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Coalition Formation and Voting in Public Goods Games*

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ABSTRACT

This study experimentally examines the voluntary formation of coalitions to provide a public good when the coalition members use different voting schemes to determine their commitment. To this end, unanimity, qualified majority voting, and simple majority voting are compared with respect to the resulting public good provision level and social welfare. At first sight, in line with theoretical predictions, the experiment shows that a change in the voting scheme implemented in a coalition does not significantly change the social welfare. However, changing the majority required to determine the coalition efforts alters the depth and breadth of cooperation; coalitions under the unanimity rule are relatively large and implement moderate effort levels while coalitions with majority voting implement high effort levels but attract only a few participants.

Keywords: Public goods; coalition formation; cooperation; voting.

JEL Code: C92, D02, D71, H41.

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INTRODUCTION

Many situations require collective action in order to realize a gain or to avoid an undesirable event. Examples may include a group of strikers fighting for a company-wide wage increase and better working conditions, a group of companies funding a lobbyist who stands up for the whole branch, or a group of countries restricting their use of a global natural resource. Very important examples of collective action problems occur in the context of international environmental agreements (IEA), in which countries form a coalition to provide a public good while other countries freeride on the coalition's effort. Probably the most-discussed problem with the least progress made during the past two decades is the prevention of climate change. Countries are still debating how this quintessential global public good can be provided.

The provision of public goods has been the motivation for numerous experimental studies (Ledyard, 1995) that have contributed to our understanding of the inherent freeriding incentives and institutions designed to solve the problem, such as punishment (e.g., Fehr and Gächter, 2000). Most public goods experiments, however, examine individual contribution decisions and only a few consider collective action. This paper adds to the latter branch of literature and experimentally examines the formation of coalitions when the coalition members use different voting schemes to determine their commitment. It thereby tries to contribute to our understanding of IEAs to provide global public goods.

IEAs have their origin in theories of cartel formation (Selten, 1973; d'Aspremont *et al.*, 1983). They are usually modeled as an n-country dilemma game with multiple stages. In the first stage, all the countries choose whether to join the coalition or not. In the second stage, the coalition members determine their contribution to the public good with the objective of maximizing their joint payoff. In the third stage, the non-members choose their contribution levels independently with the goal of maximizing their individual payoff. If the underlying game involves dominant strategies the final two stages could also be turned into a single stage because the members cannot influence the behavior of the non-members by choosing a certain action. The essential feature of IEAs is that participation in an agreement is voluntary because sovereign countries cannot be forced to join a coalition. This feature is incorporated by the concept of internal and external stability. A coalition is internally stable if no member wants to leave and it is externally stable if no non-member wants to join.[1] The IEA literature (Barrett, 1994; Hoel, 1992; Carraro and Siniscalco, 1993) derives rather pessimistic predictions. If the difference in payoffs between the non-cooperative and the fully cooperative outcome is large only a few countries are predicted to form a stable coalition. Hence, a coalition may only marginally improve upon the non-cooperative outcome. Finus and Maus (2008) suggest that the public good provision and social welfare may increase if the coalition members

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[1] The IEA literature coined the term "self-enforcing IEA" for an internally and externally stable agreement. This notion, however, is somewhat misleading. While it captures the voluntary nature of individuals' decision to participate in an agreement, it does not capture the decision to comply with the terms of the agreement.

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do not maximize their joint payoff by fully internalizing their mutual benefits but only partially internalize the benefits. Lowering the effort level required from the members leads to greater participation, which compensates for the lower effort level so that social welfare increases in equilibrium.

Assuming either full or partial internalization of the mutual benefits, the theoretical literature has not paid a great deal of attention to the question of *how* coalition members determine their public good provision level. The experimental literature on coalition formation also rarely considers the negotiation process; most experiments involve some form of voting to determine whether a coalition is to be implemented, but do not allow coalition members to negotiate and to agree on a (possibly suboptimal) effort level.

