Development economics

Lecture 5: Games in economic development

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Game theory reminder

Externalities and complementarities

Cooperative and non-cooperative games

Role of social norms in social dilemmas

Credibility and subgame-perfection

Game theory

- Game theory: interaction of multiple agents
  - What are externalities? Examples?
  - Adam Smith's invisible hand usually assumed having positive effects. When externalities included, effects can lead to non-desired equilibria: non-cooperative equilibria, persistence of outdated and ineffective technologies, underinvestment in education or investment, culture of corruption.

Game theory: basic setup

1. Players
   - How many? Who? Nature included ("luck")?
2. Order of play
   - Sequential or simultaneous?
3. Information structure
   - Who knows what? When?
4. Set of strategies
   - Full description of all actions of each player in every situation
5. Individual payoffs
   - Expressed in monetary or "utility" units.

Game theory: information

- Perfect (Imperfect) information
  - Player knows all (some of) moves of other preceding players
- Complete (Incomplete) info
  - Players (don't) know payoff functions and strategies of every other player (common knowledge)
- Perfect recall
- Common knowledge – rationality of players

Nash equilibrium

- "A strategy profile so that no individual can do better by choosing an alternative strategy, given that (all) other individual(s) are choosing the strategy according to that strategy profile."

		P2: A	P2: B
P1	A	4, 4	6, 1
P1	B	1, 6	2, 2

Nash equilibrium

- Example: Find Nash equilibrium here:

P1 \ P2	A	B
A	1, 1	0, 0
B	0, 0	1, 1

- Multiple equilibria possible
- *Mixed strategy* also an equilibrium (50–50)

Game theory: Technology adoption example

- Two types of technology: A and B (assume now that both are equally effective)
- Individual cost of adopting a new technology: $C_i = c$
- Individual benefits from using a technology: $B_i = f(n_x)$
- Cost-benefit: $V_i = f(n_x) - c$
  - **Payoffs**: $f(1) = 1$, $f(2) = 2$, $c = 1$
- **Information**: Everyone knows all payoffs and strategy sets.
- **Strategy set**?
  - Example 1: Order of play: **Simultaneous** (2 **players**)
  - Example 2: Order of play: **Sequential** (2 **players**)
- Example of a "coordination game" (other examples?)

