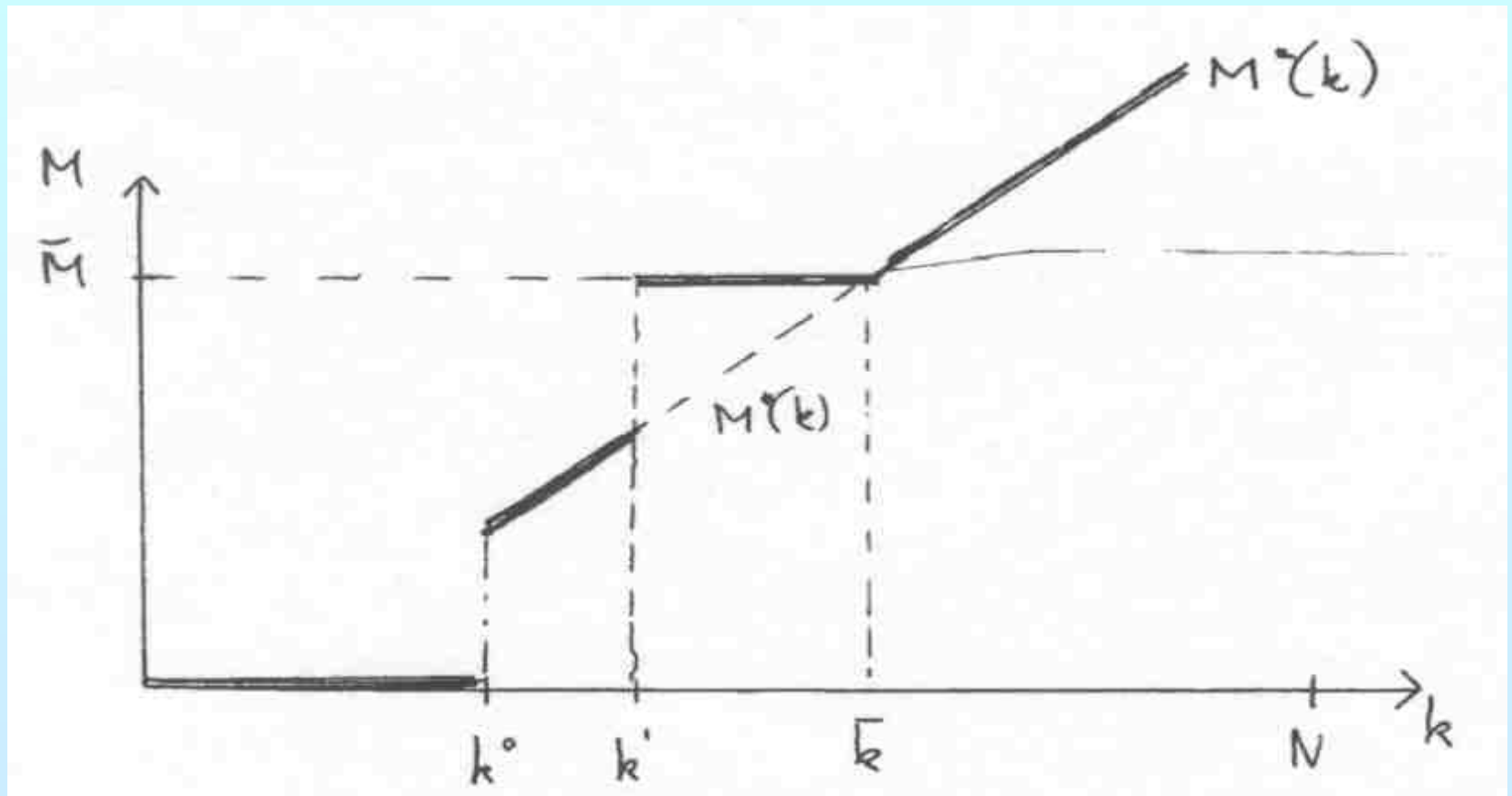
Stability

- Payoff coalition member is 0 for k^0
- Smallest integer above k^0 is the stable size
 - internally stable
 - externally stable, because $c(M) > 1$
- Comparable to Barrett (2006): stable size is small if the potential net benefits are large (pessimistic view)

Case 2

- Non-cooperative equilibrium with full adoption exists
- Assume first that outsiders do not contribute to R&D and that $M^*(N) > M'$
- Note that if $M^*(k) < M'$, the coalition may choose to invest M' in R&D anyway, in order to induce the outsiders to adopt

