Exploring the effects of spatial structure in EGT-games

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Figure 1: spatial structure in simulated PD and HD games

Abstract

view questions as proxies for attitude and knowledge and tested for coherence between the answers. Possible confounding factors such as age, gender and place were recorded and tested for significance. We find that people who oppose hosting more refugees tend to overestimate the real numbers whereas people who favor hosting more refugees tend to underestimate the real numbers. However, our data do not support a correlation between knowledge (i.e. precision of estimate) and attitude. While gender and age do not have a significant influence, answers differ significantly among the places where the interviews were conducted. In conclusion, our study shows that attitudes towards refugees depend more on their perceived presence rather than real knowledge about them.

1 Introduction

1.1 The broad topic and what has been done before

Game Theory

In 1944 the the economic scientist Neumann and Morgenstern developed the theory of games as an economic model. Much later, in the 70th the evolutionary game theory originated. Instead of playing the game once, like in the game theory, the game in evolutionary game theory is played over and over again by biologically or socially conditioned players. In the most cases a player is randomly drawn from a large population and has a specific behavior (**?**) In general the Prisoner‘s Dilemma and the Hawk-Dove game have the following notation for a two player games with the both strategies cooperation, or defection. R, T, S and P are the payoffs of the game.

	C	D
C	R	S
C	T	P

(R: Reward; T: Temptation; S: Sucker's reward; P: Punishment; C: Cooperator; D: Defector)

The Prisoner‘s Dilemma

	C	D
C	b-c	-c
D	b	o

(b: benefit, c: cost)

In a prisoner's dilemma defection the the evolutionarily stable strategy. The defector gets the benefit b when he plays with an cooperator which gets a punishment, the cost c. The relationship between payoffs is T ¿ R ¿ P ¿ S. When cooperation is mutual both have the benefit R=b-c, but pay a cost for that. Mutual defection results in Payoff P = 0 for both players. Because of the punishment of the cooperator, when the other player defects it is the best to defect regardless of the co-players decision (**?**). Though in nature there are examples which prove, that not only defection can be evolutionarily stable. Alarm calls warn other animals from predators. It seems to be that cooperation only works when the cost-to-benefit ratio is not to high and spatial structure exists (**?**).

The Hawk-Dove game

	C	D
C	b-c/2	b-c
D	b	o

Field and experimental studies had problems with the Prisoner‘s Dilemma as the only model to discuss the behavior of "players". Its difficult to estimate proper fitness payoffs. That caused various problems between theory and field - and experimental studies. Scientist needed another model for the payoffs of cooperative behavior (**??**). In the Hawk-Dove game mutual cooperators are better off, because they share the cost of cooperation and receiving the whole benefit. Although cooperation gets rewarded, not punished by playing with a defector. The payoffs P and S have a reverse order in the Hawk-Dove game which differs from the Prisoner‘s Dilemma. P becomes the worth b-c, so P and S have the reverse order. The new payoff matrix (T¿R¿S¿P) leads to persistence of cooperative players beside defectors except from very high costs (2b¿c¿b¿o) what would recover the Prisoner‘s Dilemma (**?**)

1.2 Problem and Gap of Knowledge

A lot of researchers of social, economic and biological science worked on the evolutionary game theory. It has become a powerful tool to investigate the emergence of cooperation in groups (**?**). For the Prisoner‘s Dilemma it is widely accepted, that spatial structure supports cooperation (**?**). To simulate biological processes there is an increasing discomfort with the Prisoner‘s Dilemma as the only model to discuss cooperative behavior. The Hawk-Dove game is an interesting alternative for describing behavior pattern of field studies(**?**). The processes were discussed theoretically for several times (**??**), but haven never been simulated, maybe due to a lack of computing power. To find out the different performance of the Prisoner‘s Dilemma and the Hawk-Dove game, we compare the results of various simulations. Choosing the right model to describe natural processes is a big challenge for scientist. For describing them with the right model, there has to be done further investigation on the Hawk-Dove game, especially to simulate mutations of the behavior, here called Mixed-strategies.