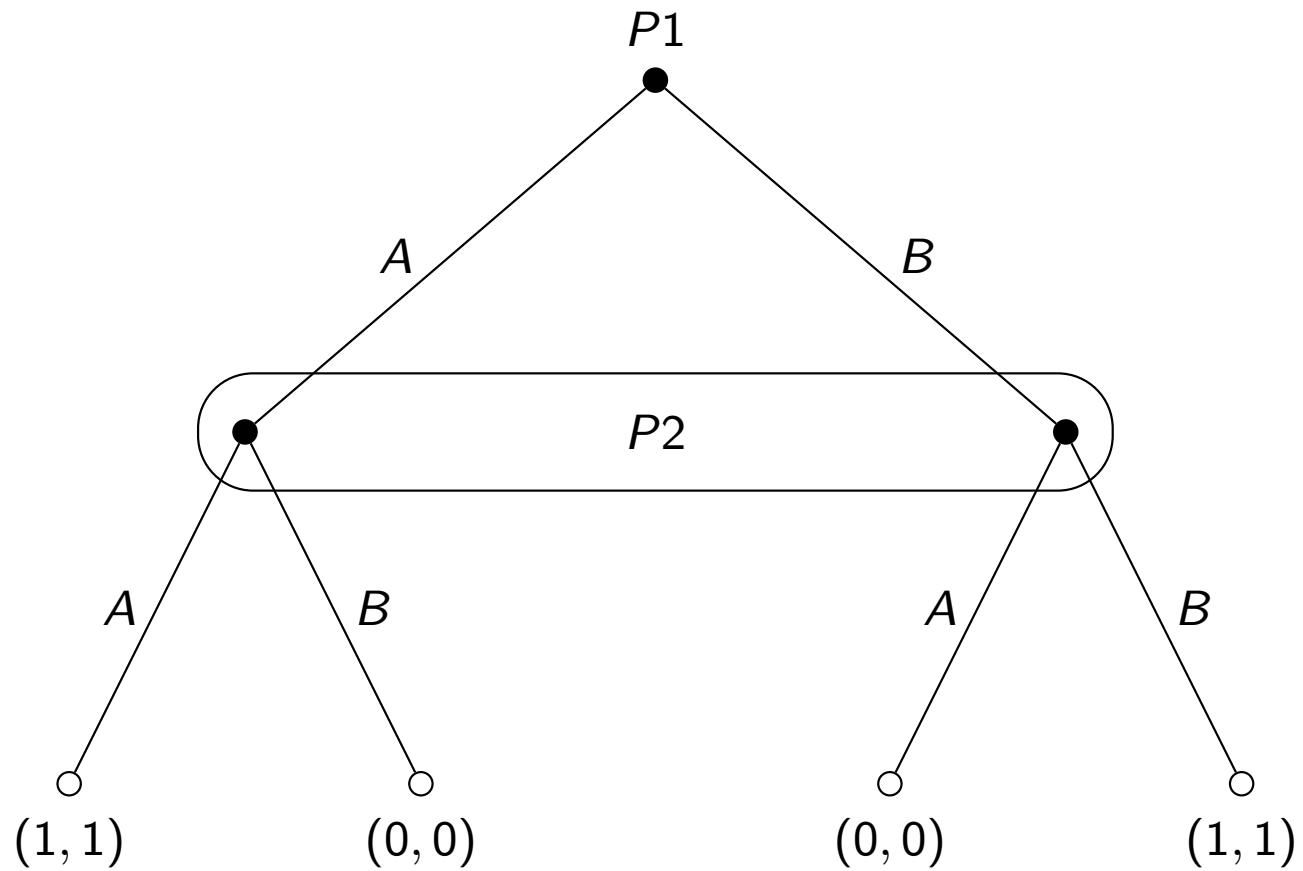
Game theory: Technology adoption example

- Example 1: Order of play: Simultaneous (2 players)

		P2: A	P2: B
P1	A	1, 1	0, 0
P1	B	0, 0	1, 1

Game theory: Technology adoption example

- Example 2: Order of play: Sequential (2 players)



Game theory: visualisation of games

- Normal form (matrix)
- Extensive form (game tree)
- (Hybrid games – mix of the two)

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Externalities, complementarities

- Think of the $E(t)$ efficiency term we defined in the Romer (1990): $Y(t) = E(t)K(t)^{\alpha}P(t)^{1-\alpha}$
- Assume now that: $E(t) = aK^*(t)^{\beta}$
  - $K^*(t)$ is the average capital stock.
  - Assume that firms are identical: $K^*(t) = K(t)$
  - Capital of others can enter positively into the production function:

