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Social Control, Participation in Collective Action and Network Stability

Abstract

This paper investigates the interrelations between social control mechanisms, social networks and collective action. We introduce a game theoretical model that explains how and under what conditions social networks rationalize participation in collective action and how can collective action reshape network relations in single encounters. The key mobilizing forces in collective action are interpersonal ties, as they transmit different forms of social control such as behavioral confirmation and social selective incentives. The paper shows that stronger social control by and large fosters participation, but eventually it decreases the chance of mass mobilization. We demonstrate that the impact of network structure is conditional to which social control mechanisms operate. In case selective incentives are strong, the minimum degree of the network is a crucial determinant of collective action. In case of strong confirmation incentives, we find a negative effect of network segregation on mass mobilization. Furthermore, the paper goes beyond the static analysis of network effects in collective action and incorporates the opportunity of forming and of severing ties in the model. We introduce an equilibrium refinement that embraces the concepts of Nash equilibrium and network stability. We show that when abandoning and forming relations are inexpensive, only networks in which contributors and defectors are highly segregated can be in this equilibrium.

Keywords: Collective action; Social dilemmas; Social networks; Social control; Structural balance

+ Authors' names are in alphabetical order. We would like to thank Andreas Flache and Russell Hardin for their comments on an earlier version of the paper.

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1. Introduction

Collective action aims at the provision of certain public goods for a community. If narrow self-interest does not provide sufficient incentives for the private provision of public goods, collective action may fail. It is widely believed, however, that some forms of *social control* might help to overcome the social dilemma that stems from the lack of incentives for voluntary contribution (e.g., Olson, 1965; Hardin, 1982; McAdam, 1986; Heckathorn, 1989; Coleman, 1990; Holländer, 1990; Weesie, 1990; Chong, 1991; Finkel and Opp, 1991; Gould, 1993; 1995; Flache and Macy, 1996; Sandell and Stern, 1998).

Social control operates as a constraint on individual decision posed by the influence, as well as by the behavior, opinion, and expectations of relevant other individuals. In most typical cases, these constraints can be translated to a system of mutual rewards and punishments that are embedded in close and durable personal relationships (cf. Gibbs, 1981; Black, 1984; Heckathorn, 1990; Macy, 1993; Takács, 2001; Villareal, 2002). It is often assumed that social control influences other individuals in the form of *selective incentives*. Selective incentives implicate that actors punish defectors and/or reward contributors (Olson, 1965). Various selective incentives (for instance, respect or social norms) take immaterial forms. When the production of these immaterial rewards do not require significant costs from the related individuals, there is no second order free rider problem (cf. Heckathorn, 1989; Rege and Telle, 2001). Alternatively, receivers might internalize selective incentives or norms (Scott, 1971). In this case, the condition for activation is the presence of an interpersonal tie that triggers the expected individual behavior.

Behavioral confirmation is another form of social control that is often incorporated into models on interpersonal influence. Behavioral confirmation stems from actors' desire to follow prevalent behavioral patterns of relevant others (e.g., Lindenberg, 1986). For instance, individuals have additional motivations to join the public protests, if their friends do so. On the other hand, it is better to stay at home, if friends remain absent from the protests (Oberschall, 1994). As this example shows, behavioral confirmation does not obviously help; it might also undermine contribution in large groups (cf. Flache, 1996). This double edge character of the contribution of behavioral confirmation to the provision of public goods is captured by modeling local interdependencies as assurance games, in which mutual cooperation is a payoff dominant equilibrium (Oberschall, 1994).[1]

[1] The theory of fairness provides a rationale for the existence of selective incentives as well as for behavioral confirmation in strategic interactions. Some recent models on human preferences indicate that fairness considerations are built into individuals' intrinsic incentives (e.g. Binmore, 1998, Nowak, Page, and Sigmund, 2000). Actors try to avoid the role of the "sucker" as well as the one of the free-rider. Experimental evidence tends to support this hypothesis in public good games: individuals partly follow their material self-interest, though they prefer to contribute to a public good if others also do so (Fehr and Schmidt, 1999; 2001; Bolton and Ockenfels, 2000). What is more, many of them are ready to reduce their own material welfare in order to punish those who do not contribute (Fehr and Gächter, 2000). The inequity aversion of fairness norms implies conform

Anonymous relations do not transmit these forms of social control as close contacts do. Intensive interpersonal ties are therefore the key routes of the spread of social influence that facilitate mobilization in collective action. As the system of actors and interpersonal ties among them is referred to as the *social network* (Wasserman and Faust, 1994: 9), macro properties of the social network are correlated with the success of mobilization in collective action. Previous studies on collective action emphasized mainly the effect of two network properties: density and centrality. Theoretical analyses demonstrated that closed and dense social networks could produce more social capital for maintaining group norms, including norms of cooperation (Marwell, Oliver, and Prahl, 1988; Coleman, 1990; Marwell and Oliver, 1993; Kim and Bearman, 1997). Gould (1993), however, pointed to the more complex effect of density in his model. Nonetheless, the positive impact of density on cooperation is supported by empirical evidence (e.g., Gould, 1995). The key importance of central actors and the efficiency of centralized structures in mobilization have been illustrated by Macy (1991), Gould (1993) and Opp and Gern (1993). There is less discussion, however, about the effects of other structural properties. The seminal work of Granovetter (1973) highlighted the importance of bridge-type 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.

