International Negotiations
Games, Strategies and Negotiations
How time changes things

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Strategy under long-term relationships?

- We have stressed the possibility of time to eliminate non-credible threats
- But how can time change strategic behaviour relative to static games?
- Time can enrich strategy spaces and the set of equilibria
- In repeated games, cooperation can emerge as the strategy spaces grow
- Indeed, under reasonable assumptions, cooperation (with cheat-detection) can be the most rewarding strategy!

Repeated games and new equilibria

Consider the following 2-player static game:

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

Repeated games and new equilibria

- Clearly, it has 2 N.E. in pure strategies:

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

- Suppose we play this game twice (repeated game)
- What are the NE of the repeated game?

Repeated games and new equilibria

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

- As we saw in the 5th set of slides playing any of the NE in each of the stages, is a NE of the repeated game
- Hence a NE of the repeated game could be (L, L) in stage 1 and (C, C) in stage 2
- Another could be: (L, L) in stage 1 and (L, L) in stage 2
- Or (C, C) in stage 1 and (L, L) in stage 2 etc...

Repeated games and new equilibria

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

- It would seem that the best these players can get in each game is $(5,5)$ by playing the payoff dominant NE (C,C), right?
- Well that is not actually correct. We have said that in repeated games the strategy spaces of the players (and with them the set of NE) can be much larger
- Let's see what the players can do in this 2-stage repeated game

Repeated games and new equilibria

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

- For simplicity suppose that the two players do NOT discount the future (that is \$1 tomorrow is as good for them as \$1 today)
- Consider the following strategy for row: S_r: In the first period play D. Then in the second period, if P2 played R, play M, otherwise, play U
- Equivalently for column: S_c: In the first period play R. Then in the second period, if P1 played D, play C, otherwise, play L
- Can you see that this is a NE of the repeated game?

Repeated games and new equilibria

	L	C	R
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- Consider the following strategy for row: S_r: In the first period play D. Then in the second period, if P2 played R, play M, otherwise, play U
- Equivalently for column: S_c: In the first period play R. Then in the second period, if P1 played D, play C, otherwise, play L
- In this NE, the 2 players can guarantee for themselves the payoff $(10, 10)$ in period 1 which is much better than what they could do in any static version of the game (since (D, R) is not a NE of the stage game!)

Repeated games and new equilibria

	L	C	R
U	0, 0	3, -1	11, -2
M	-2, 4	5, 5	9, 3
D	-3, 11	2, 9	10, 10

- Repeated interaction allowed the 2 players to cooperate and achieve (D, R) with a higher payoff than they could ever achieve in any stage game
- What did it take to achieve such a an improvement?
- A combination of stick (play the bad eqm (U, L) in the second stage if the other player doesn't cooperate in the first) ...
- and carrot (play the good eqm (M, C) in the second stage if the other player cooperates in the first)

Repeated games and new equilibria

- We can see that long-term relations with repeated interactions can lead to better outcomes through cooperation
- What could this mean for repeated negotiations?
- How do you negotiate with a long-term partner?

Repeated prisoner's dilemma: folk theorems

- We saw that in the Prisoner's Dilemma, rational pursue of individual gain made both prisoners worse off
- There is clear room to increase welfare for both
- How can time change the inefficient static outcome?

Repeated prisoner's dilemma: folk theorems

	C	D
C	-1,-1	-9,0
D	0, -9	-6,-6

Table: Prisoner's Dilemma

- Consider two prisoners playing the Prisoner's Dilemma with infinite horizon (repeated without end)
- Players discount future rents with a discount factor δ
- This is a supergame (infinitely repeated game where players discount the future)
- For each stage t of the game if s_t is a strategy profile, player i receives payoffs $U^i_t(s_t)$
- E.g. $U^R(C,D) = -9, \quad U^R(D,D) = -6$, etc.

Repeated prisoner's dilemma: discount factor δ

- What is a discount factor?
- Suppose I am to receive \$100 after a year. This is not as good as receiving \$100 today
- Suppose that for me \$100 next year is the same as \$90 today
- and suppose for simplicity that $U_t(\$100_t) = 100$

Repeated prisoner's dilemma: discount factor δ

- I discount the future by a discount factor $\delta = 0.9$: $U_t(\$100_{t+1}) = 0.9U_{t+1}(\$100_{t+1}) = 0.9 \times 100 = 90$
- What about \$100 received after 2 years?
- These will be worth $X = 0.9 \times 100$ next year, which in today's value will be $0.9 \times X = 0.9 \times (0.9 \times 100) = 0.9^2 \times 100 = \delta^2 \times 100$
- In general if players discount the future by a discount factor δ, then having a payoff of X after t years is equivalent to receiving $\delta^t X$ today

Repeated prisoner's dilemma: Folk theorem

Theorem (Folk Theorem: Friedman 1971)

Consider the following strategies for each of the two players in the infinitely repeated Prisoner's Dilemma:
Start by playing C. For as long as both players play C, continue by playing C. If either player has ever played D in the past play D.
This strategy profile constitutes a SPNE of the infinitely repeated PD, provided that players are patient enough (δ is sufficiently close to 1).
Clearly this strategy profile leads to Cooperation being played along the equilibrium path.