$$Y(t) = aK(t)^{\alpha+\beta}P^{1-\alpha}$$

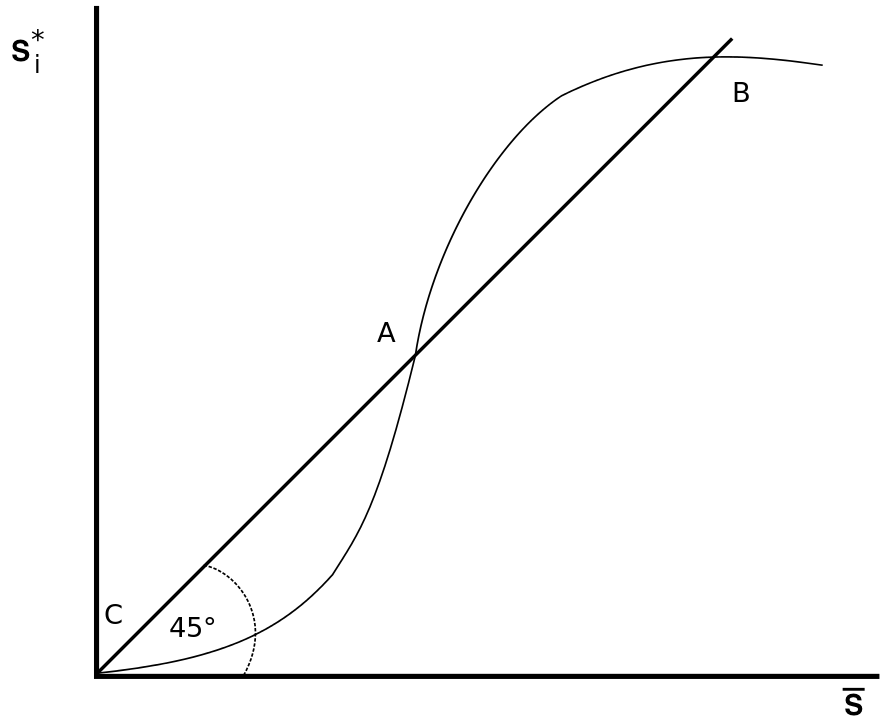
- If $\alpha + \beta > 1$: increasing returns to capital (positive externalities / complementarities); growth accelerated!
- Two takeaways:
  1. Unless "social planner", separate firms tend to underinvest: private marginal benefits lower than social marginal benefits
  2. Constant returns to capital and labor in firms and increasing returns on the level of a society ($Y_t^{soc} = aK_t^{\alpha+\beta}P_t^{1-\alpha}$)

Externalities, complementarities

- In order to get to certain level of capital, firms need to save
- But the level of savings/investments depends on the expectations of what other firms do, i.e. $aK^*(t)^\beta$ considered.
- Complementarities differ from externalities: complementarities induce similar actions ("I invest if every other firm invests too") — compare to other types of externalities (Noise? Pollution?)
- Complementarities/interlinkages important and frequent.
  - Q: Examples?
  - Q: Which firm should move first? Or when should a firm decide to move?
    - Crucial role of: 1) own action, 2) actions of others, 3) own beliefs about actions of others, 4) others' beliefs about my action, 5) etc...
    - Coordination and confidence are everything!

Externalities, complementarities

- Coordination failure (first formalized by Rodenstein-Rodan, 1943):
  - Assume firms save separately for investment
  - Expecting low average savings among firms induces lower savings in every firm: expectations and history matter!
  - All firms in a country (assumed to) save $\bar{s}$
  - Firm's best response is s_i^*
  - Complementarities exist between own production and that of other firms.



Development traps: Railroad

- What was needed for a successful construction of a railroad in a country in 19th century?
- Example: railroad cannot operate without large-scale coal mines and without large-scale steel smelters:
  - Players: 1) coal, 2) steel, 3) railroad

Railroad: invests

Coal \ Steel	Invest	Withhold
Invest	50,50,50	-100, 0, -100
Withhold	0, -100, -100	0, 0, -100

Railroad: withholds

Coal \ Steel	Invest	Withhold
Invest	-100, -100, 0	-100, 0, 0
Withhold	0, -100, 0	0, 0, 0

Externalities, complementarities

- Some questions:
  1. Role of government in solving the problem of underinvestment due to low expectations?
  2. What does patent protection do and why is it important?
  3. What can hamper patent protection?

Kremer (1993): The O-ring theory of economic development

> *"The space shuttle Challenger had thousands of components: it exploded because it was launched at a temperature that caused one of those components, the O-rings, to malfunction."*

- Expected production: $E(y) = k^{\alpha}(\Pi_{i=1}^{n} q_i)nB$
  - $q_i \ldots$ quality of worker i (probability of not screwing up)
  - $n \ldots$ number of workers
  - $B \ldots$ output per worker if not screwed up
- Profit maximizing firm:

$$\max_{k,\{q_i\}_{i=1}^{n}} k^{\alpha}(\Pi_{i=1}^{n} q_i)nB - \sum_{i=1}^{n} w(q_i) - rk$$

Kremer (1993): The O-ring theory of economic development

- Profit maximizing firm:

$$\max_{k,q_i:i\in\{1,\ldots,n\}} k^{\alpha}(\Pi_{i=1}^{n} q_i)nB - \sum_{i=1}^{n} w(q_i) - rk$$

