The economics of climate change

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Part 7: International Cooperation and Climate Policy

Readings (first part on International Cooperations):

Best fit: Perman, Common, Mcgilvray & Ma, Natural Resource and Environmental Economics,chapter 10, sections 1-4.

A Game Theoretic Perspective

Introduction

- Previous lectures analyzed
  - How much should optimally be mitigated?
  - Cost-benefit analysis of different policies
- But:
  - Climate change is about a global public good
  - But there are 193 sovereign states, each with its own agenda!
  - No international agency can establish and enforce a binding policy
- As for any public good: Too little is provided in 'private solution'
- International agreement(s) needed for large-scale internationally coordinated emission reductions
- Today:
  - What are the difficulties in forming such a coalition against climate change?

Restrictions on Agreements

- Non-excludability gives agents incentive to **free-ride**
- Three fundamental **constraints** to an international agreement:
  - IEAs have to be profitable for all potential participants
  - The parties must agree on the particular design of an IEA by consensus
  - The treaty must be enforced by the parties themselves.
- Two types of **free-riding** exist:
  - A country can decide **NOT to be a member** of an IEA or to be a member of an IEA that contributes less to the improvement of environmental quality than members of other agreements
  - A country can decide **NOT to comply** with the terms of the agreement of which it is a member

Game Theory

- When: Decisions of agents depend on decisions of other agents,

(Compare: Violation of the "No 'Market' Power assumption")

- Then: We are facing strategic actions of type "If I think that you think…"

Such a decision problem is studied using **game theory**!

- Two types of approaches:
  - **Non-cooperative** game theory:
    Assumes that binding agreements **are not** possible.
  - **Cooperative** game theory:
    Assumes that binding agreements **are** possible. Hence first-best solutions are possible as well.
    In reality this is generally not the case…
- We focus on non-cooperative games

Game Theory: Setting

- The **players of the game**
  - → Who is involved?
  - We: For simplicity 2 players
- The **rules of the game**
  - → Who decides when?
  - We: Both decide simultaneously
  - → What are the decision alternatives?
  - We: Binary decision to abate or not to abate
  - → What is the information available for decision making?
  - We: Players know the payoff matrix, but not what action opponent chooses
- The **payoffs**
  - → For any combination of actions there is a given payoff

Game Theory: Decision Tables

- Players A with actions
  - a1=pollute
  - a2=abate
- Players B with actions
  - b1=pollute
  - b2=abate

Payoff Table for Player A:

Decision table for A	Payoffs given B's action		
Alternative actions		b_1	b_2
	a_1	2	4
	a_2	1	3

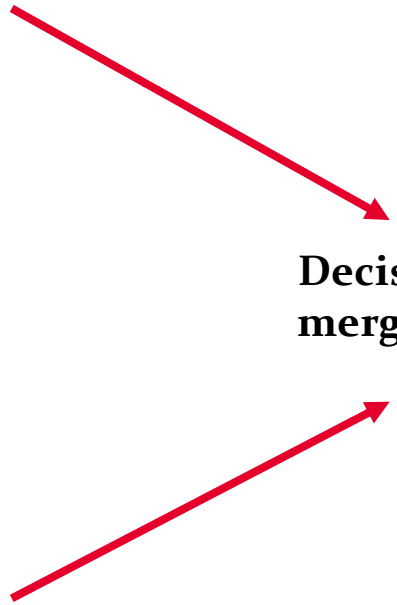
Remark: All that matter for out solution strategy for the game turns out to be that 1<2<3<4 (ordinal information). You can replace 1,2,3,4 by arbitrary numbers satisfying this relation.