Burger and Kolstad (2009) consider a 10-person linear public goods game with a binary choice where subjects must allocate either all or none of their endowment to the public good. They introduce a coalition formation mechanism whereby subjects start the game by electing either to join the coalition or not to join it. After being informed about the coalition size, all the coalition members vote to determine the joint action. If a majority vote to contribute the coalition's entire endowment is allocated to the public good; otherwise the endowment is allocated to private consumption. The coalition cannot subdivide its collective endowment. The experiment demonstrates that the possibility to form a coalition increases the overall provision of the public good. Contrary to the theory, the coalition size increases with a higher return on the public good.

Kosfeld *et al.* (2009) use a four-person linear public goods game with three stages. In the first stage, each player decides whether to participate in a costly organization or not. After being informed about the number of players willing to participate, each participant decides whether to implement the organization. Using a unanimity rule, the organization is only implemented if all the participants agree with the implementation. In the final stage, the members of the organization are bound to contribute their full endowment to the public good if the organization has been implemented before and they are free in their choice if the organization has not been implemented before. Non-members are free to choose the amount of their contributions independently from the implementation of the organization. An additional control treatment (presented in the web appendix) allows for non-compliance in the contribution stage; the members are free in their contribution decision, even if the organization has been implemented before, but face an effective punishment if they do not contribute everything to the public good. The experimental results show that the possibility to form a coalition enhances social welfare. However, players are unwilling to form coalitions that govern only a subset of players, even if these rejections are costly. Therefore, most of the implemented coalitions are grand coalitions.

McEvoy *et al.* (2010) consider a 10-person linear public goods game with a coalition formation mechanism whereby the members have the possibility to violate their contribution commitments. The control treatment with costless enforcement of the members' compliance involves only one stage in which each player decides whether to join a coalition or not. The members contribute one indivisible unit to the public good if the coalition size is equal to or greater than the theoretically stable size; otherwise, they do

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not contribute. The non-members do not contribute to the public good regardless of whether there is a coalition or not. Two stages are added to the treatments with costly enforcement of compliance. Provided that enough subjects have entered the coalition, the coalition members must decide whether to comply with the agreement, i.e., contribute to the public good, or not. Non-compliant members face a sanction (in expected values) in the final stage. Contrary to the theory, costly enforcement of compliance leads to lower public good provision than costless enforcement. The frequency of coalition formation and the overall provision of the public good, however, increase if all the subjects are required to join a coalition for it to form.

Differently from the previous experiments, Dannenberg *et al.* (2010) allow the coalition to determine its effort level endogenously. Using a 10-person public goods game with increasing marginal costs of contributing, they test three different coalition formation mechanisms. Two of them specify the coalition's effort level exogenously; after deciding whether or not to join the coalition in the first stage, the members are bound to contribute either the collectively optimal amount (Barrett, 1994) or a predefined suboptimal amount (Finus and Maus, 2008). The third mechanism includes three stages and allows the coalition members to determine their effort level endogenously; after the decision to participate in a coalition in the first stage, each member suggests a minimum contribution level in the second stage. The smallest proposal is then the binding minimum for all the members. The players choose their contributions in the final stage, during which the non-members are free to choose any level while the members must provide at least the binding minimum. The experimental results show that the coalition members under the smallest common denominator rule negotiate a contribution level below the collectively optimal level. However, as the rule can attract more participants, it increases the overall public good provision and welfare compared with the coalition formation games in which the effort level is exogenously determined.

The present study extends the latter experiment by analyzing the welfare effects if the coalition members apply majority voting to determine the minimum contribution level. To this end, qualified majority voting and simple majority voting are considered and the resulting public good provision levels are compared with those achieved by the smallest common denominator coalition (described above) in which the members apply a unanimity rule to determine their effort level. At first sight, in line with theoretical predictions, the experiment shows that the change in the voting scheme implemented in a coalition does not significantly change the social welfare. However, changing the majority required to determine the terms of the agreement alters the depth and breadth of cooperation; under the unanimity rule, coalitions are relatively large and implement moderate effort levels while coalitions with majority votes implement high effort levels but attract only a few participants.