R&D coalition of size k



Value member coalition of size k

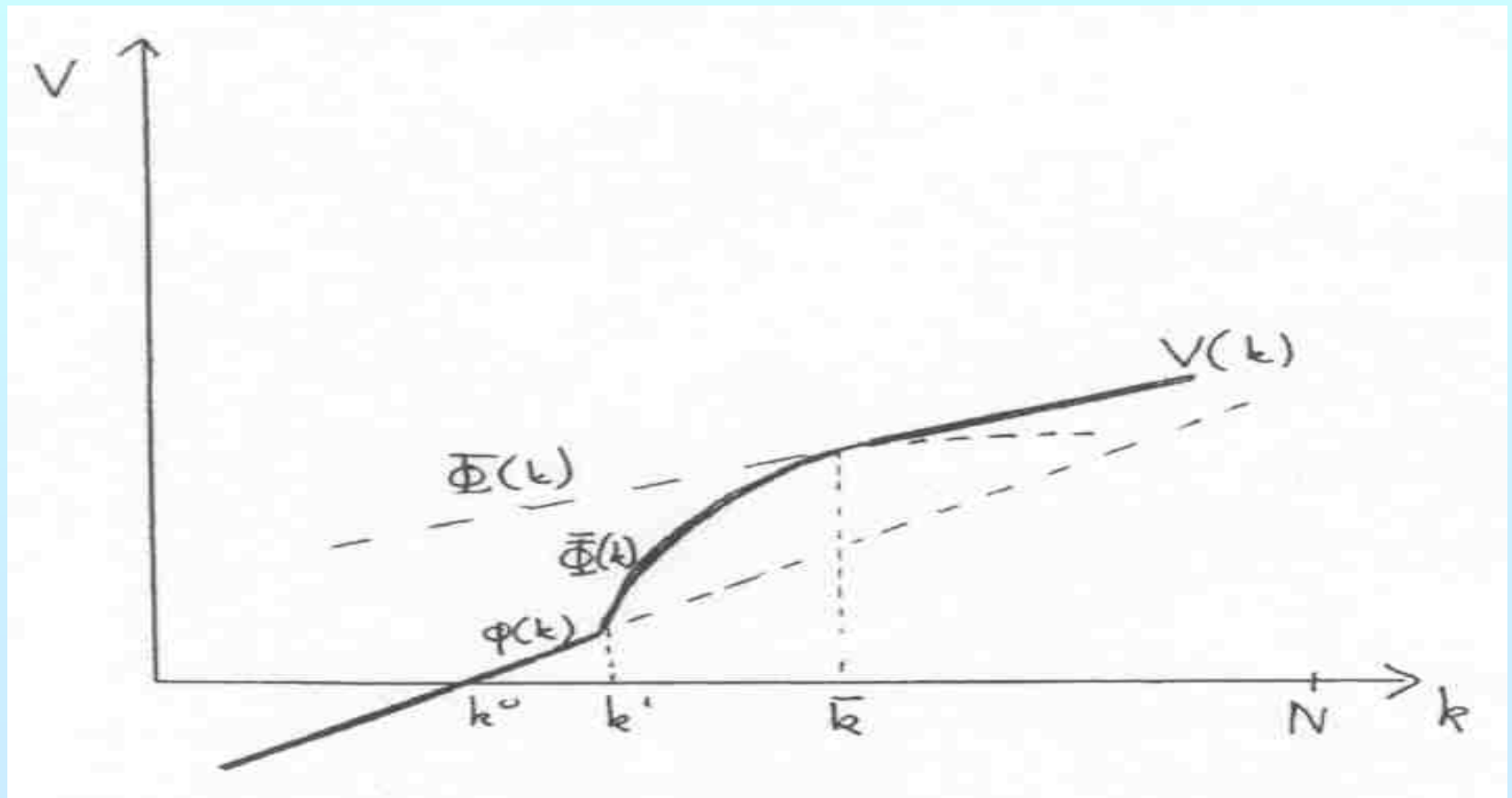
- Maximum of 0 and:

$$k - \min\left[c(M) + \frac{M}{k}\right]$$

$$N - \left[1 + \frac{M'}{k}\right]$$

$$N - \min\left[c(M) + \frac{M}{k}\right]$$

Graph of coalition member value



Equilibrium and stability

- If outsiders contribute to R&D, V' is lower bound to the value of a coalition member
- V' cuts the higher part of the value function, suppose at k'
- Smallest integer above k' is the stable size (formally we need stage 2 of the game!)
- Similar picture for $M^*(N) < M'$

Example

- Suppose $c(M) = d/M$
- $M^*(k) = \text{sqr}(dk)$; value: $k - 2\text{sqr}(d/k)$
- $N = 20, d = 225 = M', V' = 7.75$
- First-best: $M^*(N) = 67$, payoff 13.29
- Grim: size 10 ; payoffs 0.51 and 10 , resp.
- Stable coalition size 16 ; payoffs 8.5 and 16 , resp.; average payoff 10

Conclusion

- International Environmental Agreements
- Breakthrough technology
- Focus on R&D phase
- Non-cooperative R&D equilibrium
- R&D investments not socially optimal
- Large stable coalition with large average payoff possible