Furthermore, structural effects might be dependent on which forms of social control operate in the community. The variability of the nature of social control leads to diverging implications about structural effects. As macro effects of certain network properties originate from different social control mechanisms, the analysis of structural effects and of social control should go alongside each other, and the investigation should also concentrate on possible interaction effects of social control and network structure (cf. Lindenberg, 1997). Unlike in previous studies, the focus of this paper is the interaction between the impacts of social control and network properties on collective action.

The interest of actors, however, often shape the development of social ties. Egoistic incentives may also alter personal relationships in collective action situations. A critical assumption that is made even by those models that count on social network effects is the *stability* of the network. Relational ties are assumed to be exogeneously given and at most only static comparisons are made. Endogenous network development is an issue hardly investigated in the context of collective action, especially in single encounters. Previous models that combined game theory and structural change concentrated on long term network evolution, including theories of structural learning (Kitts, Macy, and Flache, 1999) and strategic network

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behavior in public good games. The incentives for non-selfish punishment can be modeled in a public good game as cost-free rewards for contributors.

formation (Bala and Goyal, 2000; Bonacich, 2001). Everyday experience tells us, however, that relationships change as a consequence of collective interdependencies, and expectations about possible changes affect individual contribution decisions.[2] In this paper, we open the floor for considering relational ties endogenously and we consider how the foresight of structural change influences collective action outcomes in single encounters. That is, besides investigating the impact of network structure on collective action, we also analyze reverse effects of public good problems on network formation.

In order to capture the interrelations between social control, network structure and collective action, this paper offers a new framework of analysis. We incorporate social control mechanisms and consequently social network effects in the *n*-person social dilemma model of collective action. We provide an analysis of the conditions under which individuals are better off by contributing to the provision of the public good and we also examine equilibrium conditions for the emergence of collective action in *single encounters*. This does not mean that we disregard the importance of repeated interaction and structural change, but we strongly believe that the discussion of one-shot situations should precede the consideration of long term or evolutionary perspectives.

To summarize the objectives of this study, we examine how different forms of social control influence decisions of rational individuals in a social dilemma situation. Besides, we focus on the impacts of structural characteristics and investigate which network properties interact strongly with selective incentives and which ones with behavioral confirmation in forming favorable conditions for the emergence of collective action. At one point of our analysis, we relax the assumption of stable networks and investigate a public goods game in which players can abandon existing relationships or build new ones in case it is in their rational interest. We try to delineate the structural conditions under which collective action can be achieved in a way that it does not destroy personal relations.

In the next section we present the structurally embedded public goods game model of collective action situations. Subsequently, we derive under what conditions would social control lead to an equilibrium in which collective action is established. This is followed by a discussion of the impact of network properties on participation and by the analysis of interaction effects of social control and network characteristics. The assumption of network stability is relaxed afterwards. Results, implications, and prospective directions are discussed in the concluding section.

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[2] Several models relying on *cooperative game theory* take account of some of those aspects that are emphasized in the present study (e.g., Jackson and Wolinsky, 1996; Dutta, Nouweland, and Tijs, 1998; Slikker and Nouweland, 2001).

2. The structurally embedded public goods game

We model collective action as a simple non-cooperative game, namely as an *n*-person public goods game with a final set of players ($\mathbf{N}=\{1, \ldots, i, \ldots, n\}$, where $n>2$) and 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, every player has to choose between two alternatives: they can either 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 enough incentives for cooperation, that is $c>\alpha$. 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 and how strong these relationships are. 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 have a direct relationship.

In collective action situations in reality, functional interdependency is often 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 behavioral confirmation 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 interdependence in a unified model that takes both into account simultaneously. As Figure 1 shows, this defines a radically new approach for modeling structural embeddedness and collective action. On one hand, the new approach 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 players, 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 (see e.g., Ellison, 1993; Morris, 2000), 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

We integrate global and local interdependence in one model in the following way. We add a network of dyadic relations to the standard *n*-person PG-game. Besides, the model incorporates the impacts of "relational" social control into the players' payoff functions and calculations. 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 every tie 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. 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. Individuals might prefer to follow the behavioral patterns of related actors. In this case, 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 behavioral confirmation consists of two elements. The first form of behavioral confirmation 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 or he would like to be assured that many friends choose the same option. The second form of behavioral confirmation 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 of the proportional type of conformity is denoted by b_2. If proportional conformity operates, the individual prefers to follow the decision of the majority of his or her friends. Moreover, we suppose that every player receives rewards (punishments) for contribution (defection) from each of his or her friends. The amount of these selective incentives from a single tie is denoted by s. One should note that in our model, selective incentives are elements of the rational calculation of the receiver, but are not of the one of the provider as they are free to produce.

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 **C** and **D** two disjoint sets of the group, such sets that **C**={**N****D**}. Moreover, let us denote r_{ic} and r_{id} the numbers of *i*'s connections who are elements of sets **C** and **D**, respectively ($r_{ic}+r_{id}=r_i$). If every member of **C** contributes and every member of **D** defects, then the payoffs of defection and contribution for *i* are the following:

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

where $j \in$ **N**\{i}. Hence, contribution of the individual *i* is rational *if*

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

From (*2*) it follows that selective incentives foster contribution relative to the number of connections of the given individual. Behavioral confirmation promotes contribution only when there are more contributing friends than defectors. In case the number of defecting friends exceeds the number of contributing friends, behavioral confirmation drives towards defection. Mass confirmation supports contribution to the extent of the difference between the numbers of contributing and defecting friends; while proportional confirmation 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. That is,

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

On the other hand, *contribution* is a dominant strategy of *i*, if

$$\alpha + r_i (s - b_1) - b_2 > c \tag{4}$$

holds.