While the experimental game is designed to incorporate key real-world issues, it is necessarily simplistic for the sake of control and tractability. In particular, the experimental subjects face exogenously specified voting schemes, whereas these institutions in real-world negotiations evolve endogenously. Furthermore, just like in most of the theoretical and experimental literature, the coalition members are assumed (and forced) to

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comply with the terms of the agreement.[2] While the former assumption can be expected to hamper cooperation, as endogenous institutional choice has been shown to enhance cooperation (Tyran and Feld, 2006; Sutter *et al.*, 2010), the latter is certainly an important precondition for cooperation. There are, however, arguments to justify this assumption. For example, the customary law may require the coalition members' full compliance and the enforcement of custom could be assumed to be solved outside the model in a kind of meta game (Barrett, 2003).

The paper is structured as follows: Theoretical Background; the Experimental Design; Results; and Conclusions.

THEORETICAL BACKGROUND

The game underlying the experiment is standard in the IEA literature (Barrett, 1994). An economy is considered with $i = 1, \ldots, n$ identical individuals who may contribute to the production of a public good. Each individual's contribution costs are assumed to depend only on his or her own contribution level, whereas the benefits are assumed to depend on the total provision of the public good. The payoff function for individual i is set by

$$\pi_i = b \sum_{j=1}^{n} q_j - cq_i^2/2, \tag{1}$$

where q_i is i's contribution to the public good with $q_i \in [0, q_i^{\max}]$, $b > 0$ denotes the constant marginal *per capita* return from contributing to the public good, and $c > 0$ represents the slope of the marginal contribution cost curve. The full cooperative public good contribution level that maximizes social welfare is given by

$$q_i^* = bn/c,$$

while the unique non-cooperative Nash equilibrium is given by

$$q_i^{NC} = b/c.$$

The Nash equilibrium involves dominant strategies such that each player's action does not depend on the contribution levels chosen by the remaining players. Throughout, interior solutions are assumed that require $q_i^{\max}$ to be sufficiently large. As the joint payoffs are maximized when all the players choose $q_i^* = bn/c$, the players generally have an incentive to form a cooperative agreement to provide the public good.

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[2] As mentioned before, some experimental studies (McEvoy *et al.*, 2010; Kosfeld *et al.*, 2009) allow for non-compliance in the contribution stage. However, they enforce the implementation of sanctions; thus, in a broader sense, they do assume compliance.

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Coalition Formation and Voting Rules

The formation of coalitions is a very complex process. The negotiation process involves multiple stages; it may be little structured *ex ante* and voting rules evolve endogenously with continuous updating of targets and expectations (Barrett, 2003). The modeling of coalition formation in this setting is necessarily much simpler. It involves three stages: in the first stage ("participation stage"), each player chooses whether to join the coalition or not. Let k be the number of members with $1 \leq k \leq n$. In the second stage ("voting stage"), the coalition members negotiate a minimum public good contribution for all the members. The negotiations proceed in such a way that all the members vote anonymously on the minimum contribution levels, starting from the level that maximizes the joint payoffs, $q_i^{\min} = bk/c$, and decreasing until the required majority of members agrees on a certain contribution level. Three different voting rules are considered: unanimity, qualified majority, and simple majority. The minimum level $q^{\min}$ is then the binding minimum contribution level for all the members. In the third stage ("contribution stage"), all the players determine their contributions to the public good. The non-members are free to choose any contribution level while the members have to contribute at least the binding minimum, i.e., $q_i \geq q^{\min}$.