1.3 Our approach and specific questions

Hypothesis:

In our study we test the following hypotheses:

- Spatial structure benefits cooperators especially in the Prisoner‘s Dilemma
- Neighborhood-size has ab influence to the effect of spatial structure
- Mixed-strategies change the effect of spatial structure

For testing the Hypotheses we simulated different Hawk-Dove and Prisoner‘s Dilemma games with NetLogo 5.1.0 and performed them with varying variables. The results of the experiments were fitted and visualized in R to make them comparable. The focus of the Experiments Data was set on the frequency of cooperators with different cost to benefit ratios.

Our experiments examined following questions:

- Which influence has spatial structure in the Hawk-Dove and Prisoners Dilemma game?
- Which effect have different neighborhood sizes to the games?
- Which influence has a mixed strategy of the players in a spatial and a non-spatial Hawk-Dove game?

2 Methods

2.1 Modeling environment

2.2 Non-spatial Prisoner‘s Dilemma and Hawk-Dove game

The first step for our model was to calculating the average payoff for cooperators and defectors in the non-spatial Prisoner‘s Dilemma and Hawk-Dove game. We worked with p for the probability of players being a defectors (probability of cooperators is 1-p). Due to the payoff matrix of the Hawk-Dove game we used Pc = o.5*(1-p)*c+b-c and Pd = p*b. For the Prisoner‘s Dilemma the average payoff for cooperator changes: Pc = (1-p)*b-c. These average Payoffs reduce or increase the fitness of the single players. In an iterated game fitter players reproduce and get an higher percentage of the population, in our case cooperators or defectors. For the next iteration (reproduction) of the game p is calculated new by comparing the fitness of defectors with the fitness of all players.

2.3 Spatial structure and neighborhood size

In our spatial games we have a 50 X 50 square lattice. Every square figures one player. The Whole lattice is updated synchronous. We introduced different neighborhood-sizes from four to 24 neighbors in our model. Therefore we worked with five different radiuses (1, sqrt2, 2, 2*sqrt2, 3,caaliber of players as unit) around the players for five neighborhood-sizes (4, 8, 12, 20, 24). Instead of using p, what was the probability to be a defector in the non-spatial game we insert a local probability pl in the average payoff therms which was calculated with the neighbors probabilities to be a cooperator or defector. With that the fitness of the players is calculated new facing the neighborhood.

Preparation: For data analysis we used the R statistics software package (**?**). For a preliminary evaluation of the data, we plotted some parameters and created a histogram of the estimate 2. Because of the highly skewed distribution of estimates we logarithmized the estimates to the base of 20,000 (i.e. the real number of refugees admitted) 3. The answers to Question 1 were numerified for analysis:

less refugees = -1
same number = 0
more refugees = 1

Regression: After preparing the data we applied two linear regression models to the data. First, we checked for a correlation between the attitude records and the logarithmized absolute estimates. We then calculated the difference between the estimates and the real number of refugees and checked for a correlation between attitude records and the logarithmized absolute difference.

Confoundig factors: In order to check whether one of the possible confounding factors had an influence on the attitude towards refugees, we conducted an analysis of variance for each of them.

Figure 2: Histograms of the estimates

Figure 3: Histograms of the logarithmized estimates

2.4 Effect of mixed strategies

3 Results

??? screenshots of spatial patterns ???

3.1 Effect of spatial structure in PD and HD games

In our first simulation experiment, we compared the effect of spatial structure on the persistence of cooperators in the PD and HD games.

(figure 4)