- FOC: $\frac{\partial y}{\partial q_i} \Rightarrow (\Pi_{i\neq j} q_i)nBk^{\alpha} = \frac{\partial w(q_i)}{\partial q_i}$
  - Marginal product of skill must equal to marginal cost of skill.
  - Equilibrium: A firm will employ workers with the same q
  - Why? $\frac{\partial^2 y}{\partial q_i \partial \Pi_{i\neq j} q_i} = nBk^{\alpha} > 0$
  - Reasoning? Firm with current high quality workers get highest benefit from another high quality workers, thus they would get the worker at relatively higher wage. Perfect matching on quality.
- Q: Lessons for development? Recall brain drain. Productivity of firms in developing countries. Investment in education.

Game theory reminder

Externalities and complementarities

Cooperative and non-cooperative games

Role of social norms in social dilemmas

Credibility and subgame-perfection

Non-cooperative games

- Prisoners' dilemma ($c > a > b > d$)

		P2: A	P2: B
P1	A	a, a	c, d
P1	B	d, c	b, b

- Tragedy of commons:
  - Groundwater use
  - Deforestation
  - Pollution
  - Low effort levels in agricultural cooperatives
  - Overfishing

Cooperative games

- Stag hunt game

		P2: A	P2: B
P1	A	a / a	b / c
P1	B	c / b	b / b

- $a > b > c$
- Also called an "assurance game". Why?

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Role of social norms

- Can solve coordination problem - recall the technology adoption game:

		P2: A	P2: B
P1	A	1, 1	0, 0
P1	B	0, 0	1, 1

- *Focal points* (Thomas Shelling) generated by establishment of social norms (which language is spoken? which dress code in a party? which side of the road to drive on?... which technology to choose?)
- Role of trust (or credibility)?

Big Weddings Bring Afghans Joy, and Debt

By **KIRK SEMPLE** JAN. 14, 2008

A middle-class wedding, like this one in Kabul, costs an average of $20,000, several times the salary of most bridegrooms. For most, the bride's family sets the terms. The bridegroom pays.

Max Becherer/Polaris for The New York Times

Why Kabul must leave the big fat Afghan wedding alone

Nelufar Hedayat

The government is curbing Afghans' expensive, lavish nuptials. But in a poor country scarred by war with little to celebrate, these weddings offer vital escape