Repeated prisoner's dilemma: Folk theorem

- Folk theorems give another twist to PD
- Patient players value cooperation: we might gain temporarily from deviating but failing to cooperate will result in future punishment: if I am patient, the possibility of such punishment will be sufficient to deter me from deviating
- Such a cooperative solution requires infinite horizon: if the game is finite the by backwards induction the only possible outcome would be to defect
- The equilibrium is not unique: any outcome preferred to (D, D) can be achieved through suitable trigger strategies! (infinite equilibria)
- Is finite horizon such a strong assumption? After all no one lives forever!

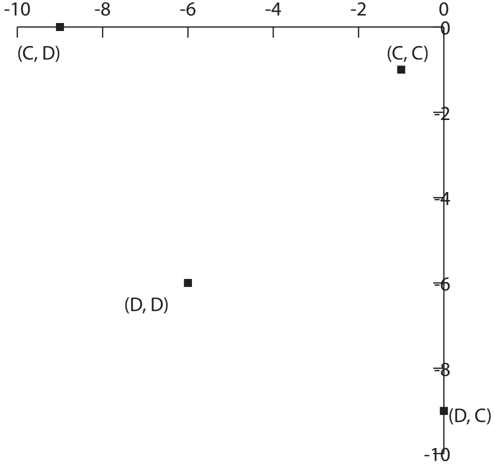
A note on the infinite horizon assumption

- Sometimes cooperation goes on beyond the physical life of a player. For example a company might survive its owner
- People need not have an infinite horizon. But still the might have no clue as to how much time they have left
- Infinite horizon implies that players cannot see the end of the game

Folk theorems more general

Consider the two players' payoffs in the prisoner's dilemma above. Let's represent row's payoff on the horizontal axis and column's payoff on the vertical axis. Then the four outcomes are points in the plane

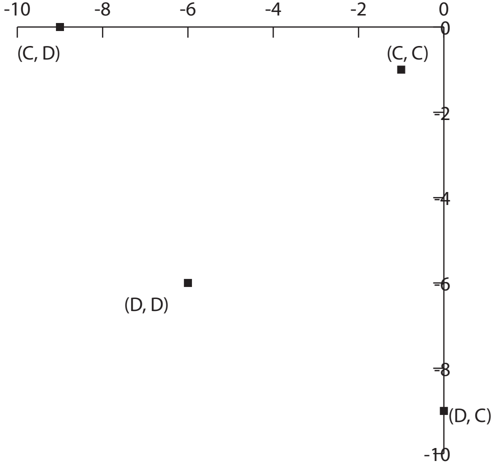
Folk theorems more general



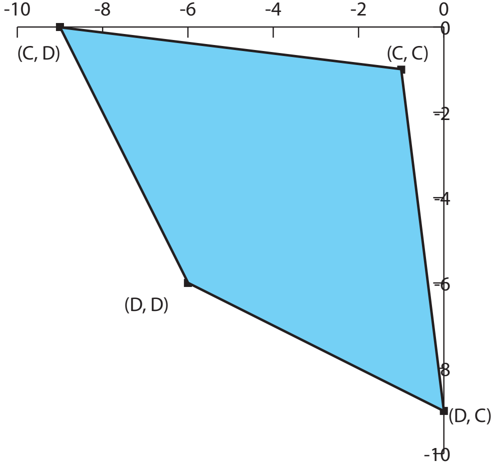
Folk theorems more general

- If the two players' discount factors are sufficiently close to 1 and
- If the game is repeated infinitely
- Then the blue area represents all the payoffs that the two players can achieve *on average* by playing different combinations of the 4 outcomes throughout the repetitions
- We call all these payoffs *feasible payoffs* because they can be achieved by different mixes of play of the 4 outcomes

