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Social Control, Network Structure and Participation in Collective Action

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Abstract

This study investigates how and under what conditions networks and social control rationalize participation in collective action. Social control mechanisms are inseparable from participation in collective action and are the sources of social network effects. Previously, these dyadic social control mechanisms between connected individuals have been represented in local interaction games. In this paper, we propose an integrative framework of analysis that combines local interaction games with the n-person social dilemma model of collective action. Predictions of the integrated model reveal non-monotonic effects of the strength of social control on full contribution. Among structural effects, network clustering deserves special attention as it undermines mass collective action when social control operates mainly in the form of conformity. In case a positive selective incentive is strong, the minimum degree of the network is a crucial determinant of mass collective action.

Keywords: Collective action; Social dilemmas; Social networks; Social control; Local interaction games

1. Introduction

This study investigates the interdependence between social control mechanisms, social networks and collective action. We analyze how different forms of social control influence decisions of rational individuals and we examine how and under what conditions networks rationalize participation in collective action. Besides, we focus on the interactions between network effects and social control as we investigate which network properties form favorable conditions for the emergence of collective action when a selective incentive is the main driving force for cooperation, and which properties favor mass mobilization when conformity is an important form of social control. In order to capture the interrelations between social control, network structure and collective action, this paper offers a new framework of analysis. The new framework integrates the n-person social dilemma model of collective action with local interaction games.

Similarly to the majority of existing models, we model the collective action problem as an n-person social dilemma. As narrow self-interest does not provide sufficient incentives for participation, a baseline economic model predicts collective action failure. Empirical studies, however, have found examples of successful mobilization caused by social control mechanisms (McAdam 1986; Finkel and Opp 1991; Chong 1991; Gould 1995). Theoretical developments, therefore, incorporated different forms of social control in the model and set down conditions for the possibility of collective action (e.g., Olson 1965; Hardin 1982; Marwell, Oliver and Prael 1988; Heckathorn 1989; Coleman 1990; Holländer 1990; Weesie 1990; Chong 1991; Hechter 1992; Gould 1993; Oberschall 1994; Flache and Macy 1996; Sandell and Stern 1998). In its most widely used meaning, social control is a constraint on individual decision posed by the influence, as well as by the behavior, opinion, and expectations of relevant other individuals (cf. Gibbs 1981; Black 1984; Heckathorn 1990; Macy 1993; Takács 2001; Villareal 2002).

Several studies pointed out that the set of relevant others in practice is not the entire society, but only related others: family, friends, acquaintances, colleagues and neighbors (e.g. Opp and Gern 1993; Oberschall 1994; Sandell and Stern 1998). Consequently, characteristics of the social network influence the impact of social control on collective action. Social network effects are important, because individuals tailor their behavior conditional on the behavior and expectation of relevant others.

For the integrated analysis of social control mechanisms and collective action, social control has to be conceptualized. As in previous studies, either in an internal or in an external form, social control will be modeled as a system of mutual rewards and punishments. My decision to join a public protest or not is contingent on the decision of my friends. Besides, I gain additional satisfaction if my action meets their expectations or sympathy. This holds also for their decisions and their calculations on my expectation. This kind of dyadic strategic interdependence and its social network perspectives are modeled in local interaction games (see e.g., Ellison 1993; Morris 2000). The existing literature on local interaction games, however, disregards the possibility of community interdependence. Local coordination games

provide an illustrative basis for the influence of certain social control mechanisms, but neglect the macro effects of coordination. Successfully coordinated behavior often provides positive externalities and additional value for the entire community. This is exactly the case when collective action established as a result of block recruitment (cf. Oberschall, 1994). In such situations, individuals cannot tailor their behavior to each friend's habit nor can their decisions be separated from collective action participation.

For these reasons, the modeling framework presented here incorporates dyadic social control mechanisms as strategic interactions and consequently social network effects in the single-shot n -person social dilemma model of collective action. We provide a simple game-theoretical analysis of the conditions under which individuals are better off by participation and we also examine equilibrium conditions for the emergence of collective action. The model assumes that players are rational and perfectly informed about the rules of the game. These restrictions do not mean that we disregard the impacts of bounded rationality, imperfect information or repeated interactions on mobilization in collective action. On the contrary, our restrictive assumptions may help to distinguish the different sources of success or failure of collective action.

As a main substantive goal of model building, we aim to present a theoretical rationale for some of the intriguing empirical results of the collective action literature. First, similar to the findings of Sandell and Stern (1998) we would like to demonstrate that collective action may exist even if rational actors prefer to free ride on all but few of their fellows in the group. Moreover, we intend to provide analytical support for Oberschall's (1994) block recruitment model.

Second, the study is to present some new predictions about the possible effects of social control and network structure in a situation where individuals are rational, well informed and there is no iteration in collective action. We aim to show that there are network structures at which the effect of social control on cooperation is non-monotonic. That is, at certain parameter values, stronger control may decrease the chance of mass collective action. This objective is in line with earlier findings that demonstrated reverse effects of social control (Kuran 1995; Flache 1996; Flache and Macy 1996).

In the next section, we provide basis for our assumptions on the mechanisms of social control and we underline our main interests in the analysis of social network effects in n -person social dilemmas. We summarize previous findings of the literature and our research questions afterwards. We present the structurally embedded public goods game model of collective action in Section 4. Subsequently, we derive under what conditions social control would lead to an equilibrium in which collective action is established. This is followed by a discussion of the impacts of network properties on participation and by the analysis of interaction effects of social control and network characteristics. Implications and prospective directions are discussed in the concluding section.

2. Social control mechanisms and their operation in the network structure

Collective action aims at the provision of certain public goods for a community. When individuals decide to participate (contribute) or not, they compare the costs (opportunity costs) of participation with the impact of a single contribution. We consider such situations in which the former is always higher than the latter. In addition, we assume that individual decisions are constrained by social control mechanisms. One can find various forms of social control in classical and recent models of collective action.

The incorporation of selective incentives into the models has been prevalent since the beginning of collective action research in sociology (e.g., Olson 1965; Oliver 1980; Marwell and Oliver 1993). Selective incentives implicate that actors punish defectors and/or reward contributors. Some of those studies also addressed the second order free rider problem that stems from the costs of providing selective incentives (Oliver 1980; Heckathorn 1989).

Another models have emphasized the positive impact of cooperation of others on the individual's own decision. Conditional cooperation mechanisms work, for instance, in critical mass models (e.g., Schelling 1978; Granovetter 1978; Marwell, Oliver, and Pahl 1988; Marwell and Oliver 1993; Oliver and Marwell 2001). The assumptions about fairness considerations in Sugden's (1984) and Gould's (1993) models also imply conditionally cooperative behavior. Besides, Oberschall's (1994) block-recruitment model also relies on conditional cooperation.