In a subgame perfect equilibrium, players choose their actions in each stage by rationally anticipating the outcome of future stages and applying backward induction. Therefore, consider the final stage, the contribution stage, first. Non-members' payoff-maximizing decision does not depend on the coalition's effort and is given by $q_i^{NC} = b/c$. In contrast, members' payoff-maximizing contribution level in this last stage is given by $q_i = \max[q^{\min}, b/c]$. That is, members provide exactly the binding minimum as long as $q^{\min} \geq b/c$ is valid. These considerations have implications for the intermediate voting stage. Knowing that all the members will provide the minimum amount, it is weakly dominant for members to suggest the collectively optimal amount of $q_i^{\min} = bk/c$ in the voting stage. There are many other equilibria in weakly dominated strategies. In the case of unanimity, any binding minimum $q^{\min} < bk/c$ is established as the equilibrium if at least two players suggest this level while all the other players suggest a larger minimum. In the case of majority voting, any binding minimum level $q^{\min}$ can be established as a weakly dominated equilibrium as long as enough players suggest that level. For convenience, all weakly dominated strategies shall be eliminated in the voting stage, which leaves a vote of $q_i^{\min} = bk/c$ for all the members. Finally consider the first stage, the participation stage. Let us denote coalition members' payoff by $\prod^{M}(k)$ and non-members' payoff by $\prod^{NM}(k)$ at a given coalition size k. A coalition is said to be internally stable if no member has an incentive to leave unilaterally, i.e., if

$$\prod^{M}(k) \geq \prod^{NM}(k-1).$$

A coalition is said to be externally stable if no non-member has an incentive to join unilaterally, i.e., if

$$\prod^{NM}(k) > \prod^{M}(k+1).$$

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Plugging in the payoff function (1) gives

$$k \leq 3 \quad \text{and} \quad k + 1 > 3.$$

That is, if we assume that players join the coalition if they are indifferent between being a member or being a non-member the game has a unique subgame perfect equilibrium for all the voting schemes; the coalition will consist of $k^* = 3$ players (provided $n \geq 3$) who maximize their joint payoff while $n - 3$ players stay outside the coalition and maximize their individual payoff (cf. Barrett (1994)). The intuition behind this is not too difficult. The members of a coalition commit to joint-payoff maximization as long as each of them is at least as well off with all the members cooperating as they would be if no player cooperated. That is, a coalition must be profitable for its members. Members earn strictly more by leaving the coalition than by staying if $k > 3$ so such a coalition is not internally stable. In contrast, a coalition with $k = 3$ members is internally stable because the members cannot achieve more by leaving. The coalition with $k = 3$ members is also externally stable because non-members are better off staying outside than joining. Thus, although each player has an individual incentive to freeride and is better off if *other* players participate in the coalition, the coalition is still formed in equilibrium because the members receive a higher payoff than without the coalition.

EXPERIMENTAL DESIGN

The experiment was designed to investigate the effects of different voting schemes on the voluntary formation of coalitions. All the treatments involved a 10-person public goods game and the payoff function for each player was given by $\pi_i = b \sum_{j=1}^{n} q_j - cq_i^2/2$ with $b = 10$, $c = 2$, $n = 10$, and $q_i \in [0, \ldots, 100]$.

The traditional voluntary contribution mechanism (VCM) served as a control treatment that only contained a contribution stage in which the players simultaneously and independently chose their contribution to the public good. The three coalition treatments involved three stages each. In the first stage, the participation stage, the subjects decided whether to participate in a coalition. The subjects' decision to become a member or remain a non-member was made simultaneously and independently. In the second stage, after being told the coalition size, all the members negotiated the minimum amount that each member should contribute (voting stage). The negotiations took the form that all the participants simultaneously and independently proposed a minimum contribution between 0 and 100.

In the treatment called *COALmin* the smallest proposed amount became the binding lower limit for the members' contributions.[3] In the treatment *COALqual_maj*, the amount proposed on which three-quarters of the members could agree by suggesting this or a higher contribution level became the binding minimum. In the treatment called *COALsimple_maj*, the amount proposed on which the simple majority of members

[3] The treatments *VCM* and *COALmin* are also used in Dannenberg *et al.* (2010).