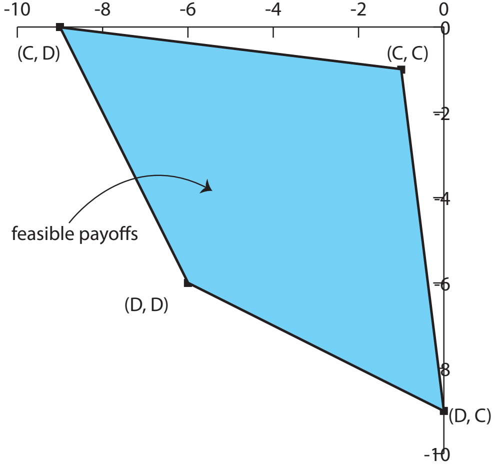
Folk theorems more general



Folk theorems more general



Folk theorems more general



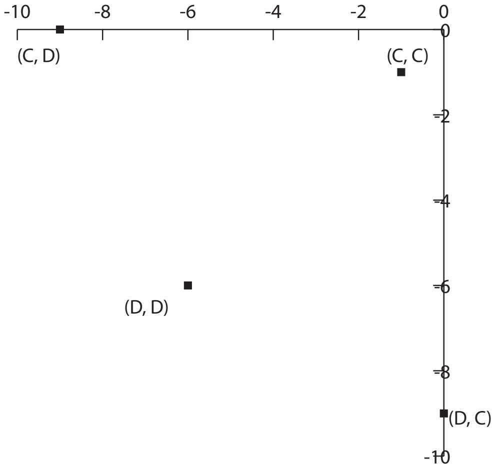
Folk theorems more general

Theorem (Folk Theorem)

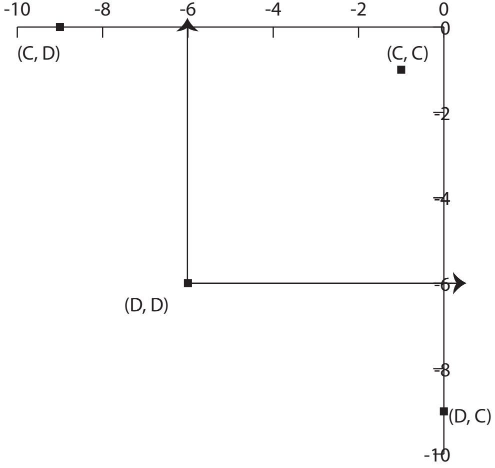
If the players are sufficiently patient (δ is close to 1), then any feasible outcome that is better for both players than the Nash Equilibrium can be achieved in the infinitely repeated game as a Nash Equilibrium

- Essentially the folk theorem tells us that in the infinitely repeated game, there is a Nash equilibrium that corresponds to any point in the blue area that is preferred by both players
- that is the discounted payoffs of these Nash equilibria correspond to any point in the blue area preferred by the two players
- but which points are these? Let's paint them red

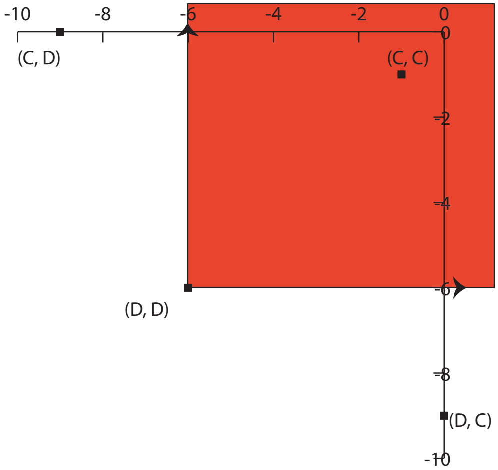
Folk theorems more general



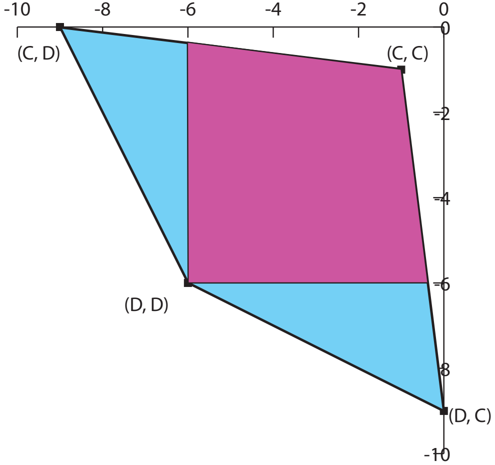
Folk theorems more general



Folk theorems more general



Folk theorems more general



Folk theorems more general

- Anything in the purple area can be achieved (as average payoff of the infinitely repeated game) if players are patient enough

Prisoner's dilemma and Axelrod (1984). An evolutionary approach

- Axelrod (1984) studies how cooperation can emerge in prisoner's dilemma through an evolutionary prism
- Axelrod (1984) presents the following version of the Prisoner's Dilemma:

	C	D
C	3,3	0,5
C	5,0	1,1

Table: Prisoner's Dilemma in Axelrod (1984).

