

# Appendix J

## Insights into the Impact of Social Networks on Evolutionary Games

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### **ABSTRACT**

*In this chapter, we explore the use of evolutionary game theory (EGT) (Nowak & May, 1993; Taylor & Jonker, 1978; Weibull, 1995) to model the dynamics of adaptive opponent strategies for a large population of players. In particular, we explore effects of information propagation through social networks in evolutionary games. The key underlying phenomenon that the information diffusion aims to capture is that reasoning about the experiences of acquaintances can dramatically impact the dynamics of a society. We present experimental results from agent-based simulations that show the impact of diffusion through social networks on the player strategies of an evolutionary game and the sensitivity of the dynamics to features of the social network.*

## INTRODUCTION

We use EGT (Cabrales, 2000; Hofbauer & Sigmund, 2003; Weibull, 1995) to model the dynamics of adaptive opponent strategies for a large population of players. Previous EGT work has produced interesting, and sometimes counter-intuitive results about how populations of self-interested agents will evolve over time (d'Artigues & Vignolo, 2003; Frey & Luechinger, 2002).

In our model, at each stage of the game, boundedly rational players observe the strategies and payoffs of a subset of others and use this information to choose their strategies for the next stage of the interaction. Building on EGT, we introduce a model of interaction where, unlike the standard EGT setting, the basic stage game changes over time depending on the global state of the population (state here means the strategies chosen by the players). More precisely, each player has three strategies available (cooperate  $C$ , defect  $D$ , and do-nothing  $N$ ), and the payoffs of the basic stage game are re-sampled when the proportion of the players playing  $D$  crosses a certain threshold from above. This feature requires long-term reasoning by the players that is not needed in the standard EGT setting. A possible example of a similar real-world situation is a power struggle between different groups. When cooperation drops sufficiently and there are many defections—the situation turns to chaos. When order is restored, that is, when cooperation resumes, the power structure and thus, the payoffs, will likely be different than before the chaos. The payoffs are kept constant while most of the players Cooperate (support the status quo) or do-Nothing, but when enough players are unhappy and choose to Defect, the power balance breaks and a radically different one may emerge afterwards.

The available strategies were chosen to abstractly capture and model violent uprisings in a society. Players playing  $C$  cooperate with the current regime and receive reward when interacting with others playing  $C$ . If a player has a good

position in a regime, it has a large incentive to continue playing  $C$ .  $D$  is a strategy played to change the payoffs over a long term, but at an unavoidable immediate cost. Intuitively, it resembles resorting to insurgency or other violent tactics to overthrow a regime. When many players play  $D$ , playing  $C$  can lead to very low payoffs. For example, one can imagine a person trying to run a small business during a violent uprising. If these costs are too high, but the player has no incentive to change the regime, playing  $N$  can limit payoffs—both negative and positive, until the situation stabilizes. Intuitively, this might correspond to going into hiding or temporarily leaving the conflicted area.

Similar to Nowak and May (1993) and Killingback and Doebeli (1996), we investigate the spatial aspect of the interaction. Previous work has shown that spatial interaction can change which strategies are most effective, for example, in Brauchli, Killingback, and Doebeli (1999) an interaction lattice changed which strategies were most effective in an iterative prisoner's dilemma game. In our model, the players are connected into a *social network*, through which the rewards are propagated (Travers & Milgram, 1969; D. J. Watts, Dodds, & Newman, 2002). Thus the players can benefit (or suffer) indirectly depending on how well off their friends in the network are. We show empirically that the connectivity pattern of the network, as well as the amount of information available to the players, have significant influence on the outcome of the interaction. In particular, the presence of a dense scale-free network or small-world network led to far higher proportions of players playing  $C$  than other social network types.

## GAME DETAILS

We consider a finite population  $X$  of players. At each stage all the players are randomly matched in triples to play the basic stage game. Each player

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