Several laboratory experiments addressed the problem of social control in public good games in recent years (e.g., Gächter and Fehr 1999; Fehr and Gächter 2000; Masclet et al. 2003; Rege and Telle 2001; 2003). These studies demonstrate that some kind of social control may play a significant role in individuals' decisions about the contribution to the public good. From our point of view, the most important results of these experiments can be summarized as follows:

Contributors seem to feel compensated for their effort by their peers' rewards and similarly, defectors seem to gain less because of a sense of guilt, embarrassment or punishment (Gächter and Fehr 1999; Masclet et al. 2003; Rege and Telle 2001; 2003).

The perception of social approval/disapproval may have an impact on cooperation even if no monetary (or physical) incentives are available. It is sufficient if the peers express their approval/disapproval by symbolic points - the provision of which is costless (Masclet et al. 2003). What is more, even the observation of the decisions or merely the presence of other players may be sufficient for higher level of contribution in a one-shot public good game (e.g., Bohnet and Frey, 1999; Rege and Telle 2003). That is, the provision of effective social control might be costless in some situations.

Behavioral economists have provided evidence for the existence of altruistic punishment of defectors. Theoretical models and laboratory experiments show that individuals have intrinsic incentives to punish free riders, even at the cost of their own welfare (Fehr and Gächter 2000; 2002; Boyd et al. 2003). That is, the internal costs of watching an unpunished free riding friend may outweigh the cost of punishment itself.

Another important observation is that if social control mechanisms are allowed to work, the level of contribution is positively correlated with the group size (Carpenter 2002). That is, more people can impose stronger control.

One should note, however, that the characteristics of social control also depend on the level of (expected) contributions of those actors who reward/punish the individual. A defector gets higher level of punishment from a cooperator than from another defector - or a cooperator gets higher reward from another cooperator than from a defector (Gächter and Fehr 1999; Rege and Telle 2003). That is, as the number of defectors increases, the social incentive for contribution decreases. Nonetheless, a contributor's positive effect on the individual's cooperation tends to be stronger than a defector's negative one.

These experimental results are mostly in line with the assumptions on social control in the most cited models of collective action. One can interpret, for example, Olson's (1965) term of social selective incentives in this way. Recent models of fairness may also allow for such behavioral consequences in public good dilemmas. However, if one intends to build a model on the assumptions developed in earlier formal analyses of collective action, one should combine at least two types of social approval. One simply rewards the cooperator (punishes the defector) irrespective of the action taken by the rewarder (punisher) herself. The other one implicates that the individual compares her decision with decision of relevant others, and gains rewards if the decisions are similar. We incorporate therefore social control into our model in the form of two separate incentives. This makes the comparison with earlier models more straightforward and allows an easy handling of different aspects of social control. Takács (2001) adopted a fairly similar dual structure of social control in his model on intergroup conflict. We follow his terminology and refer to the rewards for cooperators (punishments for the defectors) as selective incentives. The other aspect of social control that rewards the similarity between decisions is called behavioral confirmation (Lindenberg 1986) or conformity. We are well aware of further social control mechanisms, for instance, people might participate in collective action precisely because they expect others not do anything (Oliver 1984), but for the sake of simplicity, we restrict our interest for the analysis of these two forms.

Similar to Holländer's (1990) analysis, we incorporate social control in the model as an automatic response to cooperation. Nonetheless, providing social control may be costly and a second order free rider problem may emerge (cf. Oliver 1980; Heckathorn 1989). Our model, however, is restricted to those situations in which provision of social control is costless, social control is internalized (cf. Scott 1971) or the costs of not rewarding/punishing counterbalance the ones of giving approval/disapproval. As laboratory experiments show, this assumption fits the behavior of real-world individuals (e.g., Masclet et al 2003, Rege and Telle 2003). Moreover, it serves as an analytical starting point, and could be relaxed in subsequent analyses.

In our model, selective incentives and conformity operate only in dyadic connections between related individuals (friends, relatives, neighbors, etc). Those who contribute to the public good, get some (non-pecuniary) reward from their friends in the form of a positive social

selective incentive. The strength of this incentive depends on the individual's decision about contribution and the number of her friends. This form of social control is independent of the action taken by those who provide it. Behavioral confirmation or conformity, on the other hand, depends on the relations between the individual's choice and the decisions taken by her friends. The individual is rewarded if she does the same as her peers act.

Anonymous relations do not transmit these forms of social control as close contacts do; individual actions are relationally and structurally embedded (cf. Granovetter 1985). Intensive interpersonal ties are therefore the key routes of the spread of social control that facilitate mobilization in collective action. As the system of actors and interpersonal ties among them is referred to as the social network, macro properties of the social network are correlated with the success of mobilization in collective action.

The models of network effects in collective action, however, should not disregard the interdependence in the collective action situation that is inseparable from relational interdependencies. For instance, joining friends at a demonstration is partly a contribution to the success of collective action and partly a provision of conformity to all friends who participate. This does not require multiple decisions from the individual, but just a single one. For this reason we integrate global and local interdependences in a unified model that takes both into account simultaneously. As Figure 1 shows, this defines a new approach for modeling structural embeddedness and collective action. On one hand, our analysis builds on the n -person public good game with global interdependence (left side of Figure 1). As we emphasized, this standard model does not distinguish between connected and unconnected pairs of actors, that is, between friends (relatives, neighbors, etc.) and strangers. On the other hand, our integrative model is based on a "network approach" that concerns dyadic relations as local interaction games (middle of Figure 1). Local interaction games deal with a network of dyads involved in two-person games, but they are unable to cope with a situation in which the entire set of players is involved in a public good game. Unlike these network models, we assume the presence of global interdependence between the players. Global interdependence links even those who are unconnected in the social network. We will refer to our model below as the structurally embedded public goods game.

Figure 1 somewhere here

3. The impact of network structure on collective action

In most of the models on collective action, social control is considered as a possible facilitating factor of cooperation. Nonetheless, conformity does not obviously help; it might also undermine collective action in large groups. Gould (1993), for instance, showed that conformity may not foster but rather inhibit cooperation in large, but dense networks. Conformity is captured in game-theoretical terms by modeling dyadic interdependencies as

assurance games, in which mutual cooperation is payoff dominant equilibrium, but not a unique equilibrium (Oberschall 1994). Selective incentives, on the other hand, are defined as rewards (punishments) for cooperation (free riding).