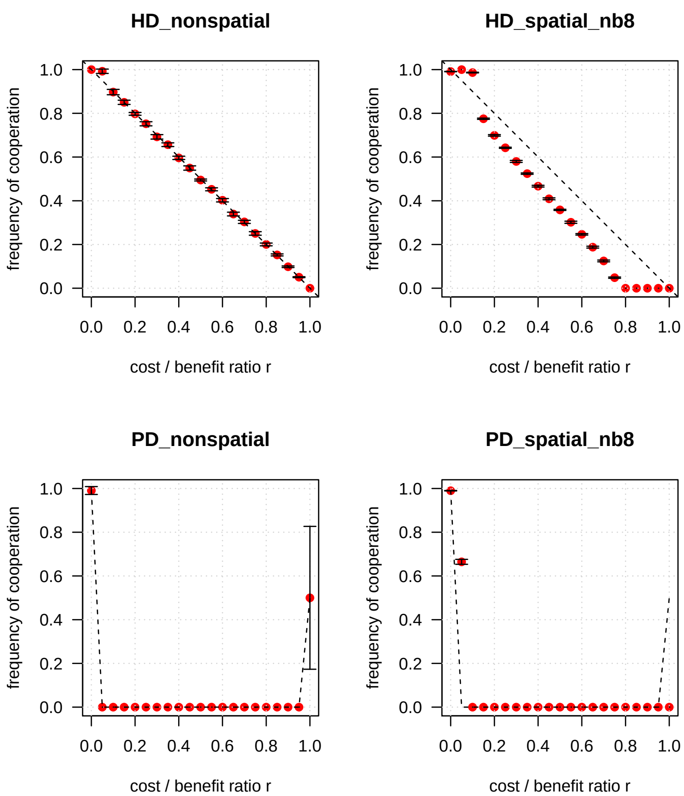


Figure 4: Comparison of HD and PD game simulations, both with and without spatial structure. [$\mathbf{t = 5000, i = 10}$]

3.2 Effect of neighbourhood size

In the second simulation experiment we investigated the effect of

HD games

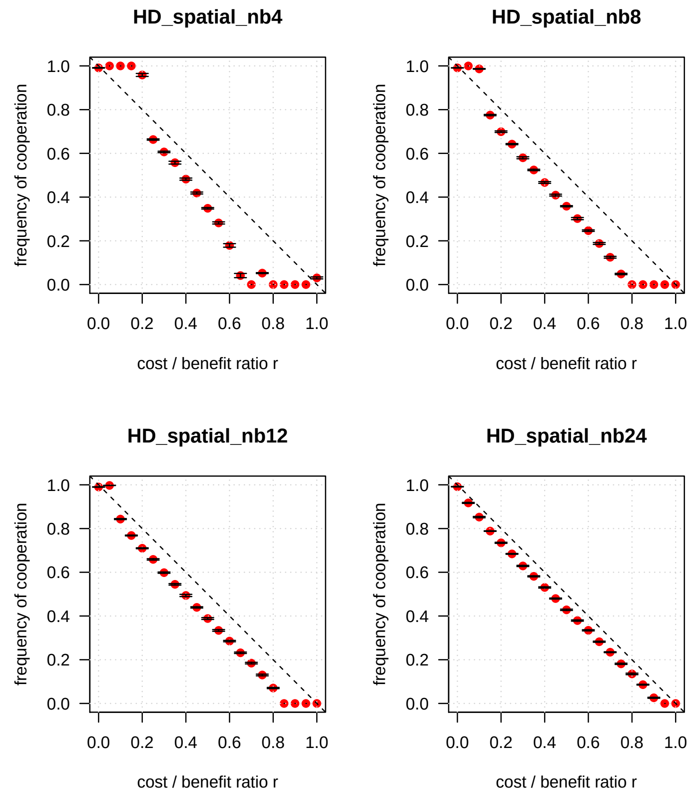
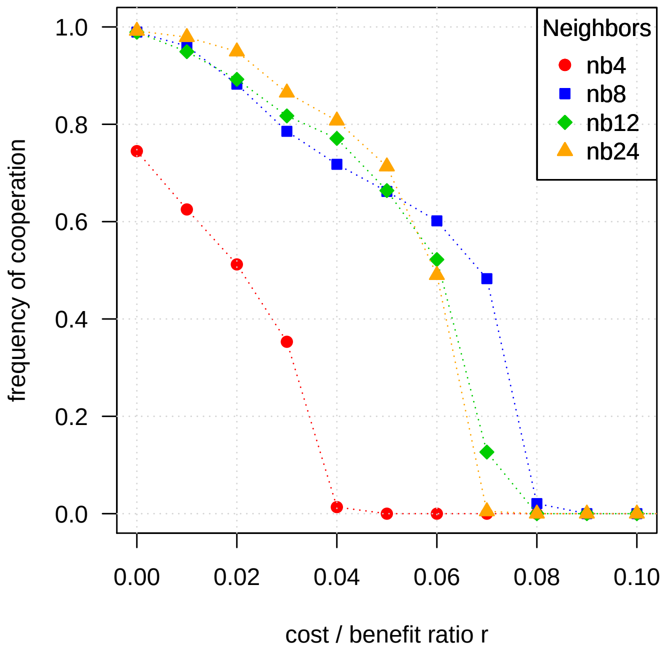