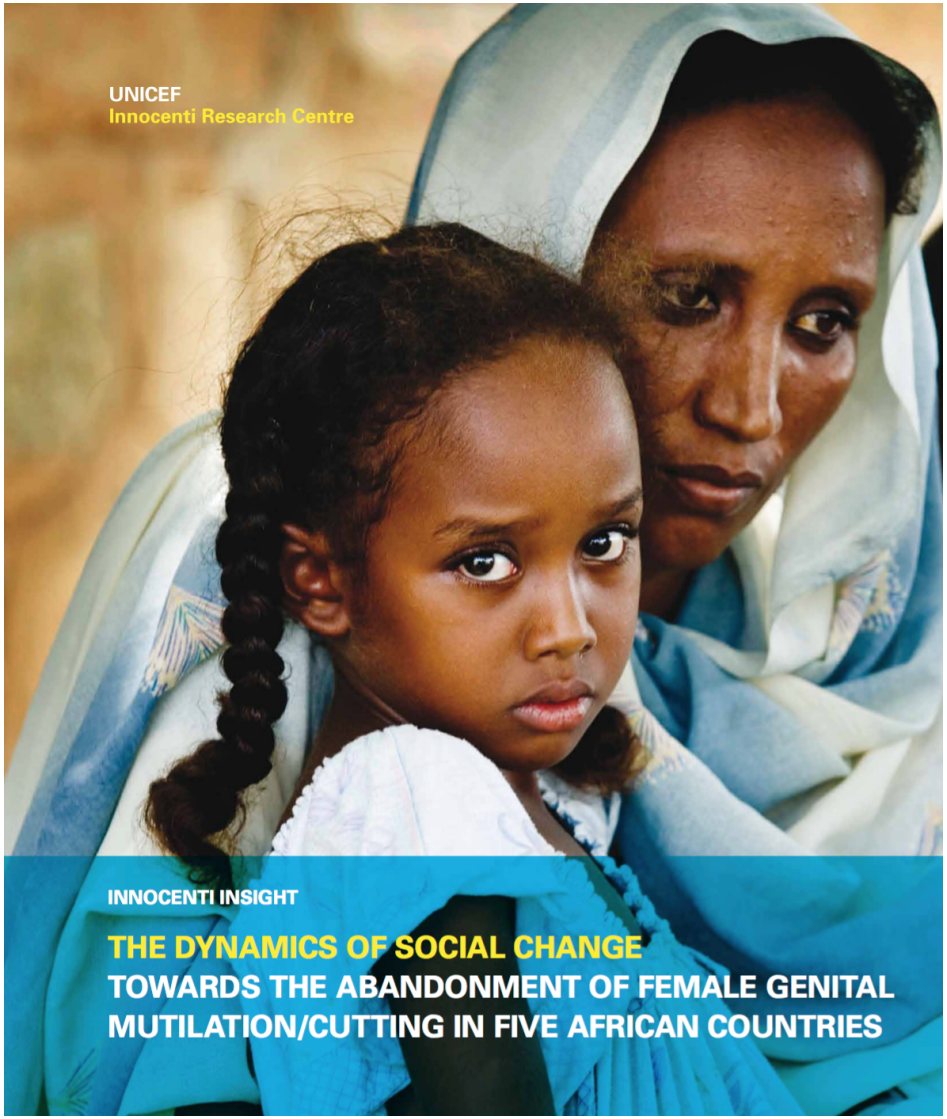
A wedding party in Kabul. 'You'd think that the legislators had more pressing things to occupy their time than too much food on the table or one guest too many at a family wedding.' Photograph: Manca Juvan

Role of social norms

- But can lead even to negative outcomes (example: lavish weddings expected even from the poor)

P1 \ P2	Little	Lot
Little	5, 5	3, 0
Lot	0, 3	3, 3

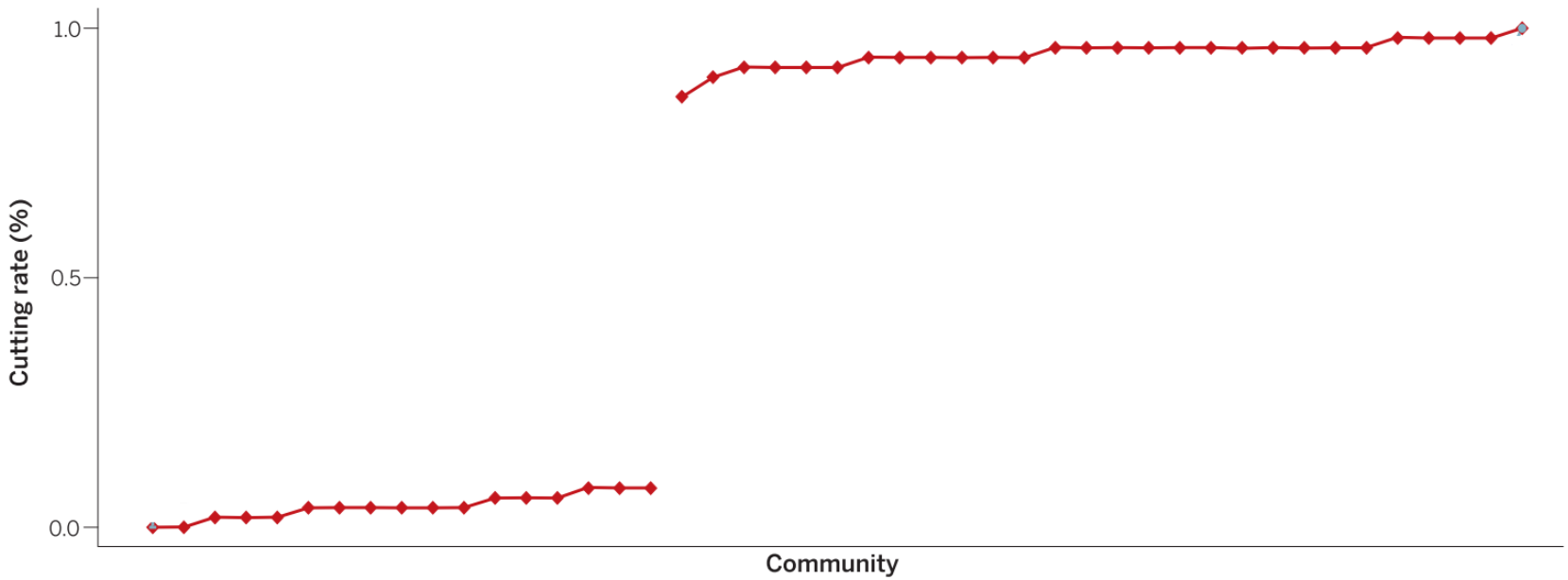
- Q: When would individuals rather select to invest Lot than Little?
  - Assume that p is a *belief* about the probability that others would invest Little.
  - Invest Lot if $5p > 3$
  - Q: What determines p? How to change it? "Keeping up with the Joneses": $u(c_i, s_i, \bar{s}) = c_i - s_i - \beta \times \mathbb{1}\{s_i < \bar{s}\}$