Some studies on collective action that encountered effects of social control, also drew attention to the consequential effects of network structure on mobilization (e.g., Marwell, Oliver and Prael 1988; Gould 1993; Kim and Bearman 1997). These studies emphasized mainly the effect of two network properties: density and centrality. Most analyses demonstrated that closed and dense social networks could produce more social capital for maintaining group norms, including norms of cooperation than atomized networks (Marwell, Oliver and Prael 1988; Coleman 1990; Marwell and Oliver 1993; Kim and Bearman 1997). The positive impact of density on cooperation is also supported by empirical evidence (e.g., Gould 1995). On the other hand, when large-scale cooperation is established, sparse networks might set more stable barriers against the spread of occasional defections (Macy 1991). Diani (2003b: 308) also concludes based on different empirical findings that dense networks support mobilization in small networks with strong identity, but the chances to find examples in large populations are low, while it may be possible to find activity in close-knit sections within them. Gould's (1993) analysis also provides examples when a highly dense network is capable to establish only a mediocre level of collective good production. How density will effect the success of collective action, depends on the rate at which normative pressure and enthusiasm about the prospects of mobilization encourage individuals to emulate the contribution of others and on the structural location of zealous actors (Gould 1993: 191).

Marwell, Oliver and Prael (1988) emphasized that network centralization has a competing impact on collective action with density. The key importance of central actors and the efficiency of centralized structures in mobilization have also been demonstrated by Macy (1991), Gould (1993), Opp and Gern (1993), Diani (1995; 2003a), and Ansell (2003). Gould (1993) emphasized that a volunteer can trigger the most contributions in a star-shaped structure. Central actors are less capable of spreading cooperation in highly dense networks with low degree variance. On the other hand, Cummings and Cross (2003) have found in an empirical study of work groups that core-periphery and hierarchical network structures were negatively associated with performance.

There is less discussion, however about other effects of degree distributions and effects of other structural properties. The seminal work of Granovetter (1973) highlighted the importance of bridging relations for getting important information and social capital. These bridging ties might also be important to disseminate contribution norms between subgroups. Subgroups, however, are often reported to be highly reluctant to change their local behavioral code and to adopt established norms from outside. The systematic analysis of the conditions under which subgroups support or hinder collective action is still lacking in the literature (an exception is a summary on policephalous movements by Diani 2003b).

As previous studies have demonstrated, structural effects are prevalent in collective action and they are caused by underlying social control mechanisms. In our analysis we will focus on the

dependence of network effects on the type of social control that operates in dyadic relations. In particular, we examine whether selective incentives, when they reward contributors, would always foster collective action or under certain structural conditions they could also hinder mass collective action. As we compare macro effects of positive selective incentives and conformity, we demonstrate what they imply for social network effects in collective action. As far as network effects concerned, we emphasize which mechanisms of social control are responsible for the impact of network properties as density, minimum degree, network clustering, and bridging ties.

4. The structurally embedded public goods game

In this section, we introduce our model that integrates social control mechanisms and local interactions into the analysis of collective action. We model collective action as an n -person social dilemma. Precisely, we assume that a final set of players ($\mathbf{N}=\{1, \dots, i, \dots, n\}$, where $n>2$) play an n -person public goods game with a linear production function. In this game, every individual has to decide whether to take part in the collective action or not. That is, each player has to choose between two alternatives: they can either participate in collective action (contribute to the provision of the public good) or not (defect). Contribution means a provision of a unit of a public good and defection means no additional provision.

The value of a unit of the public good provided by any player is α for all individuals. The action taken by the individual $i \in \mathbf{N}$ is denoted by σ_i , where $\sigma_i=1$ is contribution and $\sigma_i=0$ is defection. Contribution has a cost c , and this value is the same for everyone. Defection does not imply any cost and offers no additional gains. We assume that narrow monetary interest does not provide sufficient incentives for cooperation, i.e. $c>\alpha$. Although the cost of contribution is higher than the gain of the provision of one unit of the public good, we suppose that if there are enough contributors, the value of the public good provided to every individual is higher than the cost of contribution. In other words, there is a threshold number of contributors n^* ($1<n^*\leq n$), for which $\alpha n^*>c$.

This is a standard starting setup used by models of collective action. To incorporate structural embeddedness in the model, we assume that all players might have network ties with others. For a general model, we do not specify what sort of relationships (friendship, kinship, or simply acquaintance) these individuals have. It is sufficient to claim that these ties are the sources of transmitting social control. Such control can only be experienced between connected individuals. Moreover, direct social control is not only possible, but also inevitable between players, who are adjacent in the network.

We integrate global and local interdependencies in a unified model as follows. We consider a network of dyadic relations among the players involved in the standard n -person PG-game. To have a parsimonious model, we model the web of social contacts by an undirected and unvalued graph, in which nodes are individuals and edges are relationships. This means that we assume that the transmission of social control is independent of the direction and strength

of relationships or alternatively, every connection is mutual and equally important. We will denote the existence of a direct relationship between individuals i and j by r_{ij} ($i, j \in \mathbf{N}$, and $i \neq j$), where $r_{ij} = 1$ if there is a direct relationship between them, and $r_{ij} = 0$ if they are not directly related (they are not adjacent in the network). As we discuss undirected graphs, $r_{ij} = r_{ji}$ always holds. For the sake of simplicity, we will denote the total number of i 's ties by r_i ($\sum_{j=1}^n r_{ij} = r_i$, where $i \neq j$).

In case there is a tie between two individuals, the flow of social control or the effect of internalized norms is inevitable. The choice of a related person influences the payoff of the actor in different ways. We suppose that every player receives rewards (punishments) for contribution (defection) from each of her friends. The amount of this selective incentive from a single tie is denoted by s . We assume that actors always reward/punish those cooperators/defectors who are connected to them. One should note that, a selective incentive is an element of the rational calculation of the receiver, but is not of the one of the provider as it is free to produce and provided automatically.

In addition to this selective incentive, individuals might prefer to follow the behavioral patterns of related actors. The individual's deviation from a related player's choice implies lower payoff than the outcome where they behave in the same way. In the model, both the absolute number and the proportion of the deviators among the related actors matter. That is, we assume that conformity consists of two elements. The first form of conformity is received as a linear function of the number of friends with the same choice and we call it mass conformity. Formally, all related actors with the choice equivalent to i 's decision increases i 's payoff by b_1 . When mass conformity operates, an individual, who intends to participate in a demonstration, would like to be sure that there are enough friends in the crowd. On the other hand, in case this individual prefers to stay at home, she would like to be assured that many friends choose the same option. The second form of conformity is received as a linear function of the proportion of friends with the same choice, and we refer to it as proportional conformity. Proportional conformity is independent of the number of ties the given individual has. The coefficient for proportional conformity is denoted by b_2 . When proportional conformity operates, the individual prefers to follow the decision of the majority of her friends.