Game Theory: Decision Tables -> Payoff Matrix

- Decision Tables for the 2 players A and B with two actions/decision alternatives
- Symmetric Game = Symmetric Payoffs
- The 2 Table are generally merged into one :

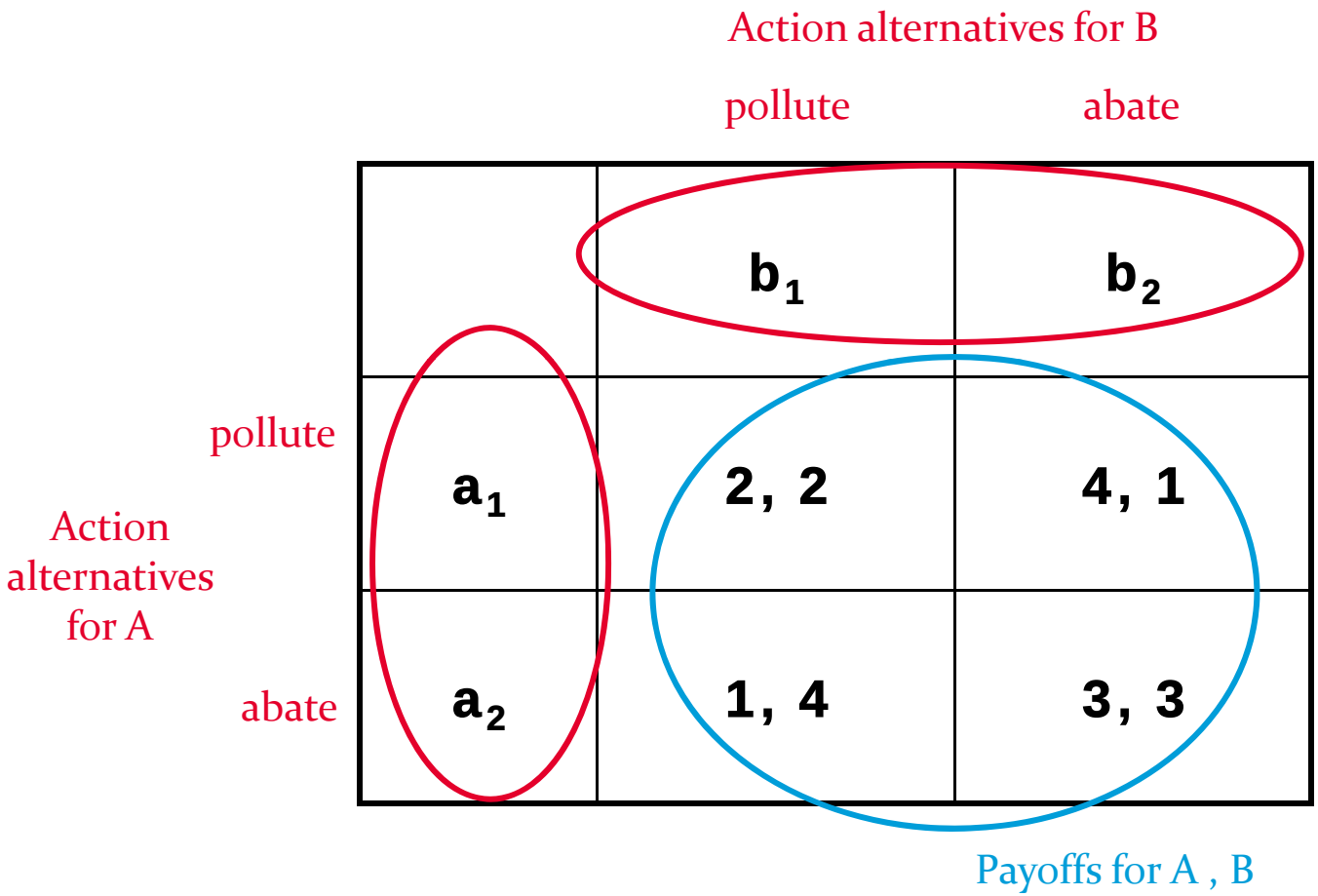
Decision table for A	Payoffs given B's action		
Altenrative actions		b_1	b_2
	a_1	2	4
	a_2	1	3

Decision table for B	Payoffs given A's action		
Alternative actions		a_1	a_2
	b_1	2	4
	b_2	1	3



Decision tables are merged into payoff matrix

Game-theory: pay-off matrix



First number: pay-off to A , second number: pay-off to B

Question: Who should choose which strategy?