Social convention theory uses game-theoretic models to explain behaviour in the presence of [...] social norms. [...] When a social convention or a social norm is in place, decision-making is an interdependent process in which a choice made by one family is affected by and affects the choices made by other families [...]. The theory offers an explanation of the reasons daughters and their families continue to choose FGM/C, and why it is so difficult for individual girls or families to abandon FGM/C on their own.

Efferson et al. (2015): Female genital cutting and social coordination norms?

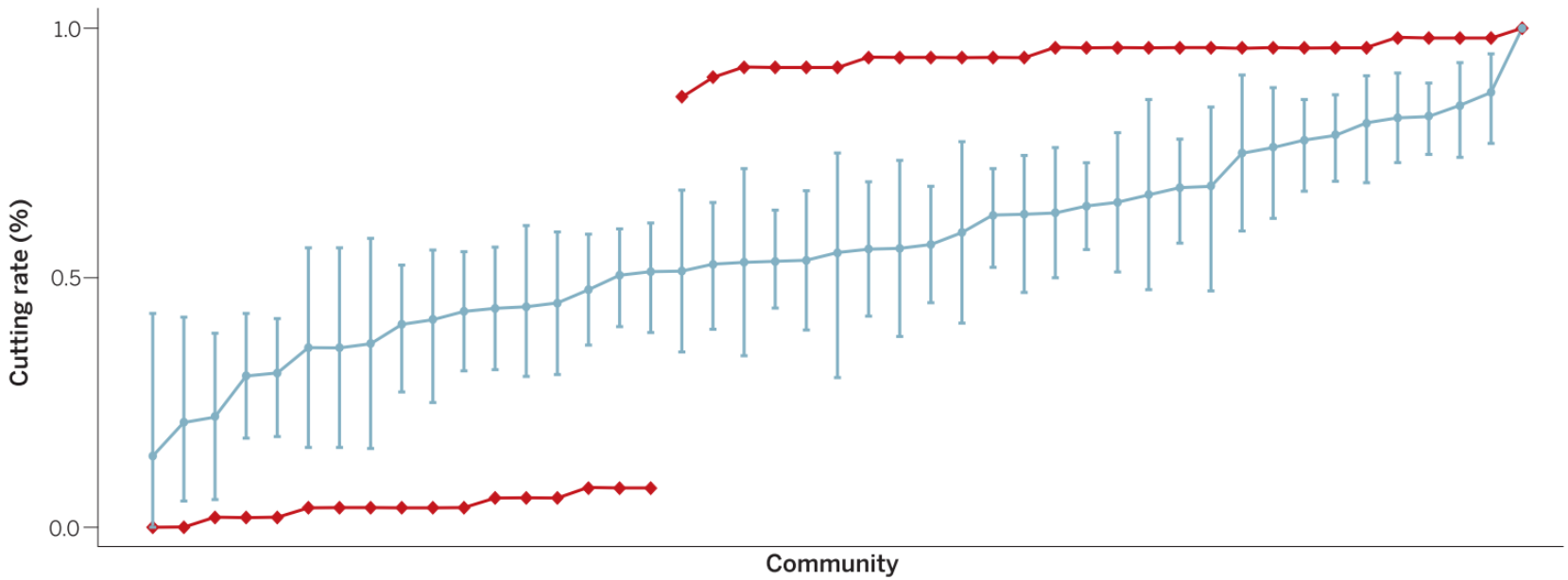
Figure 1: Social norms?