For the sake of simplicity, we assume that $\alpha, c > 0$; $b_1, b_2, s \geq 0$, as we present all of them as rewards in (1). However, this assumption could easily be relaxed in a subsequent analysis. Assuming social control in terms of punishments instead of rewards would lead to a slightly different model with similar results. Denote \mathbf{C} and \mathbf{D} two disjoint sets of the group \mathbf{N} , such that $\mathbf{C} = \{\mathbf{N} \setminus \mathbf{D}\}$. Moreover, let us denote r_{ic} and r_{id} the numbers of i 's connections who are elements of sets \mathbf{C} and \mathbf{D} , respectively ($r_{ic} + r_{id} = r_i$). If every member of \mathbf{C} contributes and every member of \mathbf{D} defects, then the payoffs of defection and contribution for i are the following:

$$\pi_i(\sigma_i = 0) = r_{id}b_1 + \frac{r_{id}}{r_i}b_2 + \alpha \sum_{j=1}^n \sigma_j \quad (1)$$

$$\pi_i(\sigma_i = 1) = r_i s + r_{ic}b_1 + \frac{r_{ic}}{r_i}b_2 + \alpha \left(\sum_{j=1}^n \sigma_j + 1 \right) - c$$

where $j \in \mathbb{N} \setminus \{i\}$. One can see that in a given network, social approval is the strongest if one cooperates in a cooperating social environment. Cooperation or defection in a group of defectors implicates weaker approval. Our model allows for the assumption that a community of defectors fosters individual's defection (this is the case if b_1 and b_2 are large comparing to s). Nonetheless, it is possible within this modeling framework that the defectors provide more approval for cooperators than for other defectors (in this case s is large relatively to b_1 and b_2). Social approval is the weakest if one defects while her friends cooperate.

From (1) it follows that the contribution of the individual i is rational if

$$\alpha + r_i s + (r_{ic} - r_{id}) \left(b_1 + \frac{b_2}{r_i} \right) \geq c. \quad (2)$$

From (2) it follows that a selective incentive fosters contribution relative to the number of connections of the given individual. Conformity promotes contribution only when there are more contributing friends than defectors. In case the number of defecting friends exceeds the number of contributing friends, conformity drives towards defection. Mass conformity supports contribution to the extent of the difference between the numbers of contributing and defecting friends; while proportional conformity promotes contribution to the extent of the proportion of contributors among the related individuals.

In case the cost of contribution is too high we cannot expect any provision of the public good. If there are strong incentives for contribution, however, then collective action can be established. Defection is not a strictly dominant strategy of i anymore, if the individual's benefits from social control and provision of a unit of the public good exceed the cost of contribution at least in the case when all of those players contribute who are connected to the individual ($r_i = r_{ic}$). That is, if

$$\alpha + r_i(s + b_1) + b_2 \geq c. \quad (3)$$

Moving a step further, contribution can be a dominant strategy of i , if the individual's benefits from social control and provision of a unit of the public good exceed the cost of contribution even in the case when all of those players defect who are connected to the individual ($r_i = r_{id}$). That is, if

$$\alpha + r_i(s - b_1) - b_2 > c \quad (4)$$

holds. Hence, under certain conditions, social control rationalizes unconditional cooperation in collective action.

Due to the simplifications of the model, it is relatively easy to calculate an arbitrary actor's payoffs for a certain decision. One should note, however, that the costs and benefits of contribution and defection differ for players in different structural positions. Thus, it is misleading to conduct an equilibrium analysis similar to that is adopted in n -person games with a homogeneous set of players. In our model, the conditions for contribution at the individual level do not fully specify the macro level determinants for the emergence of collective action.

5. Possibility of collective action

After a brief analysis of individual decisions, let us now consider under which conditions collective action may emerge assuming an exogenously given network. Primarily, we search for situations in which collective action is an equilibrium over the set of pure strategies. Foremost, we focus on the conditions for the emergence of full contribution in which each actor contributes to the provision of the public good. We also analyze the conditions for the existence of partial contribution equilibria, primarily because of their relevance for the predictions about the emergence of full contribution. In this way, we spare some additional assumptions and carry out a less extensive analysis. Nonetheless, most statements about the conditions for full contribution could be generalized with little modification to any subgroup of a given set of individuals.

For the sake of simplicity, we assume that $r_i > 0$ holds for all i . One can see from (2) and (4) that a situation in which all actors defect (overall defection) is a Nash equilibrium if there is no i for whom contribution would be a dominant strategy. This means that $c \geq \alpha + r_i(s - b_1) - b_2$ should hold for all i .

On the other hand, full contribution is a Nash equilibrium if there is nobody for whom defection is a dominant strategy. In other words, in case $(c - \alpha - b_2) / (s + b_1) \leq r_i$ holds for all i ($r_i > 0$, that is the graph is connected), then full contribution is a Nash equilibrium. That is, for full contribution being Nash equilibrium the network should have the property

$$\min(r_i) \geq \frac{c - \alpha - b_2}{s + b_1}, \quad (5)$$

where $\min(r_i)$ is the minimum number of ties individuals have in the group (minimum degree). A network parameter (here the minimum degree) on one side of the equation and social control parameters and other incentives on the other side simplifies the analysis of network structure on collective action. In this case, we could make it transparent that as a

necessary structural condition for overall mobilization in collective action everyone has to be connected to the network to a certain extent. Individuals with few connections make overall participation impossible. As far as social control concerned, a stronger selective incentive and stronger conformity increase the chance of overall contribution. Moreover, in spite of the significant difference between their micro effects, selective incentives and mass conformity influence for the emergence of full contribution equilibrium exactly the same way.

In case the threshold number n^* is not very high, partial contribution can also produce beneficial collective action. A partial contribution outcome, where all $i \in \mathbf{C}$ contributes and all $j \in \mathbf{D}$ defects, is a Nash equilibrium, if such \mathbf{C} and \mathbf{D} ($\mathbf{C} = \{\mathbf{N} \setminus \mathbf{D}\}$) non-empty sets exist for which

$$\alpha + r_i s + (r_{ic} - r_{id})(b_1 + \frac{b_2}{r_i}) \geq c \quad \text{for all } i \in \mathbf{C} \quad \text{and} \quad (6)$$

$$\alpha + r_j s + (r_{jc} - r_{jd})(b_1 + \frac{b_2}{r_j}) \leq c \quad \text{for all } j \in \mathbf{D} \quad (7)$$

hold. In this case, there is no clear relation between a certain network property and partial contribution equilibrium that would be independent from the structural distribution of contribution choices.