Prisoner's dilemma and Axelrod (1984). An evolutionary approach

- Axelrod extended an open invitation to the scientific community for the best strategy in a repeated prisoner's dilemma
- A strategy would be a computer code giving the computer instructions about how to play the game in each round depending on the history
- Players had perfect memory: they remembered if they had played against another player before and the outcome
- The game was given an evolutionary touch

Prisoner's dilemma and Axelrod (1984). An evolutionary approach

- The game was given an evolutionary touch
- 63 strategies were submitted. At the first round each strategy was represented equally (by the same number of players as other strategies)
- in each round each player was randomly assigned to play the game with another player from the population
- in each round the population evolved according to how well the strategy did in the previous round. For example a strategy that on average had twice the payoffs of another strategy would have double the players of the other strategy in the next round (Darwinian fitness)

Prisoner's dilemma and Axelrod (1984). An evolutionary approach

- Why did Axelrod talk about evolution and cooperation?
- Strategies with higher payoffs are evolutionarily superior (think of payoffs as ability to find food in an animal population)
- They have more offspring and are represented more heavily in the next round (generation)
- Strategies that don't score well have less food (fitness/descendants) and gradually the go extinct (or are left with very few players playing them)
- Axelrod (1984) shows through his tournaments that there are evolutionarily stable strategies that involve cooperating with each other

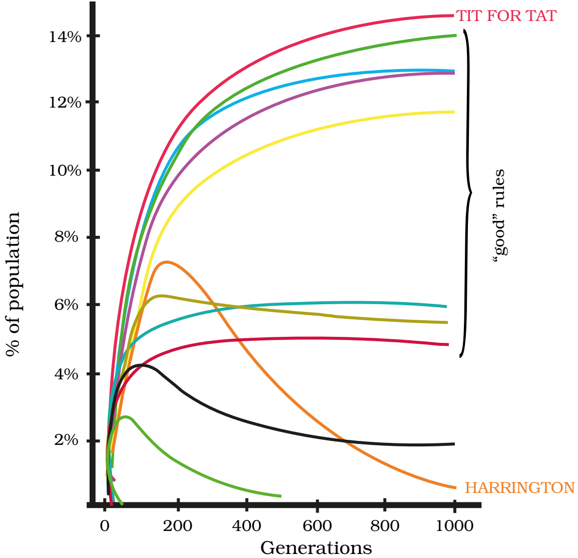
Prisoner's dilemma and Axelrod (1984). An evolutionary approach

- Some of the strategies submitted to Axelrod's (1984) tournaments:
- RANDOM: play in each round at random
- DEFECT: defect in each round
- FRIEDMAN or GRIM: never defects first but if someone defects, it never forgives and defects for ever with that player
- DOWNING: trying to figure out what kind of opponent it had and whether there was room to exploit weaknesses
- TRANQUILLISER: tried to tranquillise the opponent by playing cooperate and every now and then cheat and gain from cheating
- and many others

The winner: tit-for-tat

- The most successful strategy was “tit-for-tat” by Anatol Rapoport from the University of Toronto
- TIT-FOR-TAT: start by playing C. In each round you meet the same player, play whatever they played last time the two of you met
- Let’s see how the various strategies fared after many generations:

Axelrod's (1984) tournament results



Tit-for-tat: why it won (according to Axelrod)

- It is interesting to note HARRINGTON, the only nasty strategy among the 15 best scoring strategies
- HARRINGTON tried to exploit weaknesses in opponents
- For about 200 generations it found “victims” and went well (not as well as t-f-t or other good strategies
- But easy victims went extinct after 200 generations and HARRINGTON could no longer prey on weak strategies, so it went extinct. Against punishing good strategies HARRINGTON couldn’t fare well