Solution Concept: Nash Equilibrium

- To predict the outcome of the game we need **assumptions** how players/countries handle strategic interdependence:
- Countries **maximize their own net benefit** from their actions taking into account the **other countries' likely action**
- **No collaboration** between countries takes place

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Standard **solution** for a non-cooperative game:

- A set of choices is called a **Nash equilibrium** if each player
  - is choosing the best possible action
  - given the other players action
- Then: Neither country would benefit by deviating unilaterally
- Or: **A Nash equilibrium is a strategy combination, where all strategies of all players are the mutually best responses!**

Game theory: Searching Nash

Try (Abate,Abate) with payoff (3,3)

		B's strategy	
		Pollute	Abate
A's strategy	Pollute	2, 2	4, 1
	Abate	1, 4	3, 3

- First number: pay-off to X; second number: pay-off to Y
- Who should choose which strategy?

Game theory: Searching Nash

Try (Pollute,Abate) with payoff (4,1)

		B's strategy	
		Pollute	Abate
A's strategy	Pollute	2, 2	4, 1
	Abate	1, 4	3, 3

- First number: pay-off to X; second number: pay-off to Y
- Who should choose which strategy?

Game theory: Finding Nash

		B's strategy	
		Pollute	Abate
A's strategy	Pollute	**2, 2**	4, 1
	Abate	1, 4	3, 3

Game theory: Finding Nash

		B's strategy	
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- Nash-equilibrium: {Pollute, Pollute}
- But {Abate, Abate} gives higher pay-off to both players: **Nash-equilibrium is NOT efficient**, not the social optimum!!
- Known as the prisoner's dilemma
- Typical problem with International Environmental Agreements!

Binding agreement?

- Can we transform the non-cooperative game such that {Abate, Abate} becomes a stable NE?

- We can include penalties for defection!
  -> Can change payoff matrix to make {Abate,Abate} Nash equilibrium

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- BUT: Why should countries pay penalty?
  No supranational body can enforce agreement!

- Hence any International Environmental Agreeement (IEA) must be *self-enforcing*!

Self-enforcing IEA

- A self-enforcing IEA is an equilibrium outcome to a negotiated environmental problem that has the **following properties**:
  - There are N countries in total, of which K choose to cooperate
  - Each *cooperating country* selects abatement level that maximises aggregate pay-off for cooperating countries
  - Each *defecting country* maximises individual pay-off
  - ***No signatory country can gain* by unilaterally withdrawing** from agreement (internal stability)
  - *No non-signatory country can gain* by unilaterally acceding to the agreement (external stability)

Some results from the literature (symmetric countries)

- Coalition is **smaller than maximum size**:
  The more countries join, the larger is the incentive not to join
- The lower the **benefit-cost ratio**, the smaller the coalition
- Suppose for some (unmodeled) reason that:
  - **One country commits first** to some emission reduction
    (in technical terms: acts as a Stackelberg leader)
  - Then other countries decide

-> The number of participants and global welfare is at least as high as under the Nash assumption

Some further results

- When **countries differ** in their costs and/or benefits, it becomes harder to establish a coalition
- **Transfers** between countries make it easier to form a coalition (but are rarely observed in reality, at least for environmental agreements)
- One way to help an IEA to come about is **linkage:**
  Combine the IEA with some desirable club
  (like joining WTO, NAFTA, EU)

Conclusion

- Emission reductions are a global public good, which induces free-rider behavior
- No international agency can enforce an IEA
- Hence:
  - IEAs have to be **profitable for all** potential participants
  - The parties must agree on the particular design of an IEA by **consensus**
  - The treaty must be **enforced by the parties themselves**.
- Some results in the literature
  - Coalition does usually **not cover all** countries
  - Coalition is **smaller, the smaller is the benefit-cost ratio**
  - Coalition is **larger, the more similar countries** are