# Solutions to the Problem of Free Access

## Part II
## Common Property Resources (CPR)

2008

# Outline

- Repeated interactions, Punishment and Cooperation
- Alternative game structures

1 Conclusion

# Common property and cooperation



- The tragedy of the commons and free-access stories may be too pessimistic.
- It assumes that individuals do not try to improve on the situation.
- Decentralized mechanisms that induce cooperation may exist.
- Three theoretical arguments:
  1. Decentralized contracting with side payments. The Coase solution as in LW (1984).
  2. Repeated interactions.
  3. The payoff structure of the PD game may not be representative.

# Cooperation with repeated interactions

## The role of punishment



- Free access result assumes *one-shot* game. (Prisoners' dilemma)
- Many commons are exploited in small-number (small-community) settings with repeated interactions.
- Repeated interactions introduce the possibility of punishment for non-cooperation.

# One-shot PD game

- 2 herdsmen: 1 and 2
- Common pasture land
- Strategies: 1 or 2 goats on pastureland
- Payoff matrix on next slide.
- Nash equilibrium leads to too many goats.

herdsman II

| herdsman I | 1 | 2 |
|---|---|---|
| 1 | 5, 5 | 3, 6 |
| 2 | 6, 3 | 4, 4 |

Number of goats

# Infinitely-repeated PD game

- Payoff matrix of stage game:
  - cooperate C
  - defect D

Player II

| Player I | | $C$ | $D$ |
|---|---|---|---|
| | $C$ | $b-c, b-c$ | $-c, b$ |
| | $D$ | $b, -c$ | $0, 0$ |

# Infinitely-repeated PD game

- Assume that each player adopts the following trigger strategy:

$$\text{at period } \tau \text{, choose} \begin{cases} C & \text{if } (C, C)\ \forall t = 1, 2, ..., \tau - 1 \\ D & \text{otherwise.} \end{cases}$$

- The strategy constitutes a Subgame Perfect NE.

# Infinitely-repeated PD game

## Proof of SPNE



- Given what the other is doing, no-one has an incentive to deviate from the chosen strategy.
- If both players stick to their strategy and assuming cooperation in the past, the discounted payoff is:

$$V_i = b - c + \beta(b-c) + \beta^2(b-c) + \ldots \quad (1)$$
$$= \frac{b-c}{1-\beta} \quad (2)$$

- If player I considers a deviation from the trigger strategy at one period, he will choose D and receive a short term gain of $b$. In the future, player II's strategy dictates to play D forever. Player I cannot do better but to play D also. This yields zero profits forever. The value of a deviation from the trigger strategy is thus:

$$V_i' = b$$

# Infinitely-repeated PD game

- Starting from a history of cooperation, player I will not deviate from the trigger strategy as long as

$$V_i > V_i' \Rightarrow \frac{b-c}{1-\beta} > b \Rightarrow \beta > \frac{c}{b}$$

# Infinitely-repeated PD game

- Remark: One must make a difference between a deviation from the initial trigger strategy and a switch to defection if the other player has defected in the past. In this last case, there is no deviation from the proposed strategy.
- To be complete, we must also show that the trigger strategy constitutes a best response for player I off the equilibrium path. In other words, the threat to punish a defection must be *credible*.
- Off the equilibrium path, one player (at least) has defected in the past. Player I's strategy dictates him to defect now. Can he do better? No, because given player II's strategy, player II will defect also. Hence, the punishment threat is credible.
- The proposed trigger strategy is thus a SPNE if

$$\beta > \frac{c}{b}$$

# Infinitely-repeated PD game

## What does it teach us?



1. The strategies are *history dependent*.
2. Repeated interactions introduce the possibility of punishment for non-cooperative behavior.
3. Since punishment takes place in the future, the discount factor is important.
4. It is all about comparing short-term gains with long-term losses.
5. Perpetual defection is also a SPNE.

How reasonable is it to assume infinite future interactions when life on earth has an end?

# Finitely repeated PD game

- Assume that the game ends at t=T.
- Since there is a final period, we solve the problem recursively.
- The final period is just like a one-shot game. Both players defect. This is the unique NE.
- What happens at T-1?
- Since defection is the only equilibrium in the last period, non-cooperative behavior cannot be punished at T-1.
- Therefore, both players will defect at period T-1.
- And so on back to t=0.

# Finitely repeated PD game



- The introduction of a final period removes the possibility of cooperation with threat of punishment.
- Does this mean that cooperation is not generally possible in repeated PD games?
- What if the final period were not well known?

# The repeated PD game with an uncertain final period

- Let $\pi$ be the probability that the interaction will continue over to the next period.
- Assume that players choose the same trigger strategy as before:

$$V_i = b - c + (\pi\beta)(b - c) + (\pi\beta)^2(b - c) + \ldots \quad (3)$$
$$= \frac{b - c}{1 - \pi\beta} \quad (4)$$

- We get the same result as the infinitely repeated PD game, except that the "effective" discount factor is now lower.
- Cooperation is now harder to sustain but it is still possible.