Figure 5: Effect of varying neighborhood size in the HD game. [$\mathbf{t = 5000, i = 10}$]

PD games



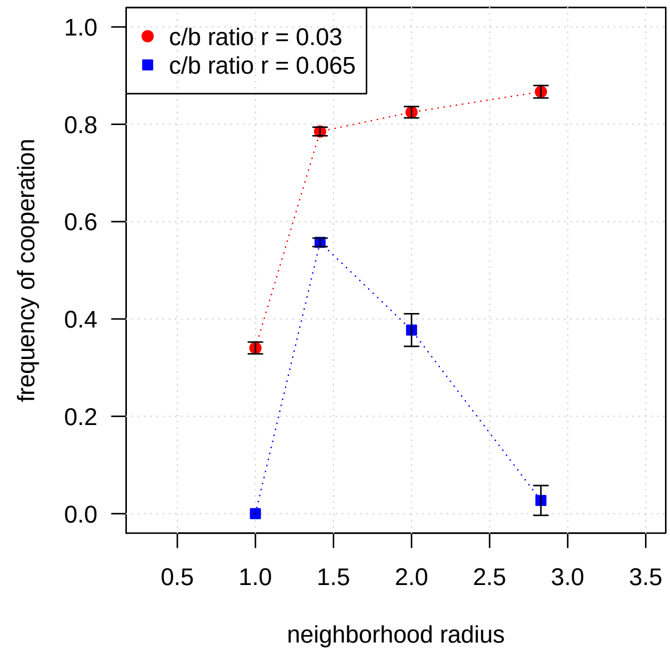


Figure 6: Spatial PD game simulations with different neighborhood sizes. [**t = 5000, i = 10**]

Figure 7: Spatial PD game simulations with fixed cost-benefit-ratio and different neighborhood sizes. Radius 1 is adequate to 4 neighbors, radius 1.4 = 8 neighbors, radius 2 = 12 neighbors and radius 2.8 = 24 neighbors. [**t = 10000, i = 10**]

It is widely assumed that spatial structure allows for the evolution of cooperation in PD games. However, this goes only for a small range of cost-benefit ratios. Cooperation is only evolutionarily stable for r-values $\leq$ 0.09, for bigger r-values it disappears from the population.

In spatial HD games: small neighborhoods = bigger profit when r is small, and small neighborhoods = bigger disadvantage when r is big.

In spatial PD games:

Found anomality

r 0.03, nb4 -¿ stable at propC 0.35 after 2500 steps -¿ stable r 0.065, nb4 -¿ cooperators die after 900 steps -¿ unstable r 0.03, nb8 -¿ stable at propC 0.77 after 10000 steps -¿ stable r 0.065, nb8 -¿ stable at propC 0.55 after 2500 steps -¿ stable r 0.03, nb12 -¿ stable at propC 0.825 after 7500 steps -¿ stable r 0.065, nb12 -¿ randomly oscillating around propC 0.33 after 10000 steps -¿ half-stable r 0.03, nb24 -¿ stable at propC 0.85 after 4000 steps -¿ stable r 0.065, nb 24 -¿ cooperators die after 7400 steps -¿ unstable

- **spatial structure does not automatically make a system stable**

- **two variables influence whether a system is stable: neighborhood size and cost-benefit ratio**

fixed r: at 0.03 and 0.065 varying neighborhood size 5000 steps, 5 repetitions

3.3 Effect of mixed strategies

In our third experiment, we compared the effect of spatial structure in the mixed-strategy HD game with that in the pure-strategy game.