3. Possibility of collective action

After the brief analysis of individual decisions, let us now focus on group-level outcomes. First, let us consider under which conditions can collective action be an equilibrium assuming an exogenously given network. 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 $c \geq \alpha + r_i (s - b_1) - b_2$ holds for all *i*.

On the other hand, a situation in which each actor contributes to the provision of the public good (*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

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

where $\min(r_i)$ is the minimum number of ties individuals have in the group (minimum degree). The expression of a network parameter (here the minimum degree) on one side of the equation and social control parameters and other incentives on the other side, makes the analysis of the impact of network structure on contribution easier. 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. Isolates and loose connections make overall participation impossible. As far as social control concerned, stronger selective incentives and conformity always increase the chance of overall contribution. Moreover, one can see that, in spite of the significant difference between their micro effects, selective incentives and mass conformity influence full contribution equilibrium in exactly the same way.

As equation (5) shows, the structural conditions for full contribution equilibrium are rather strong. In case the threshold number n^* is not very high, *partial contribution* can also produce beneficial collective action. A partial contribution outcome, where all $i\in$ **C** contributes and all $j\in$ **D** defects, is a Nash-equilibrium, if such **C** and **D** (**C**={**N\D**}) non-empty sets exist for which

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

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

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 equilibrium does not exist in a network in which everyone is tied to everyone else. In the next section, we will show further structural determinants of the conditions of partial contribution equilibria.

In several cases, the structurally embedded public goods game has multiple equilibria. For equilibrium selection there are certain commonly used criteria. Here we adopt the concept of *payoff dominance*.[3] An equilibrium is payoff-dominant if it provides more (or equal) payoff for every player than any other equilibrium.

If full contribution and overall defection are two Nash equilibria of the game and the number of players exceeds the threshold number $n*$,[4] then full contribution always dominates overall defection. 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 defect. 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. The conditions for full contribution being a Nash equilibrium are given in (5). Partial contribution equilibrium exists in which all $i\in$ **C** cooperates and all $j\in$ **D** defects (**C**={**N\D**};

[3] 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 special point of view of our study, hovewer, the concept of payoff dominance provides the most fruitful selection mechanism.

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

C and **D** are non-empty sets), if equations (*6*) and (*7*) hold. In case both equilibria exists, full contribution is payoff dominant over partial contribution if rewards for all $j \in$ **D** are higher in the former case. That is,

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

which is simplified to

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

where n_d is the number of members of **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 when 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) seminal 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 that community was the close-knit network of the family, 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.

Partial contribution is more likely, however, if there are large subsets of the community with high level of minimum degree and many overlapping ties within the subgroups. In this case, members of those subsets may cooperate, while loosely tied individuals 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 in it, 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.

4. 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 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 only. 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 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). 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).

The results of our model do not try to falsify the hypotheses on central actors' opportunities for mobilization. However, the model shows that the central position, in itself, does not strengthen social control. For example, in the factory, where workers think of organizing a wild cat strike, a central actor cannot convince those for whom she or he is the only connection to the workers' community, if one tie does not provide enough social benefits.

Figure 2 somewhere here

Payoff dominance: controversial effects of social control

Similar incentives and structural characteristics foster the existence of a partial contribution equilibrium as of the emergence of full contribution. 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 is more stable, if everybody knows that any provision of the public good is possible only if everybody 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 contribution.

The model mostly predicts positive correlation between 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 lower likelihood of collective action. Let us illustrate the controversial effect of social control with a simple example. Figure 3 shows a network structure in a 5-person version of the structurally embedded public goods game. For the sake of simplicity we focus on the effect of selective incentives (s) and consider other parameters as given. Let the other parameters be c=3, α=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. At the given parameter values, in a possible partial contribution equilibrium players A, B and C participate in the 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 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 the 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 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 micro effects of selective incentives and behavioral confirmation on individuals' contribution, both types of social control may inhibit collective action under specific circumstances. The non-monotonic effect of selective incentives 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, 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 may 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 *selective incentives*, then from (*5*) it follows that full contribution is a Nash equilibrium if

$$r_i \geq \frac{c-\alpha}{s} \tag{9}$$

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

$$r_j \leq \frac{c-\alpha}{s} \tag{10}$$

holds for all $j \in$ **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 **D** of individuals for whom the number of relations r_j equals to $(c-\alpha)/s$. From equations (*8*) and (*9*) it is transparent 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 a 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:

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

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

Equations (*11*) and (*12*) show that for the existence of partial contribution equilibrium the difference between contributing and defecting neighbors 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 $i \in$ **C** cooperates and all $j \in$ **D** defects. From equation (*8*) it follows that full contribution equilibrium is payoff dominant over partial contribution, if

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

and n_d is the number of individuals (defectors) in **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, full contribution cannot be a payoff dominant 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 inhibits full contribution in the group. It is more likely in a segregated community that there is a subgroup for which *(11)* and (*12*) holds, while *(13)* is less likely. One should note that a larger **D** should be more segregated to inhibit collective action. Furthermore, in a more dense network, **D** should be, again, more segregated to construct a situation where full contribution is not a payoff dominant equilibrium.