The existence of partial contribution equilibrium is most likely in a segmented network. For instance, if there is a dyad that is isolated from the rest of the network and both individuals have their only connection with one another, then partial contribution in which they defect is an equilibrium, given that full contribution is an equilibrium, if $c \geq \alpha + s - b_1 - b_2$. On the other hand, partial contribution equilibria do not exist in a network in which everyone is tied to everyone else.

No further formal analysis is necessary to see that partial contribution is more likely if there is a large subset of the community with high minimum degree and relatively dense relations. In this case, members of this subset may cooperate, while individuals with few connections and some small segregated subgroups will be free riders. Thus, according to the model, when, for example, workers of a factory launch a wild cat strike and members of the major workshops participate, some new or part-time employees, members of small, peripheral units, and those who work individually outside the workshops may stay out of the strike without a negative impact on the contribution of the rest of workers. In the next section, we will show further structural determinants of the conditions of partial contribution equilibria.

If there is one Nash equilibrium over pure strategies of the game, we consider it as the expected outcome. In several cases, however, there are multiple equilibria. For equilibrium selection there are different approaches we could follow. Without choosing sides in the ongoing debate, the only assumption we make is that if there is a payoff dominant

equilibrium, we consider it as the expected outcome of the game.¹ An equilibrium is payoff-dominant if it provides more (or equal) payoff for every player than any other equilibrium. In this study, we do not go into further analysis of what happens when none of the existing equilibria is payoff dominant.

If full contribution and overall defection are two Nash equilibria of the game and the number of players exceeds the threshold number n^* ,² then full contribution always dominates overall defection. In this case, it is likely that collective action emerges. Partial contribution equilibria, however, are not always dominated by full contribution. If there is a subset of players for whom collective defection provides higher rewards than collective contribution, then full contribution is not payoff dominant over the partial contribution equilibrium, in which this subset of players defects. In other words, full contribution is payoff dominant equilibrium in case it is a Nash equilibrium, and there are no partial contribution equilibria, or if they exist, in any set of possible defectors, contribution of the whole set provides higher payoffs for its members, than the equilibrium where they defect. That is, the existence of partial contribution equilibrium may undermine full contribution as a likely outcome.

The conditions for full contribution being a Nash equilibrium are given in (5). Partial contribution equilibrium exists in which all $i \in \mathbf{C}$ cooperates and all $j \in \mathbf{D}$ defects ($\mathbf{C} = \{\mathbf{N} \setminus \mathbf{D}\}$; \mathbf{C} and \mathbf{D} are non-empty sets), if equations (6) and (7) hold. In case both equilibria exist, full contribution is payoff dominant over partial contribution if rewards for all $j \in \mathbf{D}$ are higher in the former case. That is,

$$n_d \alpha + r_j s + r_j b_1 + b_2 > c + r_{jd} \left(b_1 + \frac{b_2}{r_j} \right) \text{ for all } j \in \mathbf{D},$$

which is simplified to

$$n_d \alpha + r_j s + r_{jc} \left(b_1 + \frac{b_2}{r_j} \right) > c \text{ for all } j \in \mathbf{D}, \tag{8}$$

where n_d is the number of members of \mathbf{D} . The smaller the number of defectors in the partial contribution equilibrium, the smaller the likelihood that full contribution dominates this partial contribution equilibrium. That is, full contribution is more likely to be undermined by some defectors if there are small and segregated subgroups in the community. These subgroups should be small enough not to have, even collectively, a significant effect on the public good. Moreover, they should be segregated not to be influenced too strongly by outside pressure. One should note that if the entire community can be split into such small segregated subgroups, then any level of contribution might be undermined by strategic considerations, even in case of strong social control and relatively high density of the network.

Granovetter's (1973) study provides a classical example of this kind. He points to the failure of collective action in an ethnic Italian community in Boston that could be characterized by

dense network and strong social ties. The source of cohesion in this community was the close-knit family network, in which every member knew and influenced one another. The emphasis on intra-family relations, however, resulted in the ignorance of other types of relations. Thus, one could observe high level of cohesion in any part of the community, although the lack of ties between families inhibited the provision of community-level public goods.

6. Social control, network properties, and collective action

Density and full contribution equilibrium

In this section we turn to a closer analysis of the effect of certain network properties and of their interactions with social control on collective action. First, consider the preconditions of full contribution equilibrium. Equation (5) reveals that the key structural property that is associated with the emergence of full contribution is the minimum degree of the network. Among other network characteristics, density positively correlates with the likelihood of full contribution equilibrium. The relation between density and the chance of full contribution being an equilibrium can be derived from the statistical relation between density (the number of edges in the graph) and the minimal number of individual relations (the minimum degree). The higher the density of a network is the smaller the likelihood that there will be individuals with zero or few connections. It is easy to see that the general likelihood of $\min(r_i) \leq t$ ($t < n-1$) decreases, if density or the number of relations (r) increases (if n is given), which means that the likelihood of full contribution equilibrium on average increases by network density. The general likelihood $\min(r_i) \leq t$ ($t < n-1$) is equal to one, if $r < (t+1)n/2$ and it is zero, if $r > (n-1)(n-2)/2 + t$. For the range in between, extensive calculations are necessary. In Figure 2 we only provide an illustration of the general likelihood that the minimum degree of a random graph with n nodes and r relations reaches a certain level ($\min(r_i) = t$). This likelihood is associated with some known properties of degree variance (cf. Snijders 1981). Higher degree variance is associated with a smaller likelihood of full contribution equilibrium. The relationship between degree variance and full contribution equilibrium is weaker when density is very low or very high. As Figure 2 shows, density positively correlates with minimum degree, which supports the density-cooperation hypothesis (cf. Coleman 1990; Marwell and Oliver 1993; Gould 1993).

Figure 2 somewhere here

The distributions are overlapping, which means that higher density does not necessarily mean a higher minimum degree and consequently a higher likelihood of full contribution equilibrium. In highly centralized networks, in which most relations lead to relatively few individuals, the minimum degree and the likelihood of full contribution equilibrium is low.

This result is in contradiction with findings that emphasize the efficiency of centralized structures in mobilization for collective action (see Macy 1991; Opp and Gern 1993; Gould 1993).

The model shows that the central position in itself does not strengthen the effect of social control in collective action. For example, in the factory, where workers are thinking of organizing a wild cat strike, a central actor will not be able to initiate collective action, if other workers have only connections to her and not to each other, since one tie is not likely to provide sufficient social benefits for them to participate. The central actor will be left alone with her enthusiasm. When the network of informal connections in the workshop resembles a star-shaped structure, workers in peripheral positions will not participate, because they would not be confirmed for their behavior by their peers. In a dense network, workers in relatively central structural positions will more likely have a key role in mobilization than in a sparse network as the colleagues in peripheral positions reassure each other that they have been convinced to participate. This also leads to a prediction that is competing with the theoretical results of Gould (1993) about the impact of density on the influence of central actors in collective action.