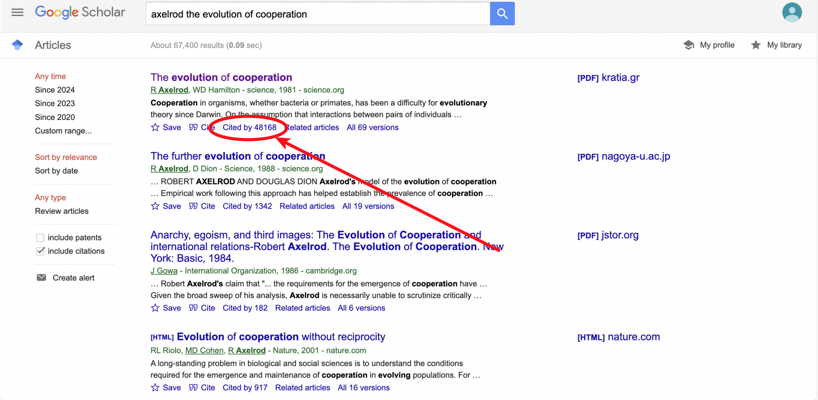
Tit-for-tat: why it won (according to Axelrod)

Axelrod (1984) attributes t-f-t's success to some of its properties:

1. It's "godness". By never attacking first, it could avoid unnecessary conflict with other punishing strategies
2. Clarity: Very simple and easy to decipher. Other strategies read it correctly and avoided unnecessary fights against t-f-t
3. It is forgiving. While it doesn't let anyone take advantage of it for more than once, it can forgive mistakes. So it can cooperate in the future with strategies that defected, contrary to GRIM which is so punitive that it lost the possibility of such future mutually beneficial cooperation

Tit-for-tat: why it won (according to Axelrod)

Tit-for-tat enjoys status of a legend in many circles. See how many citations the book has received:



Tit-for-tat: the counterview

- Tit-for-tat has received such an enormous recognition that it is often presented as proof that cooperation is the only strategy that can survive evolutionarily
- However the picture is more nuanced
- Many game theorists have shown that tit-for-tat is not as robust as Axelrod (1984) suggested
- In particular, t-f-t is sensitive to:
  1. the choice of initial strategies. It fared well against the 63 strategies in Axelrod's (1984) tournaments. However with different strategy mixes it can fail
  2. the initial percentages of strategies. Altering the initial proportions of strategies in the population, can eliminate t-f-t and have nasty or very punishing strategies prevail (tat-for-tit or GRIM)

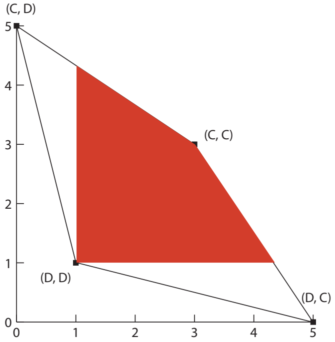
Where is the truth?

- If we are to assess soberly Axelrod's (1984) contribution to using Game Theory in order to understand cooperation, what could we say?
- Arguments against the view that Axelrod made a unique contribution to Game Theory and cooperation:
  1. The possibility of cooperation in repeated Prisoner's Dilemma has been known since the 1940s and had been proved long before Axelrod. Axelrod didn't really make a contribution to Game Theory
  2. Axelrod presents T-f-T as an ultra dominating strategy, arguing that cooperation will prevail in almost any situation where there is benefit of cooperation despite incentives to cheat. This is not the case
  3. Nasty strategies often prevail in subsequent tournaments
  4. TfT did not eliminate other strategies, it ended up with about 1/6 of the population
  5. Axelrod's arguments apply to bilateral interactions. Not necessarily multi-person interactions

Where is the truth?

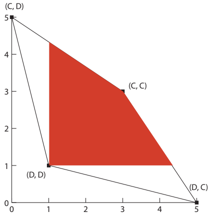
Axelrod's (1984) contribution

- Although Axelrod wasn't the first to show that cooperation can be sustained in repeated games, he gave us a very powerful tool of equilibrium selection: evolutionary criterion
- Remember that the Folk theorems predict that any mixture preferred to a NE, can be sustained in infinitely repeated games (red area below for Axelrod's (1984) game)



Where is the truth?

Axelrod's (1984) contribution



- Axelrod gives us an evolutionary criterion to converging to one of these points
- Although different mixes of initial strategies might lead to different basins of attraction, some do favour good strategies and the exercise becomes a question of what population we are matched against, particularly in a negotiation (REMEMBER, DO YOUR HOMEWORK, STUDY THE OTHER PARTY)

Time and negotiations

- Our dynamic analysis has highlighted that repeated interactions and time can alter the dire results of static games
- Think of how you can use this strategic analysis in different kinds of negotiations: Is selling a house you own the same as setting a price for you olive oil with one of your long-term customers?
- Do you expect a random once-of buyer and your customer to exhibit the same strategic behaviour?
- What tools do we apply when we analyse a strategic situation?
- Think of Greece's 2015 infamously failed negotiation approach. A game theorist conceived of it as a static game. Was he right? More on this hopefully soon!