In the case where only *proportional conformity* (b_2) operates and s and b_1 are equal to zero full contribution being a Nash-equilibrium is completely independent of any network characteristic. 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 the 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:

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

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

Given that full contribution equilibrium exists, the necessary condition for partial contribution equilibrium is that for some individuals the proportion of contributors among their neighbors have to exceed a certain threshold and for other individuals it has to remain below this threshold. This is more likely to happen in segregated 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

$$\min\left(\frac{r_{jc}}{r_j}\right) > \frac{c-n_d\alpha}{b_2} \tag{15}$$

where $j \in \mathbf{D}$, and n_d is the number of individuals (defectors) in **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 in case of partial contribution should exceed a certain threshold. 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 neighbors also matters. Full contribution is payoff dominant also when in partial contribution equilibrium some defectors have only few contributing friends in case they have also only few defecting friends. This also means that if proportional conformity is highly relevant, full contribution payoff dominant equilibrium is also possible in highly centralized structures in case central actors are connected to diverse subgroups.

From the analysis of marginal effects of social control we could summarize that the minimum degree of the network is a strong determinant of collective action in case selective incentives operate. Segregation has a strong influence when behavioral confirmation mechanisms are strong. The impact of density has a more direct relationship with selective incentives, though, it is also connected to behavioral confirmation through the influence of the number of ties on the level of segregation. Moreover, 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. If the segregated subgroups have dense networks, however, the hypothesis may fail even in case behavioral confirmation plays a significant role. In this case, single bridging connections do not change defectors' incentives.

5. Collective action and network stability

So far we have assumed that the social network is exogenously given. Individuals were able to decide whether they participate in collective action or not, but they were not able to choose their friends or to quit existing relations. Their decision was constrained by social control mechanisms that were transmitted by existing ties. The static view of social networks is very popular in research on collective action, despite the fact that in reality, individuals change their connections over time, create new friends, and abandon other relations. Furthermore, individuals might choose their friends strategically in order to maximize rewards and minimize punishments that originate in social control (cf. Harsanyi, 1969). This is especially relevant when social control mechanisms are delayed after collective action decisions. For instance, honors as selective incentives are awarded for the heroes of a revolution well after the uprising. Even internalized selective incentives are activated only after the collective action ("I am proud that I was part of it").

For these reasons, in this section we relax the assumption that the social network is given and relations cannot change. As a first step, we consider the structurally embedded public goods game with the extension that actors in the single-shot game also decide about breaking or keeping their social ties. The requisite of symmetrical relationships is not relaxed. This means that a dyadic connection is not preserved if one of the actors prefers to abandon it. We assume that the other actor cannot pay compensation in order to save the relation. In this way, we remain in the realm of non-cooperative games (cf. Bala and Goyal, 2000).

In order to analyze the consequences of this model extension we introduce a new concept of network stability. We define a *social network* as *stable* in a given strategy profile in the (collective action) game, if there is no $i \in N$, for whom an abandonment of any one or more of his or her relations (from r_i) would result in a better outcome, assuming exactly the same strategy profile and no other change in the network.

This concept is an equilibrium concept in network terms. A network is stable, assuming everything else is given, if actors have no incentive to abandon one or more of their relations, that is nobody has an incentive to change his or her network strategy from keeping his or her relations to breaking some of them.

Theorem: If breaking relations is free then a) only a relation between a defector and a contributor can be unstable; b) such a relation is *always* unstable if $b_2>0$ and the defector has at least one tie to another defector (at least the defector wants to abandon the relation under any conditions).

Proof: a) Abandoning a relation between two defectors decreases their payoff with some proportion of behavioral confirmation and there is no source of compensation. Even when behavioral confirmation incentives are zero, there is no improvement by breaking relations. Abandoning a relation between two contributors decreases their payoff with some proportion of b and also with s and there is no source of compensation. b) The payoff of a defector in any strategy profile can consist only the following elements: c, $n_c\alpha$, $r_{id}b_1$, and $(r_{id}/r_i)b_2$. The first three elements do not change, if he or she abandons a relation to a contributor. The last element always increases in case $b_2>0$ and $r_{id}>0$, which completes the proof.

Corollary 1: If breaking relations is free and behavioral confirmation rewards are positive, then a stable network in the collective action game exists only when the network is fully segregated (contributors have ties to contributors and defectors are connected to defectors) except that there might be defectors who are only connected to contributors.

Corollary 2: Every network is stable in a full contribution and in a full defection strategy profile.

The corollaries point to a single network property (*segregation*) that is relevant for network stability in the structurally embedded public goods game. This result is similar to the structural balance theorem (Heider, 1946; Cartwright and Harary, 1956), but with the important distinction that relations in this model are filled with content and there are both local and global interdependencies in the network structure.

The situation is somewhat more complex when there are costs of abandoning a relation. We still assume that a tie can be broken unilaterally and the other side cannot apply compensation mechanisms to save the relation. In this case, part a) of the theorem still holds, that is a relation between two contributors or a relation between two defectors cannot be unstable. Part b) of the theorem, however, might not always hold even when $b_2>0$ and when a defector has at least one tie to another defector. If we denote the cost of abandoning one relation by a ($a\geq 0$), then for a defector $j\in$ **D** it is more beneficial to break a relationship with a contributor, if

$$b_2 \frac{r_{jd}}{r_j\left(r_j-1\right)} > a \qquad (16)$$

holds. This follows from the proof of part b) of the theorem, since benefits of abandoning a tie to a contributor are expressed on the left side of equation (*16*). The decision of a defector about breaking a tie with a cooperator is independent of selective incentives and mass conformity. Stronger proportional conformity, however, increases instability, since a contributor friend causes more frustration for a defector when there is more emphasis on the distribution of contributing and defecting friends. The neutrality of selective incentives and mass conformity is due to the assumption that they are rewards and not punishments. Furthermore, as network parameters in equation (*16*) show, it is less likely to break a tie when the individual's ego-network is larger.