Payoff dominance: non-monotonic effects of social control

Similar incentives and structural characteristics foster the existence of a partial contribution equilibrium as of the emergence of full contribution (see equations 6, 7, and 8). The existence of partial contribution, however, might inhibit full contribution becoming payoff dominant. As a consequence, social control may have adverse effects, and the influence of network structure is strongly shaped by the relative importance of different types of social control. The emerging complexity cannot be interpreted as a purely technical problem and it has a clear substantial relevance. Contribution may be more stable, if everybody knows that any provision of the public good is possible only if everyone contributes to it. The possibility of partial contribution equilibrium means that some people reckon that others might contribute anyway, and therefore their incentives for contribution weaken. That is, if the conditions for contribution become more favorable for a subgroup of players, the rest of the group is tempted to become a free rider. Thus, strategic considerations may lead to the disappearance of large-scale collective action.

The model mostly predicts positive correlation between the strength of social control and collective action. Weak control is never favorable for collective action and extremely strong incentives always facilitate full contribution. In a certain range of parameters and in certain structural conditions, however, stronger social control might result in a lower likelihood of collective action. The double edge character of conformity is apparent at the micro level and therefore not surprising if it appears also in macro predictions. More surprising is that a stronger selective incentive may also undermine the emergence of collective action.

Let us illustrate the reverse effect of a positive selective incentive with a simple example. Figure 3 shows a network structure in a 5-person structurally embedded public goods game.

For the sake of simplicity we focus on the change in the strength of selective incentive (s) and consider other parameters as given. Let the other parameters be $c=3$, $\alpha=1$, $b_1=1$, and $b_2=1$. From equation (5) it follows that full contribution is an equilibrium outcome at any non-negative value of s . As we emphasized earlier, the full contribution equilibrium is always payoff dominant compared to the overall defection equilibrium, but not always when compared to partial contribution equilibria.

At the given parameter values, in a possible partial contribution equilibrium players A, B and C participate in collective action, while D and E defect. This equilibrium exists if C receives sufficient incentives for contribution, in spite of her connection to D and if D does not have sufficient incentives to turn to contribution. After substituting the parameter values into equation (6), it follows that C may cooperate in case of D's defection if $s \geq 2/9$. Moreover, one can see from equation (7) that D might defect in this case if $s \leq 1$. There is also a third condition, the one that tells us whether the partial contribution equilibrium in which D and E defect is dominated by full contribution. Equation (8) shows that full contribution is not payoff dominant if $s \leq 1$. Considering this network and these parameter values, there is another partial contribution equilibrium in which A, B, and C defect while D and E participate in collective action. This equilibrium exists if $1 \leq s \leq 10/9$. However, full contribution equilibrium is always payoff dominant in comparison to this equilibrium. Since there are no other partial contribution equilibria in this game, the full contribution outcome is a payoff dominant equilibrium except the cases at which $2/9 \leq s \leq 1$. That is, a small value of s ($0 < s < 2/9$) is more favorable for mass collective action than a value almost equal to one.

Figure 3 somewhere here

This example demonstrates that in spite of the significant difference between the micro effects of a selective incentive and conformity on individuals' contribution, both types of social control may inhibit collective action under specific circumstances. The non-monotonic effect of a selective incentive shows that stronger social control is not always beneficial for mass collective action. As far as the network structure is concerned, counterproductive effects of control parameters show up when it is possible to divide the group into fairly segregated subsets. Adverse effects of social control are stronger if certain subsets have dense connections within while other subsets are not as cohesive. The phenomenon is even more likely if the latter subsets are relatively small.

Let us take our example about a wild cat strike in a factory. When normative pressure is low but significant (small selective incentives), workers of the major and most cohesive workshop participate in the strike only if their friends at peripheral units also join their demonstration. In this case, these friends do not risk the failure of the strike. However, when normative pressure becomes stronger, members of the major workshop sufficiently enforce each other to strike without the participation of peripheral units. In this case, workers at the periphery with connections to the central workshop do not have the same responsibility and they might stay out of the conflict and collectively free ride on the effort of the major workshop.

Interactions of network structure and social control

In the next step we consider the relationship between different forms of social control and the effect of network structure on collective action. In order to make the analysis as simple as possible, we inquire the marginal effects of s , b_1 and b_2 , respectively, by assuming that the two other parameters are equal to zero.

If social control only means the operation of a positive selective incentive, then from (5) it follows that full contribution is a Nash equilibrium if

$$r_i \geq \frac{c - \alpha}{s} \quad (9)$$

holds for all i . On the other hand, from (7) it follows that partial contribution equilibrium exists if there is a \mathbf{D} subset of actors, in which

$$r_j \leq \frac{c - \alpha}{s} \quad (10)$$

holds for all $j \in \mathbf{D}$. Equations (9) and (10) show that full contribution and partial contribution can only exist at the same time in case there is a subgroup \mathbf{D} of individuals for whom the number of relations r_j equals to $(c - \alpha)/s$. From equations (8) and (9) it follows that full contribution is always a payoff dominant equilibrium. Consequently, the structural determinants of full contribution being a payoff dominant equilibrium are equivalent to the conditions of Nash equilibrium. As we demonstrated before, the existence of full contribution equilibrium depends on the minimum degree of the network and therefore positively correlated with density and negatively correlated with degree variance and centrality measures.

Let us now consider the structural effects in case where only mass conformity (b_1) operates and s and b_2 are equal to zero. In this case full contribution is Nash equilibrium if $r_i \geq (c - \alpha)/b_1$ for all i . The existence of partial contribution equilibrium is much more likely than in the previous case as the conditions for this are given as:

$$r_{ic} - r_{id} \geq \frac{c - \alpha}{b_1} \text{ for all } i \in \mathbf{C} \text{ and} \quad (11)$$

$$r_{jc} - r_{jd} \leq \frac{c - \alpha}{b_1} \text{ for all } j \in \mathbf{D}. \quad (12)$$

Equations (11) and (12) show that for the existence of partial contribution equilibrium the difference between contributing and defecting friends for some individuals have to exceed a certain threshold, while for others it has to remain below this threshold. This happens most likely, if contributors and defectors are segregated in the network. Local confirmation pressure drives certain parts of the network towards contribution and other parts towards defection.