# The PD game structure



- Provides a good representation of the appropriation problem in many CPRs.
- But some collective action problems have to do more with the provision of a public good, such as the creation, maintenance, or improvement of a resource.
- The PD game payoff structure may not be appropriate there.
- Imagine that the gains from providing a public good alone outweighs its costs. This situation can be depicted by the *Game of Chicken*.

# The game of chicken

The game:

- Two small-scale marine fishers.
- Threatened by foreign large trawlers.
- They must protect themselves against encroachment by foreign boats through lobbying efforts.
- Those efforts are a public good.
- Before arrival of foreign trawlers, both get 10 each.
- Total cost of lobbying effort: 4

# The game of chicken

- (C,C) is when both contribute equally to lobbying effort.
- (D,D) is when none contributes and foreign trawlers enter the fishery.

Player II

| Player I | | $C$ | $D$ |
|---|---|---|---|
| | $C$ | $8, 8$ | $6, 10$ |
| | $D$ | $10, 6$ | $2, 2$ |

# The game of chicken

## Pure strategy Nash equilibrium



- Two Nash equilibria: (C,D) and (D,C).
- Just like the PD game, each prefers the other to contribute alone.
- Unlike the PD game, if the other does not contribute, it is better to do it yourself. (Each player prefers to be a “sucker" than doing nothing.)
- The equilibrium will depend on what one expects the other to do.
- A third possibility is a *mixed strategy*.

# The game of chicken

## Mixed strategy Nash equilibrium



- Mixed strategy: Player *i* cooperates with probability $\pi_i$ and defects with probability $1 - \pi_i$.

$$\max_{\pi_1} J_1 = \pi_1[\pi_2 8 + (1-\pi_2)6] + (1-\pi_1)[\pi_2 10 + (1-\pi_2)2]$$

$$\begin{array}{ll} \pi_1^* = 1 & \text{if } \pi_2 < 2/3 \\ \pi_1^* = 0 & \text{if } \pi_2 > 2/3 \\ \pi_1^* \in (0,1) & \text{if } \pi_2 = 2/3 \end{array}$$

- draw the reaction functions...

# The game of chicken

## Mixed strategy Nash equilibrium



- The mixed-strategy equilibrium is

$$\pi_1 = \pi_2 = 2/3$$
$$E[J_i] = 7.33$$

- There is a loss due to cases where both players end up not cooperating.

# The game of chicken



- Obviously, the situation can be easily improved through some communication. The players could devise a self-enforcing game that would make each one better off:
  - Toss a coin.
  - If head, player I contributes and player II does not.
  - If tail, player I does not contribute and player II does.
- Contrary to the PD game, this plan is self-enforcing. Once it is agreed that one will do the lobbying, none has an incentive to deviate from the agreement. The expected utility is now (8,8) instead of (7.33,7.33).

# Assurance games

- In other settings, symmetric, coordinated actions are required from all participants.
  - The breeding grounds must be protected by all
  - Anti-erosion practices must be adopted by all
  - Self-restraint on the use of dynamite fishing
  - Programs of pest control
  - Monitoring of outside entrants
- In order to benefit from one's own effort, it must be the case that all players contribute a minimal effort also.
- The difference with the PD setting is that free riding on the public good brings a lower gain than the one from cooperation by all. Such game structures are referred to as *assurance games*. (Sen QJE 1967, Runge 1981)

# Assurance games

- Contrary to the game of chicken, players prefer mutual defection to being a sucker.
- This game has two NE in pure strategies.

Fisher II

| | | 1 | 2 |
|---|---|---|---|
| Fisher I | 1 | 8, 8 | 1, 6 |
| | 2 | 6, 1 | 2, 2 |

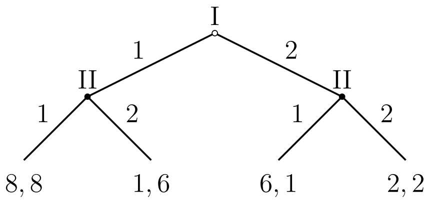
Number of boats

# Assurance games

- The game also has a mixed strategy equilibrium. Can you find it?
- The resulting equilibrium will depend on each other's expectations about their move.
- A problem arises if player I has "pessimistic views" about player II. Player II would then expect player I to defect not because player I is thought to be a free rider, but because player II knows that player I thinks that player II is a free rider.
- The problem can be resolved through some prior communication to "reassure" each other about their intentions.

# Assurance games

- Another possibility is that one player can precommit by moving first.
- Extensive form:



# Assurance games

- In that case, player I can be sure to obtain the best outcome.
- Similarly, a repeated assurance game easily leads to a cooperative outcome.

# to be continued

- x

# Summary

- x

# Outlook

- X