We should also consider the conditions of abandoning multiple relations in case a defector $j\in$ **D** has ties with more contributors. Assuming that breaking each tie has a cost of a, how many relations should the defector abandon? If we denote this number with x ($r_{jc}\geq x\geq 0$), individual j should maximize the net benefits of his or her action, that is we should find the maximum value of

$$b_2 \frac{x r_{jd}}{r_j\left(r_j-x\right)} - xa, \qquad (17)$$

which is the difference between the benefits and the costs of abandoning x relations. From the derivative of (*17*) it follows that as x increases, the net benefits are also increasing ($r_{jd}>0$). This means that the most beneficial for a defector is to abandon all his or her ties to contributors. It might well be that meanwhile it is not profitable to break one or only few ties, it is profitable to abandon all connections to contributors.

This result has the corollary that a network will be stable in a strategy profile, if there is no defector who would be better off by abandoning every relation to contributors. Substituting to (*17*) it means that there is no defector $j \in \mathbf{D}$, for whom

$$b_2 \frac{r_{jc} r_{jd}}{r_j \left(r_j - r_{jc} \right)} > r_{jc} a,$$

holds, which can be simplified to

$$\frac{b_2}{r_j} > a. \tag{18}$$

This interesting result shows how high proportional behavioral confirmation and small ego-networks cause instability in the network. Individuals who have more relations are less likely to benefit from breaking relations.

This result has the corollary that, in case there are costs of abandoning relationships, not only highly segregated structures can be stable. As a prerequisite of network stability, there should not be any $j \in \mathbf{D}$ for whom equation (*18*) is satisfied. This means in proper terms that the minimum degree of the group of defectors is associated with the stability of unsegregated networks. The higher the minimum degree, the more likely the stability of unsegregated structures. As an overall consequence, larger and denser networks on average are more likely to be stable.

Let us take the example of the wild cat strike in a factory. When only some workers participate, conflicts between strikers and goons may emerge afterwards. These conflicts might even result in breaking old friendship ties. The model predicts that a more interconnected community is more likely to remain cohesive even after these heated discussions. Where workers are less embedded, however, segregated fractions of strikers and moderates may be formed. A more interconnected community might be too valuable for its members to ruin it for one conflict.

As a natural subsequent development, we examine the possibility that actors are not only able to abandon relations strategically, but they also can *build* ties in order to enjoy higher payoffs from the structurally embedded game. As we consider non-directed relations, we exclude the possibility of one-sided tie formation (cf. Bala and Goyal, 2000). Two individuals have to agree in order to form a new connection, which would normally lead us out from the realm of noncooperative analysis. Still, for the sake of simplicity, we do not go into the details of strategic analysis that is offered by a growing body of studies (e.g., Jackson and Wolinski, 1996; Dutta, van den Nouweland, and Tijs, 1998; Slikker and van den Nouweland, 2001; Jackson and van den Nouweland, 2002). We concentrate on the structural determinants and consequences of collective action, and for this objective it is sufficient to present some basic cost-benefit analyses of dyadic tie formation. We simply assume that there is no bargaining problem about who should bear the costs. Tie formation has the same costs for both parties and a tie is formed only if rewards for both parties are higher than the costs.

In a utopian setting in which contacts are formed freely, all contributors would be interested to be matched with all other contributors and all defectors would be happy to build relations with other defectors to enjoy higher behavioral confirmation benefits. In case selective incentives are more important than behavioral confirmation, contributors would even be interested to get any kind of connections including also ties to defectors. Moreover, in a full contribution strategy profile highest benefits would come from a network in which everyone is tied to everyone else.

This is not likely to be a short-term scenario, first because of the costs of forming new ties, and second because a symmetric relationship requires a mutual agreement of the parties. For instance, contributors might approach defectors in order to gain higher selective incentives, but defectors are not likely to give in. New relationships are most likely formed between two contributors or between two defectors. Two unconnected contributors $i, j \in \mathbf{C}$ both have an incentive to be matched, assuming a cost of forming a tie f, if

$$s + b_1 + b_2 \frac{r_{kd}}{r_k (r_k + 1)} > f \quad , k=i, j, \tag{19}$$

which follows from a comparison of marginal benefits and costs. It is remarkable to see that the number of defector friends increases the chance that a new tie is formed between two contributors. Furthermore, individuals with many connections (high r_i) are less likely to form new connections, as it does not give them sufficient marginal benefits (if $r_{id} > 0$).

Two unconnected defectors $i, j \in \mathbf{D}$ both have an incentive to be matched, assuming a cost of forming a tie f, if

$$b_1 + b_2 \frac{r_{kc}}{r_k (r_k + 1)} > f \quad , k=i, j, \tag{20}$$

considering a similar reasoning as in the case of two contributors. Here the likelihood of a new connection increases with the number of relations to contributors. Again, individuals with many connections are less likely to form new ties (if they are connected at least to one defector).