Consider any partial contribution equilibria where all $i \in \mathbf{C}$ cooperates and all $j \in \mathbf{D}$ defects. From equation (8) it follows that full contribution equilibrium is payoff dominant over partial contribution, if

$$\min(r_{jc}) > \frac{c - n_d \alpha}{b_1}, \text{ where } j \in \mathbf{D}, \quad (13)$$

and n_d is the number of individuals (defectors) in \mathbf{D} . It means that the necessary structural condition for full contribution equilibrium being payoff dominant over a given partial contribution equilibrium is the existence of contacts between each defector and a certain number of contributors in the latter equilibrium. In case there are defectors that are only connected to defectors in partial contribution, full contribution will not be payoff dominant compared to this equilibrium. Here again we have to emphasize the importance of universality; all defectors should be integrated to the required extent in order to achieve the benefits of full contribution. Density within the subset of defectors in this respect is irrelevant. What matters is the minimum degree of connectedness to the subset of contributors. Strong segregation of defectors inhibits full contribution in the community.

In case when only proportional conformity (b_2) operates and s and b_1 are equal to zero, the conditions for full contribution being a Nash equilibrium are completely independent of network characteristics. Nonetheless, the minimum degree should also be greater than zero in this case. If this presumption holds, then the existence of full contribution Nash equilibrium depends only on payoff parameters. That is, $b_2 \geq c - \alpha$ should hold.

In this case, segregation plays an even more important role for the emergence of partial contribution equilibria. The conditions for the existence of partial contribution equilibrium are:

$$\frac{r_{ic} - r_{id}}{r_i} \geq \frac{c - \alpha}{b_2} \text{ for all } i \in \mathbf{C} \text{ and} \quad (14)$$

$$\frac{r_{jc} - r_{jd}}{r_j} \leq \frac{c - \alpha}{b_2} \text{ for all } j \in \mathbf{D}. \quad (15)$$

Given that full contribution equilibrium exists, the necessary condition for partial contribution equilibrium is that for some individuals the proportion of contributors among their friends has to exceed a certain threshold and for other individuals it has to remain below this threshold. This is more likely to happen in clustered network structures. Dense subgroup structures increase, but overlapping dense structures decrease the chance of partial contribution equilibria. In a highly dense network it is less likely that a subgroup exists that is sufficiently isolated from others.

Full contribution is payoff dominant over partial contribution, if

$$\min \left(\frac{r_{jc}}{r_j} \right) > \frac{c - n_d \alpha}{b_2} \quad (16)$$

where $j \in \mathbf{D}$, and n_d is the number of individuals (defectors) in \mathbf{D} in the partial contribution equilibrium. It means that the necessary structural condition for full contribution being payoff dominant over a given partial contribution equilibrium is that the proportion of contributors among the connections of each defector should exceed a certain threshold in case of partial contribution. This is a requirement of minimum relative connectedness, unlike in the case of mass conformity, when it was a requirement of minimum absolute connectedness to contributors. Here the number of defecting friends also matters. Full contribution can be payoff dominant also when in the partial contribution equilibrium some defectors have only few contributing friends. On the other hand, they should also have only few defecting friends. This also means that if proportional conformity is highly relevant, then full contribution can be payoff dominant equilibrium also in highly centralized structures. For this, central actors have to be connected to diverse subgroups.

This short analysis of marginal effects showed that the minimum degree is a strong determinant of overall collective action in case selective incentives operate. Network clustering and segregation of defectors has a strong influence when conformity mechanisms are strong. The payoff dominance of full contribution equilibrium is not likely in centralized structures when mass conformity is strong, but it is possible in case proportional conformity is prevalent. Another often-cited network hypothesis, according to which bridging ties support the transmission of contribution incentives between subgroups, is not relevant if only selective incentives are at work. In case the segregated subgroups have dense networks the hypothesis may fail even if conformity plays a significant role. In this case, single bridging connections do not change defectors' incentives.

7. Discussion

This study investigated the effects of social control and network structure on the emergence of collective action in n -person communities. We analyzed network effects in single encounters, and highlighted interactions between social control and structural characteristics. To reach these objectives, we proposed a new, integrated framework of analysis. The new framework combined the analysis of n -person games with local interaction games.

We discussed different social control mechanisms that are transmitted by interpersonal relationships. These mechanisms were incorporated in the standard n -person public goods game. Relationships and individuals were considered anonymous, there were no leaders, privileged actors, or binding coalitions. Social control mechanisms, namely selective incentives and forms of conformity were modeled as rewards that influence individual decisions through actors' relationships to relevant others. We demonstrated that as a consequence of social control, macro properties of the social network matter for the emergence of collective action.

Some results support widely accepted hypotheses about the facilitating factors of collective action. Besides, the analysis also shed some new light on the underlying mechanisms of social network effects in collective action. Results support the hypothesis that strong social control, on average, facilitates collective action. We also emphasized that it is not always necessary to provide a selective incentive for cooperation. Public good provision might be possible even in a large group where members match their behavior with a little subgroup of their friends (cf. Oberschall 1994). On the other hand, the analysis stressed that under certain circumstances, stronger social control may inhibit overall contribution. Not only conformity, but also selective incentives might have adverse effects. This result provides indirect support to the "double edge of networks" hypothesis of Flache (1996) and it fits in the theoretical research line that demonstrates reverse effects of social control mechanisms (e.g., Kuran 1995; Flache and Macy 1996; Macy and Willer 2002).

Among social network effects, we demonstrated that density on average increases contribution. This is in favor of the density-cooperation hypothesis (Coleman 1990; Marwell and Oliver 1993). Density is associated with stronger cohesion, which helps efficient forms of social control to spread in the network. Actually, density is not obviously the most useful indicator of cohesion, if the network has subgroups (Friedkin 1981). Our results showed that the minimum degree of the network and fragmentation are more directly related to full contribution than density itself. Density increases the chance of full contribution mainly because it is correlated with these measures. The model also showed that the impact of minimum degree on full contribution is correlated with the strength of selective incentives, while the lack of clear network clusters foster collective action if conformity plays a significant role in players' decisions. We also showed that clustering in a community might inhibit full contribution even when social control is relatively strong.

Nonetheless, we did not relax many of the model restrictions in this analysis. The floor is open, however, for generalizations as we tried to develop a flexible framework of analysis.

That is, several restrictive assumptions of the model can be relaxed in subsequent research without shifting the basic building blocks of the model.