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Table 1. Summary of experimental design.

Treatment	Stages	n	b	c	No. of subjects
VCM	Contribution	10	10	2	100
COALmin	Participation voting contribution	10	10	2	100
COALqual_maj	Participation voting contribution	10	10	2	100
COALsimple_maj	Participation voting contribution	10	10	2	100

could agree by suggesting this or a higher amount became the binding minimum. In all three coalition treatments, the members were informed about all the proposed minimum amounts (arranged in descending order) and the binding minimum. The non-members did not make any decisions at this stage and were only informed about the coalition size. In the third stage, the contribution stage, the members and non-members chose their contributions to the public good. While the non-members could freely choose their contribution level, the members were bound to provide at least the binding minimum. At the end of the game, the participants were informed about the average contributions provided by the members and non-members and their own payoff.

Table 1 summarizes the key features of the experimental design and the number of subjects in each treatment. The experimental sessions were held in a computer lab at the University of Magdeburg, Germany, using undergraduate and graduate students recruited from the general student population (recruiting software Orsee, Greiner, 2004). In total, 400 students participated in the experiment, 100 of whom took part in each treatment. In each session, 20 subjects were seated randomly at linked computers (game software Ztree, Fischbacher, 2007) and paid € 1.00 as a show-up fee. A set of written instructions and a record sheet were handed out. The experimental instructions included several numerical examples and control questions. The instructions involved a neutral frame for the context and language of the experiment in order to avoid any potential biases the subjects may have regarding certain frames (see the appendix for the instructions). The questions tested the subjects' understanding of the payoff function given in (1) to ensure that they were aware of the payoff-maximizing strategy and the dilemma situation. After reading the instructions and answering the control questions correctly, the subjects began the game. At the beginning, the 20 subjects were randomly assigned to one of two 10-person groups. The subjects did not know their fellows' identities but they knew that they remained within the same group of players throughout the game (partner matching). All the decisions were made under completely anonymous conditions. Five 12-round sessions with two groups per session were conducted for each treatment with the first two rounds being practice rounds. This resulted in 100 group-level observations (10 groups and 10 non-practice rounds) and 1000 individual-level observations per treatment. During the game, earnings were presented in experimental dollars and 100 experimental dollars converted to 1 euro. At the end of the experiment, one of the non-practice rounds was randomly selected for the determination of payments.

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The sessions lasted for about 60–90 min and the subjects earned on average € 11.60 in the games. The earnings were paid in cash.[4]

EXPERIMENTAL RESULTS

The results section proceeds according to the stages of the game. It is first analyzed whether coalitions are actually formed and how many subjects participate under the different voting rules. The individual minimum proposals, the binding minimum implemented in the coalitions, and the contributions chosen by the members and non-members are then studied. Finally, the overall impact of coalition formation and voting on public good provision and welfare is presented by comparing the average contribution and payoff levels in the coalition games and the VCM.

Participation in the Coalitions

In line with previous coalition formation experiments, the first result shows that players almost always implement a coalition. Under the unanimity rule there are always at least two players who form a coalition. Under the qualified majority rule and the simple majority rule, at least two players form a coalition in 90% and 89% of the cases, respectively. Previous experiments have shown that the grand coalition is particularly compelling as it eliminates the possibility to freeride on the coalition's effort. In McEvoy *et al.*'s (2010) experiment, coalitions are more likely to form when they require full participation instead of the minimum profitable size. The experiment conducted by Kosfeld *et al.* (2009) shows that subjects are reluctant to implement coalitions in which a subset of players has the opportunity to freeride. The authors demonstrate that the inequity aversion of at least some players may explain this behavior. It seems, however, that these subjects need a mechanism that disallows the formation of smaller coalitions directly or gives subjects the power to reject them, in order to discipline potential freeriders effectively. The present study does not offer such a mechanism. The coalition members may boycott the coalition by suggesting a low minimum contribution but they cannot prevent the coalition from forming. Perhaps for this reason large coalitions are rarely implemented: 81% of the coalitions in *COALmin*, 93% of the coalitions in *COALqual_maj*, and 98% of the coalitions in *COALsimple_maj* consist of 6 or fewer players. No group manages to implement the grand coalition consisting of all 10 players.