Concerning the building of multiple new relations, for all individuals involved, the set of new ties should provide higher benefits than the cost of tie formations. Assume a coalition of contributors in which multiple ties are formed. The cost of forming one tie *f* is the same for every new relation and for both sides. Denoting the number of new ties of individual $i \in \mathbf{C}$ by y_i, this structural change is beneficial for *i*, if

$$s + b_1 + b_2 \frac{r_{id}}{r_i(r_i + y_i)} > f \qquad (21)$$

is satisfied. This shows that the marginal benefits of forming more ties are decreasing. The first new tie is the most valuable, in case there is at least one connection to a defector. If new dyads are not beneficial, no larger coalition that contains a new set of ties can be feasible. Similarly, assuming a coalition of defectors in which multiple ties are formed, the marginal benefits of forming new ties are decreasing.

If we consider the example of strike, one may predict that in a loosely tied group of workers, the collective experience of the demonstration might bring strikers closer to each other. The collective action might be a symbolic event around which a new community can be formed. The rationale behind this process is the participants' urge to find reinforcement for their decision. Nonetheless, similar mechanisms operate among those who did not participate in the wild cat strike. They also seek reinforcement, and may form the group of "moderates" or "rational egoists". In a more interconnected community, however, workers are already get enough feedback from their peers; thus, it is less likely that such an event can contribute to the building of a larger or an even more dense social network. Nevertheless, those who have many friends with opposite directions may seek new acquaintances even in a dense network.

We showed that the most profitable for a defector is to break all of her or his ties with contributors (assuming that she or he prefers to break any tie and has at least one relation to another defector). On the other hand, we also showed that forming the first new tie to another defector has the highest marginal benefits, in case there is at least one connection to a contributor. As a subsequent step, we consider that relations can be abandoned and new ties can be formed at the same time.

When equation (*18*) is satisfied, defectors prefer to break all their ties with contributors. As this happens, building one new tie to another defector has exactly the same marginal benefit as building multiple connections. This marginal benefit is greater than zero when mass conformity is larger than the cost of tie formation ($b_1 > f$). When this condition is satisfied, defectors are motivated to establish relations to every defector. The situation is similar for contributors, except that they are less motivated to abandon relations to defectors because of selective incentives, but once segregated, they are more motivated to form new ties to other contributors ($s+b_1>f$ should hold).

Conditions (*18*) and (*20*) are sufficient conditions for structural change, but they are not necessary conditions. There might be individuals (in this case, defectors) who do not benefit from abandoning relations and do not benefit from building new ties, but they benefit from the *combination* of the two. Consider, for instance, a defector who has a single tie to a contributor. This defector has no incentive to break this relation when $a>0$. He or she has no incentive to be tied with other defectors when $f>b_1+0.5b_2$. Replacing the existing tie with a connection to a contributor, however, is beneficial for this individual in case $b_1+b_2>f+a$. This is not at all unlikely when the cost of abandoning a relation is small.

In general, a defector $i\in\mathbf{D}$ is better off by a structural change in which he or she abandons x ties to contributors and newly forms y ties to defectors, when

$$yb_1+b_2\frac{yr_{ic}+xr_{id}}{r_i\left(r_i-x+y\right)}>xa+yf \tag{22}$$

holds. From (*22*) it can be seen that for a defector abandoning all relations with contributors is always more profitable than just breaking up some of them, even when considering the simultaneous possibility of tie formation. Hence, after substituting r_{ic} for x, the necessary conditions of a beneficial structural change for $i\in\mathbf{D}$ are given as

$$b_2\frac{r_{ic}}{r_i}>r_{ic}a+y\left(f-b_1\right). \tag{23}$$

Similarly, for a contributor $j\in\mathbf{C}$ a structural change in which he or she abandons x ties to defectors and newly forms y ties to contributors is beneficial, when

$$\left(y-x\right)s+yb_1+b_2\frac{yr_{jd}+xr_{jc}}{r_j\left(r_j-x+y\right)}>xa+yf \tag{24}$$

holds. From (*24*) it can be seen that for a contributor forming the first new relation with another contributor is always at least as profitable as further ones, even when considering the simultaneous possibility of abandoning ties. Hence, after substituting *1* for y, the necessary conditions of a beneficial structural change for $j\in\mathbf{C}$ are given as

$$b_1+b_2\frac{r_{jd}+xr_{jc}}{r_j\left(r_j-x+1\right)}>xa+f+\left(x-1\right)s. \tag{25}$$

After looking at individual benefits and costs of abandoning and forming ties, we would like to say more about the conditions of the stability of the entire network. In this perspective, we have to extend the concept of network stability. We call a social network (*strongly*) *stable* in a given strategy profile in the (collective action) game, if there is no $i \in N$, for whom any change in his or her relations (in his or her ego-network) would result in a better outcome in the game. By “any change” we mean any combination of abandoning existing and of forming new relations.

If there are no costs of abandoning and forming ties, only a perfect segregation of contributors and defectors with fully connected networks within the subsets **C** and **D** is a (strongly) stable network. This is not a case, however, if there are costs of abandoning and forming ties. For these cases, in which unsegregated networks can also be (strongly) stable, there should not be any $i \in \mathbf{D}$ for whom equation (*23*) is satisfied with any values of y and there should not be any $j \in \mathbf{C}$ for whom equation (*25*) holds with any values of x. This is most likely at high costs a and f, and with larger ego-network sizes.