Cutting rates in Gezira communities. Red diamonds show ordered cutting rates as predicted by the coordination game model (*12*).

Efferson et al. (2015): Female genital cutting is not a social coordination norm

Figure 2: Female genital cutting is not a social coordination norm



Cutting rates in Gezira communities. Red diamonds show ordered cutting rates as predicted by the coordination game model (*12*). Green dots show actual cutting rates across the 45 communities with 95% boot-strapped confidence intervals.

Efferson et al. (2015): Female genital cutting is not a social coordination norm

- Method used:
  - Sample: Gezira, Sudan
  - How to detect cutting in large samples?
    - In Sudan henna applied to a girl's feet when she is cut (not on other occasions) - feet of nearly all girls photographed
    - Researchers accompanied by doctors: Asking has the girl been "purified"?
- Results: no discontinuity on a community level as predicted by social norms model. Q: Problems?
  - Cutting can be clustered within groups within societies; Survey + Implicit Association Test on perceptions of cutting conducted, both speak against.
- Q: Why important to know?
  - If social norm: "development workers must assemble a critical mass of families in a short period of time to move the share of cutting families from above to below the threshold"

Role of social norms

- Can turn Prisoners' dilemma into a coordination game:

		P2: A	P2: B
P1	A	4, 4	$(6-x)$, 1
P1	B	1, $(6-x)$	2, 2

- For which values of x would this be a Prisoners' dilemma?
- For which values of x will this be a coordination game?
- How do you understand the x?

Role of social norms: altruistic enforcement

- Fehr and Gächter (2002): availability of punishment improves cooperation in public goods game.

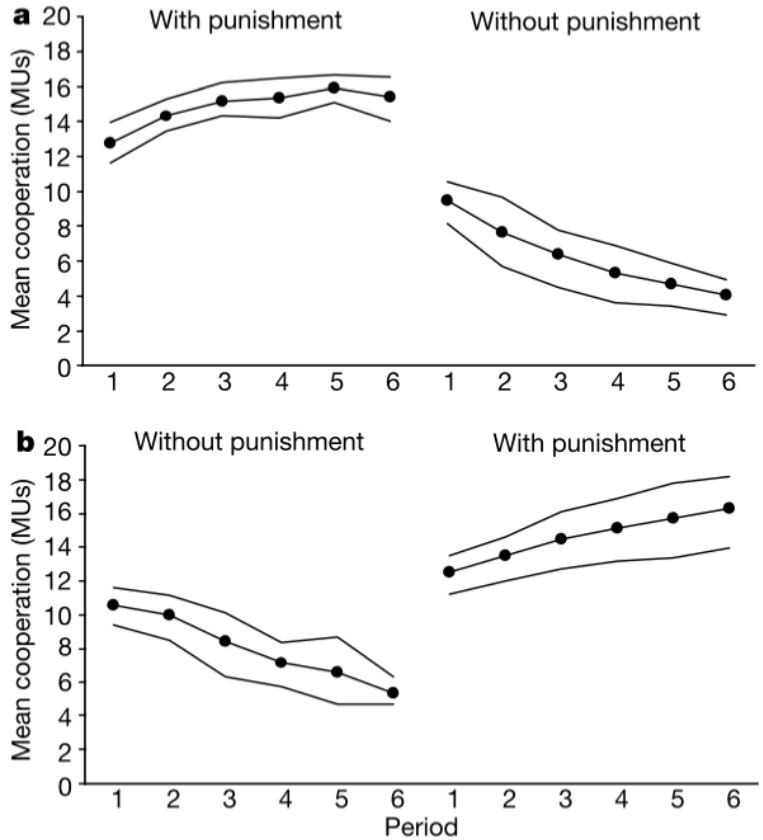


Figure 2 Time trend of mean cooperation together with the 95% confidence interval. **a**, During the first six periods, subjects have the opportunity to punish the other group members. Afterwards, the punishment opportunity is removed. **b**, During the first six periods, punishment of other group members is ruled out. Afterwards, punishment is possible.