The left panel in Figure 1 shows the average coalition size across all the rounds for each coalition treatment. While in *COALmin* on average half of all the players form a coalition (5.07), the coalitions are significantly smaller in *COALqual_maj* (3.68) and *COALsimple_maj* (3.56) (Mann–Whitney test, $p < 0.05$ and $p < 0.01$, respectively).[5]

[4] Overall, 18 out of 400 subjects earned negative payoffs in the games. In these cases, the payoffs were cut off at zero and the subjects only received the show-up fee.

[5] The statistical tests are based on group averages as units of observation. All the reported tests are two-sided throughout the paper.

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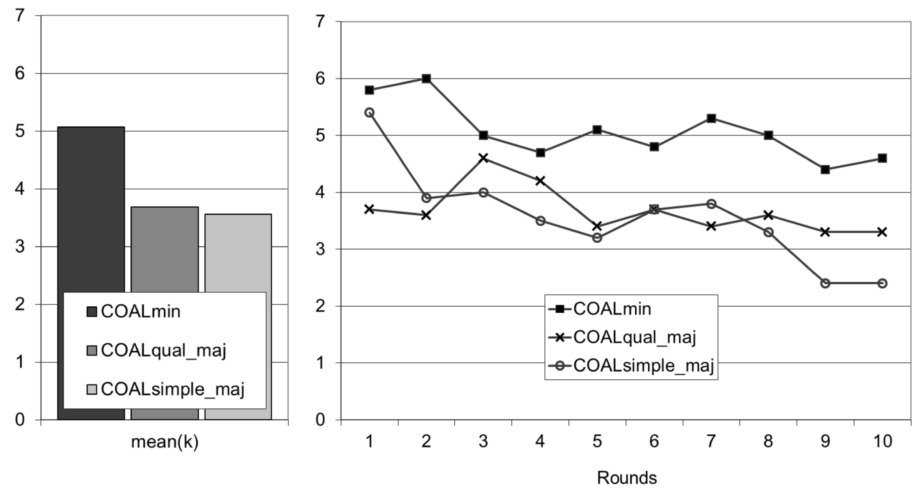

Figure 1. Average coalition size across rounds (left) and over time (right).

The right panel in Figure 1 shows the average coalition size over time. While the coalition size in *COALmin* and *COALqual_maj* is relatively stable at around 5 and 3–4, respectively, in *COALsimple_maj* it decreases over time from over 5 to fewer than 3. The Spearman rank correlation between the coalition size and the number of rounds is negative and highly significant in the latter treatment ($\rho = -0.40$, $p < 0.01$). It seems that some players are willing to join the coalition at the beginning but learn from experience during the course of the experiment. Table 2 presents the results of a probit estimation model of the individual decision to join the coalition. The players in *COALmin* are more likely to join than the players in *COALqual_maj* and *COALsimple_maj*. The results furthermore show that the players are more likely to join when they have already been a member in the previous round and they are less likely to join if the coalition has agreed on a high minimum contribution in the previous round.

Minimum Contribution Levels within the Coalitions

The next point of interest is the minimum effort level upon which a coalition can agree. The decision on the binding minimum level is particularly important since the subjects' contributions are highly sensitive to the binding minimum: 63% of the members' decisions on contributions are exactly at the minimum level and 81% are nearby, with the difference being 5 tokens or fewer. It is therefore evident that the binding minimum level has a large impact on the coalition's actual effort level.