6. Stable network equilibrium

In the previous section we relaxed the traditional assumption of models of collective action that the social network is given and individuals cannot change their relations among each other. The analysis we provided is in particular suitable for situations in which social control mechanisms are *delayed* compared to participation decisions in collective action. There are situations, however, when structural changes and behavior in the collective action game are simultaneous. Furthermore, even when this is not the case, structural changes can be anticipated by the actors at the time of their participation decision in collective action. Under such circumstances, these actions are part of the same strategy, structural decisions and equilibria should be considered together with individual decisions and equilibria in collective action. For example, workers who think of participation in a wild cat strike may take account of the risk of loosing friends and the opportunity of finding new ones. Let us consider a worker, who works in a peripheral unit in which the majority does not prefer to join the strike of the major workshop. If this worker has some friends in the major workshop, then she or he has to decide about participation but also about the community she or he wants to be embedded in at the same time.

In this perspective, we can formulate an equilibrium refinement that embraces the concepts of network stability and Nash equilibrium in the context of games played in social networks. This concept does not only help equilibrium selection in the case of multiple equilibria, but also fits more to the study of games that are played in social networks. The equilibrium defined below integrates the main ideas that have been put forward in this paper. Moreover, it also provides directions for future research.

We define a *stable network equilibrium* as a network of social relations and a strategy profile in the (collective action) game, in which there is no $i \in N$, for whom any combination of changes in his or her action and in his or her ego-network would result in a better outcome.

It is clear that only a Nash equilibrium strategy profile and only (strongly) stable networks can be in stable network equilibrium. Strong network stability and Nash equilibrium in the collective action game, however, are necessary but not sufficient conditions for stable network equilibrium. Consider for instance, the case of a fully segregated stable network in partial contribution equilibrium. Contributors are connected to every other contributor and defectors are connected to every other defector. In this situation, nobody has an incentive to abandon relations, to form new ties, or to change his or her strategy in the collective action game. Restructuring relations *and* changing the action in collective action, however, can be beneficial for some players. When forming new ties and abandoning existing relations are free, there would *always* be players for whom such changes are beneficial. This has the consequence that *only full contribution and full defection with complete networks can be stable network equilibria* (assuming positive selective incentives or positive behavioral confirmation and no costs for structural change).

For the proof of this statement, we demonstrate that in partial contribution equilibria, either contributors or defectors would have the incentive to abandon all their existing ties, form new ties with every member of the other camp and change their action in the collective action game. Contributors are better off by remaining in the fully connected camp of contributors if

$$\alpha + (n_c - 1)s + (n_c - n_d - 1)b_1 \geq c. \tag{26}$$

On the other hand, defectors have no incentive to become “integrated” contributors, if

$$\alpha + n_c s + (n_c - n_d + 1)b_1 \leq c. \tag{27}$$

Equations (26) and (27) cannot be simultaneously satisfied when selective incentives or mass conformity are positive, which completes the proof.

7. Discussion

This study investigated the effects of social control and network structure on the emergence of collective action in *n*-person communities. Unlike most previous studies, we analyzed network effects in single encounters, and highlighted interactions between social control and structural characteristics. Furthermore, we examined a feedback mechanism, namely the impact of the prospect of collective action and of social control on the formation of network structure. The examination of reverse effects has been carried out in the context of one-shot interactions.

For these objectives, this paper proposed a new, integrated framework of analysis. For modeling collective action problems, this framework combined the analysis of *n*-person public good games and local interaction games. In our model, structural embeddedness was incorporated in the standard *n*-person public goods game through different social control mechanisms that are transmitted by interpersonal relationships. Relationships and individuals were considered anonymous, there were no leaders, privileged actors, or binding coalitions. Social control mechanisms, namely selective incentives and forms of behavioral confirmation were modeled as rewards that influence individual decisions through actors' relationships to relevant others. As a consequence of social control, macro properties of the network of individual relations are associated with the emergence of collective action. In this paper, while analyzing individual motivations, we could point to some important macro conditions for the emergence of collective action. We investigated one-shot interactions with perfect and complete information and carried out standard equilibrium analyses.

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 showed that the pressure operating in overlapping dyads could create a basis for contribution, even when individuals are ready to exploit most of their fellows in the group. That is, social control might work effectively even in a situation in which not every individual knows and influences each other (cf. Sandell and Stern, 1998). We also emphasized that it is not always necessary to provide selective incentives for cooperation. Public good provision might be possible even in a large group where members conform their behavior to a little subgroup of their friends (cf. Gould, 1993; Kim and Bearman, 1997). On the other hand, the analysis stressed that under certain circumstances, stronger social control may inhibit overall contribution. Not only behavioral confirmation, 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 controversial 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 show that the minimum degree of the network and fragmentation are more directly related to contribution than density itself. Density increases the chance of full contribution mainly because it is correlated with these measures. The model also shows that the impact of minimum degree is correlated with the strength of selective incentives, while the lack of segregation can foster collective action if behavioral confirmation plays a significant role in players' decisions. We also showed that segregation in a community might inhibit full contribution even when social control is relatively strong.