Ostrom et al. (1999): Revisiting the Commons

Fig. 1. The government-owned Chiregad irrigation system (right panel) was constructed in Nepal to replace five farmer-owned irrigation systems whose physical infrastructures were similar to the Kathar farmer-managed irrigation system (left panel). In planning the Chiregad system, designers focused entirely on constructing modern engineering works and not on learning about the rules and norms that had been used in the five earlier systems. Even though the physical capital is markedly better than that possessed by the earlier systems, the Chiregad system has never been able to provide water consistently to more than two of the former villages. Agricultural productivity is lower now than it was under farmer management (*37*). Not only do the farmers invest heavily in the maintenance of the farmer-owned system on the left, they have devised effective rules related to access and the allocation of benefits and costs. They achieve higher productivity than most government-owned systems with modern infrastructure. [Photographs by G. Shivakoti (left) and E. Ostrom (right)]

Policy

- Different policies when dealing with Stag hunt (coordination failure) and Prisoners' dilemma game. Why?
  - Persistent enforcement: Prisoners' dilemma
  - Temporary push: Stag hunt (make a focal point more salient using subsidies or certification)

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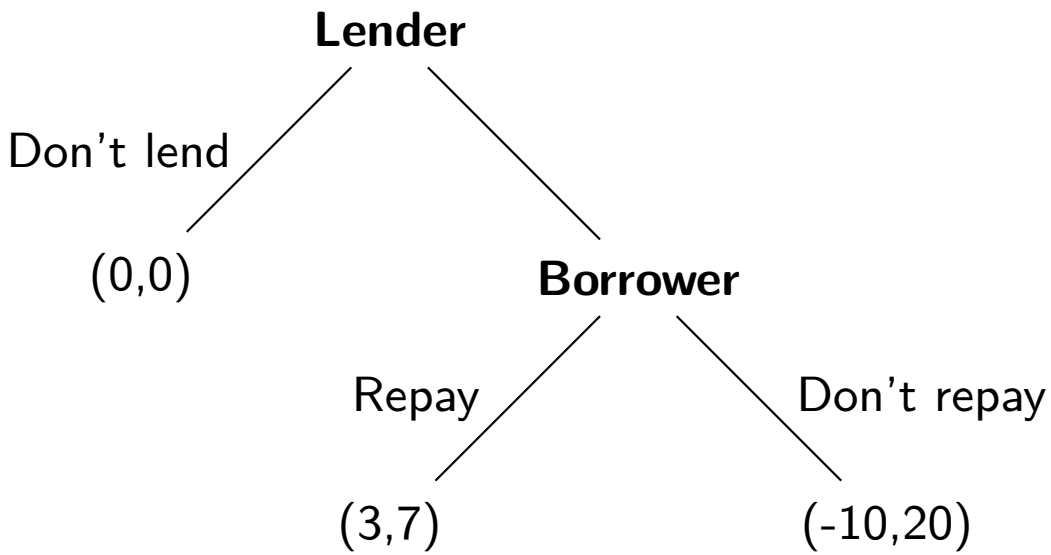
Credibility and subgame-perfection

Credibility and subgame-perfection

- Assume a problem of a lender borrowing money where the lender does not have an assurance of borrower's repayment (trust-like interaction):



Credibility and subgame-perfection

- In **sequential games** we define a **credible equilibrium** as a subset of a Nash equilibria, which are credible (trustable)
- Solve by **backward induction**:
  - Although (3,7) would be desirable for the Lender, the Borrower is unlikely to play it as (-10,20) is more teasing for her. In anticipation, the Borrower better does not lend.