For instance, the analysis can be extended to cases in which a different production function is assumed for the public good provision. Basically, it is not even necessary to assume an increasing production function. Similar results can be produced for cases in which $\alpha < 0$, where we have the problem of sustaining a public bad (cf. Kuran 1995). Similarly, instead of rewards of social control, punishments could be considered, for instance in the form of negative selective incentives for defectors. This modification, however, would not reshape model predictions radically. Another example is to relax the assumption of binary social relations (two individuals are either friends or not). We could assume that there are good friends and also mere acquaintances in the network by ordering weights to each tie. The strength of social control would then depend on the strength of the given tie.

As we investigated one-shot interactions with perfect and complete information and forward-looking, strategically rational individuals, a natural development is the consideration of repeated structurally embedded games. Furthermore, the rationality assumptions of the game theoretical approach could be regarded as serious shortcomings, although we are convinced that there are well-founded theoretical reasons for taking this type of actor-model as given.³ The presented equilibrium analysis also presumes perfect information of actors that is very likely an implausible assumption in large communities. One possible way to tackle this problem is to consider limited information and structurally constrained information flows. A game theoretical analysis in this direction is presented by Chwe (1999, 2000). Another possible way of relaxing the strict assumptions of the model is to consider boundedly rational actors. Backward-looking learning models fitted to collective action problems go in this direction (Macy 1993; Macy and Flache 2002).

A critical assumption that can be relaxed in a subsequent analysis is the stability of the network. Individuals develop new relationships and sometimes abandon old ties, and this might have some consequences also for their decisions in collective action, especially if the structural change is a cause or a consequence of their behavior in the public context. This could be followed by a dynamic interrelated analysis of repeated collective action problems and structural dynamics. Most important, however, is that any model extension and theoretical development should also be fruitful for empirical research.

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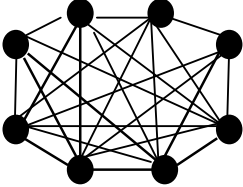
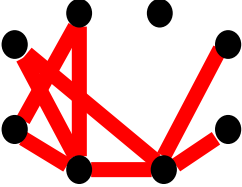
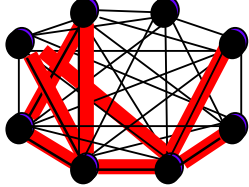
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Figure 1: An Illustration of Our Approach

Global interdependence	Local interdependencies	Global and local interdependencies
<i>n</i> -person public goods game	local interaction games	structurally embedded games
		

Note: Thin lines symbolize global interdependence in *n*-person relations and thick lines mark interpersonal relations between actors.

Figure 2: The general likelihood of the minimum degree being t in a network $n=8$ with r connections

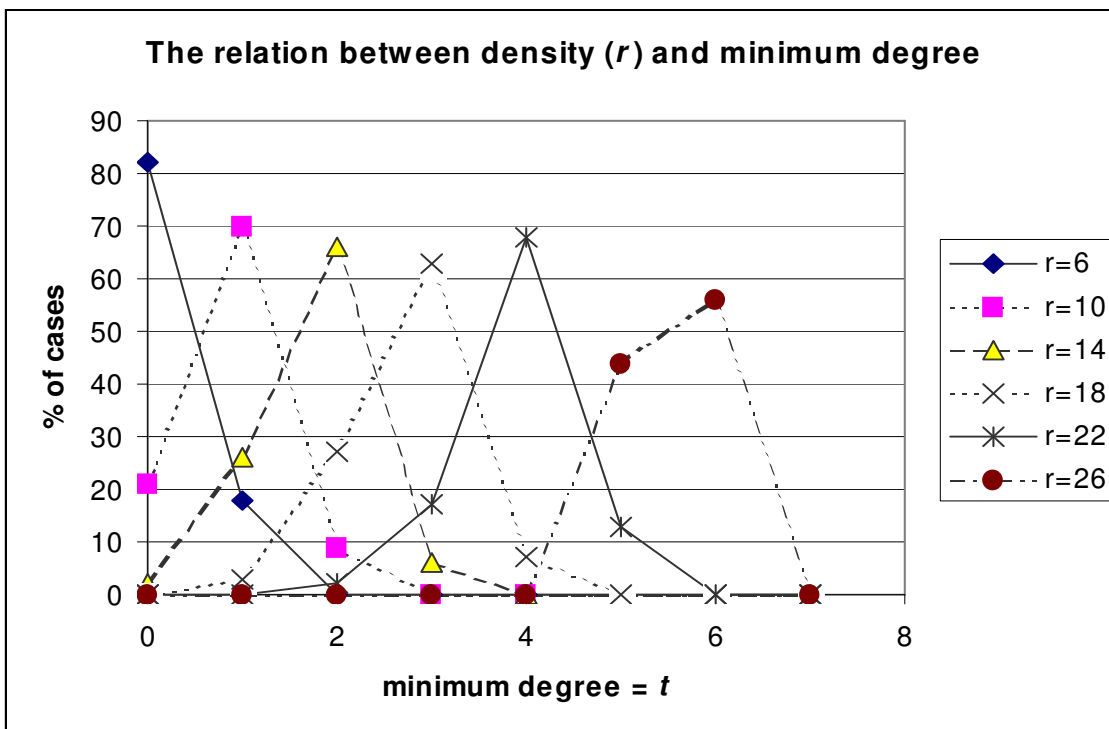
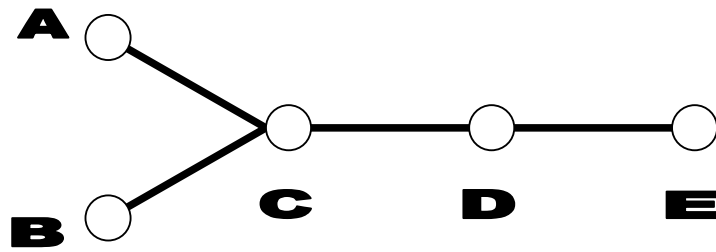


Figure 3 Illustration of a 5-person structurally embedded public goods game



ENDNOTES

¹ One should note that from a purely theoretical and general viewpoint, payoff dominance cannot serve as a solution for the problem of equilibrium selection in games. If one approaches the problem of uniqueness from the perspective of our study, however, the concept of payoff dominance provides the most fruitful selection mechanism. Experimental findings are also ambivalent about whether subjects play the payoff dominant equilibrium or another outcome. In coordination games with multiple equilibria, for example, in case of few players and a salient payoff dominant equilibrium this outcome is played often, but more players and a higher resistance makes the rival risk-dominant equilibrium a more likely outcome (e.g., Corbae and Duffy 2002).

² As we defined above: $\alpha n^* > c$. For the production of public goods, for which this assumption does not hold, the overall defection equilibrium is likely to be payoff dominant.

³ The emphasis here is both on *this type* and on *taking it as given*. See Granovetter (1985) and Raub and Weesie (1990) on this issue in the context of network models.