We introduced a new concept of *network stability*, and demonstrated that if abandoning relations is possible, contributors and defectors might become segregated in the network. Hence, segregation itself can be the result of the collective action problem and effective social control. In a segregated structure, partial contribution is protected by the lack of ties between the subgroups. This is yet another mechanism that shows controversial effects of social control. Moreover, the model shows that denser networks can be more stable even if they are less segregated. Furthermore, individual level analysis of the possibility of building new ties demonstrated that from a partial contribution equilibrium those contributors can improve on their situation who have only few connections and relatively many of them leads to defectors, meanwhile those defectors are keen to build new ties who have few ties and relatively many goes to contributors among them. For a synthesis of analyses, we also introduced a new equilibrium concept that combines stability of actions and network stability in structurally embedded situations. Our aim was to provide a foundation for subsequent research that recognizes the interrelation of collective action and network structure.

The presented framework also has its limitations. Some of the shortcomings are due to restricted place. 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 assumption we could relax is the binary character of 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. In such a framework, ties are not abandoned or built, but weights are reconsidered. This model extension would also allow to consider asymmetric ties (for a similar dynamic analysis see Kitts, Macy, and Flache, 1999).

We adopted a model of forward-looking, strategically rational individuals. This could be regarded as a serious shortcoming, although we are convinced that there are well-founded theoretical reasons for taking this type of actor-model as given.[5] The presented equilibrium analysis also presumes perfect information of the 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 sophisticated 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).

Simplifications and shortcomings of the model also indicate directions for future research. A further step would be a more detailed analysis of the interdependence of different network characteristics. Another direction of research leads towards the elaboration of the iterated structurally embedded public goods game. Moreover, model extensions might aim at incorporating the role of information flow or bounded rationality in the individual decision processes. A further major development would be a dynamic interrelated analysis of repeated collective action problems and structural dynamics. For the complexity of this problem, however, agent-based simulation techniques would be more appropriate than analytical methods.

[5] 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.

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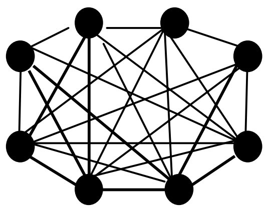
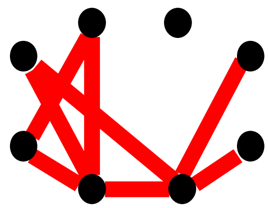
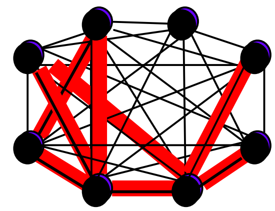
Figure 1: An Illustration of Our Approach

Global interdependence	Local interdependencies	Global and local interdependencies
n-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

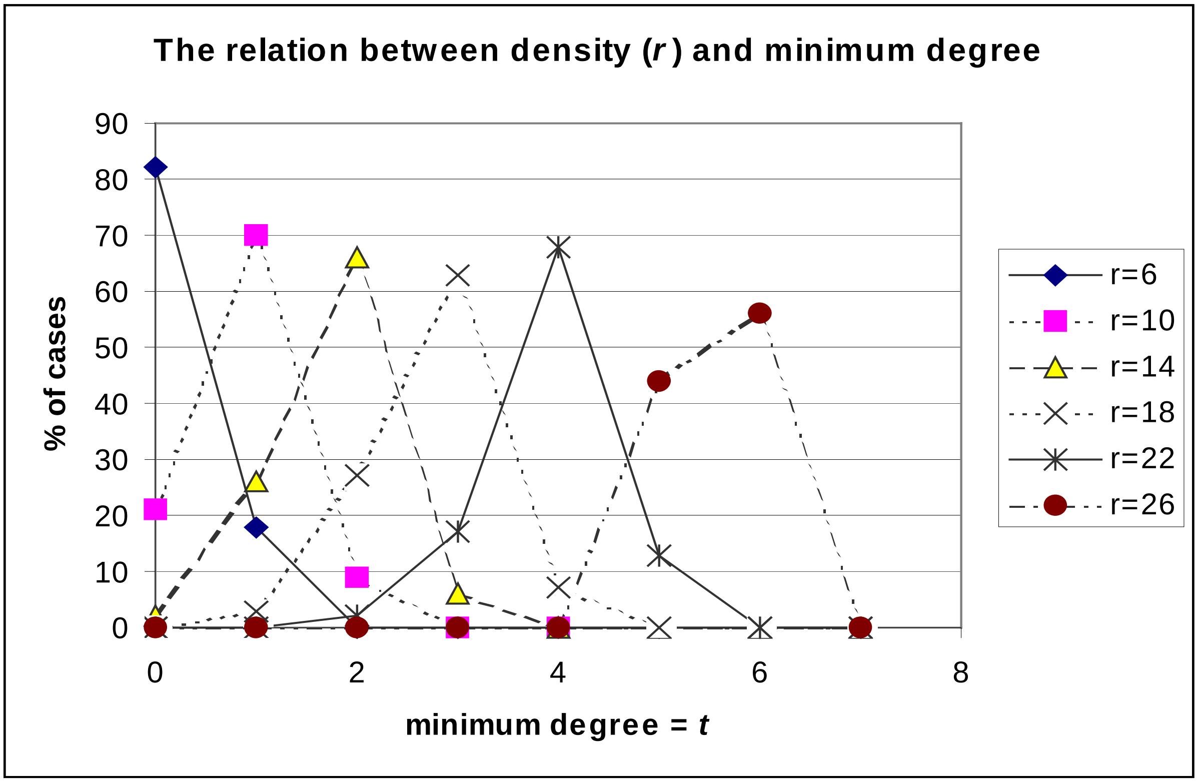


Figure 3 Illustration of a 5-person structurally embedded public goods game