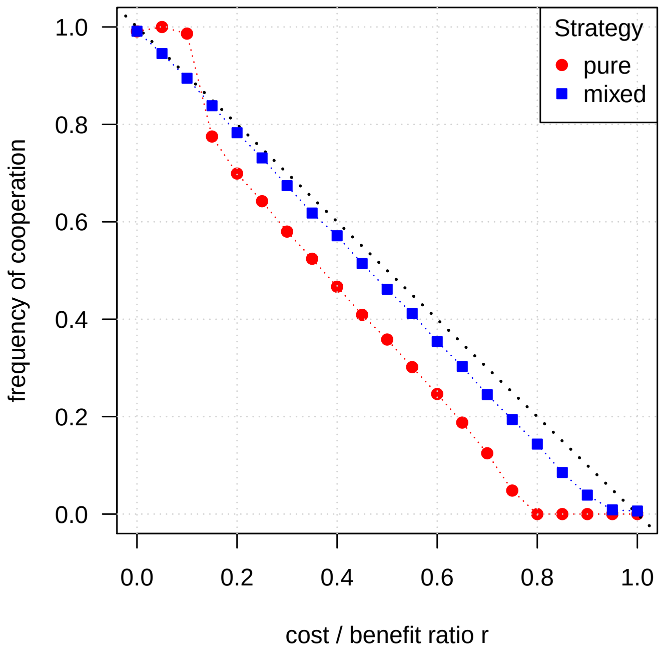


Figure 8: Spatial HD game simulations with neighborhood size 8 and different strategies. The dotted black line depicts the frequency of cooperation in nonspatial games. [$\mathbf{t = 10000, i = 10}$]

4 Discussion and Conclusions

4.1 Main findings

spatial structure
different neighborhoods
mixed strategies

"What does cooperation mean in die Hawk-Dove game?"

–¿ two variables influence whether a system is stable: neighborhood size and cost-benefit ratio

(Ohtsuki et al 2006: "natural selection favours cooperation, if the benefit of the altruistic act, b, divided by the cost, c, exceeds the average number of neighbours, k, which means b/c ¿ k. In this case, cooperation can evolve as a consequence of social viscosity even in the absence of reputation effects or strategic complexity.")

4.2 Limitations

While gender and age do not have a significant influence on attitude, answers differ significantly among places where the interviews were conducted. We therefore assume that the selection of interview sites is relevant for the outcome. Due to the limited time and number of researchers in our study, our results can not be fully generalized. For reproducing our study on a large scale one should aim to select the interviewees as representative as possible.
Besides the selection of interview sites, the scheme of interviews might constitute a certain limitation to our study. As the interviews were conducted orally, the responses might be influenced by interactions between interviewer and interviewees. For example, interviewees might attribute a pro-refugee opinion to the interviewer and therefore not be honest when having a different opinion themselves. This goes especially for interviewers speaking English. Interviewees might assume that they are talking to migrants and might therefore not want to express a negative attitude towards refugees. Several times it occurred that interviewees were in company of other people who would try to influence the answers by making comments. Although we explicitly asked the interviewees for their personal opinion, the results may have been biased in some cases. To increase objectivity and avoid bias by personal interactions, one could switch to anonymized printed questionnaires in future studies.

4.3 Final conclusions, applications and further research

In conclusion, we found that people who oppose hosting more refugees tend to overestimate the real numbers whereas people who favor hosting more refugees tend to underestimate the real numbers. However, our data do not support a correlation between precision of estimate and attitude. We cannot tell from our data if this means that subtle perception rather than knowledge influences people's attitude towards refugees. We therefore recommend further investigating this question with a more differentiated questionnaire that incorporates a well-defined proxy for the interviewees knowledge on refugees.
While gender and age did not significantly influence attitude in our study, answers differed significantly among places where the interviews were conducted. When reproducing this study, places for the interviews should be selected so that they represent an average of the population. Furthermore, we recommend using printed questionnaires to ensure objective and honest answers.

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