Before turning to this, I will first report the individual minimum proposals as they are the determinant of the binding minimum. A sensible measure to assess the minimum proposals is the benefit internalization ratio, i.e., the ratio of the minimum proposal to the joint-payoff-maximizing level, $q_i^{\min}/(bk/c)$. The internalization ratios of the individual

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Table 2. Probit estimation of individual participation decision.

Variables	Rd. 1–10 ci
ci_lag	1.270***
	(0.0803)
k_lag	3.11e-05
	(0.0241)
COALqual_maj	−0.145*
	(0.0869)
COALsimple_maj	−0.197***
	(0.0602)
int_min_lag	−0.103***
	(0.0374)
outvoted_lag	−0.110
	(0.128)
round6_10	−0.0841
	(0.0521)
Constant	−0.545***
	(0.110)
Observations	2650
Clusters	30
Wald chi2	384.17***

Note: Robust standard errors in parentheses (clustered at group level), significance ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.
Definition of variables: ci = 1 if subject is coalition member, 0 otherwise; ci_lag = 1 if subject was coalition member in the previous round, 0 otherwise; k_lag = coalition size in the previous round; *COALqual_maj* = 1 if subject plays in the *COALqual_maj* treatment, 0 otherwise; *COALsimple_maj* = 1 if subject plays in the *COALsimple_maj* treatment, 0 otherwise; int_min_lag = previous round internalization ratio based on the binding minimum; outvoted_lag = 1 if subject's minimum proposal in previous round was below the binding minimum, 0 otherwise; round6_10 = 1 if last five rounds, 0 if first five rounds.

minimum proposals cover a wide range from 0% to over 200%. The individual minimum proposals do not significantly differ between voting schemes (Mann–Whitney test, $p > 0.10$). In all the coalition games, about a quarter of the subjects suggest a minimum below 100%, about 60% suggest a minimum between 100% and 200%, and the remaining subjects suggest more than 200%. Table 3 presents the results of a linear regression of the internalization ratio of the individual minimum proposals. The regression results confirm that the introduction of majority voting does not significantly affect

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Table 3. Linear regression of internalization ratios of individual minimum proposals.

Variables	Rd. 1–10 int_qimin
int_qimin_lag	0.402***
	(0.0651)
round6_10	0.0155
	(0.0603)
k	0.00554
	(0.0336)
COALqual_maj	0.0246
	(0.0953)
COALsimple_maj	0.0101
	(0.0914)
Constant	0.776**
	(0.282)
Observations	763
Clusters	30
R-squared	0.238***

Note: Robust standard errors in parentheses (clustered at group level), significance ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Definition of variables: int_qimin = internalization ratio of subject's minimum proposal; int_qimin_lag = internalization ratio of subject's previous round minimum proposal; round6_10 = 1 for the last five rounds, 0 for the first five rounds; k = coalition size; *COALqual_maj* = 1 if subject plays in the *COALqual_maj* treatment, 0 otherwise; *COALsimple_maj* = 1 if subject plays in the *COALsimple_maj* treatment, 0 otherwise.

the internalization ratio of the proposals. Thus, changing the required majority to determine the coalition's effort level does not change the individual minimum suggestions but merely the outcome of the negotiations. The regression results furthermore show that the internalization ratio of the proposal is not significantly affected by the coalition size and it is higher when the player has already made a high proposal in the previous round. These findings indicate that players have quite different views on what the coalition should do.

Drawing from the theory in Theoretical Background, the prediction for payoff-maximizing players is that they propose an internalization ratio of 100% when they have entered the coalition. Deviations from this prediction may be caused by other-regarding preferences. For example, a lower internalization ratio may be suggested by inequity-averse agents if they want to reduce unfavorable payoff differences for freeriders outside the coalition. A plausible explanation for suggesting a higher minimum may be that these

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players are trying to lead by example. By joining the coalition and suggesting a high effort level, they might be hoping that other players will follow and the group will coordinate on a high provision level over time.[6] The following sections will show, however, that leadership does not pay off. The *average* internalization ratio of the proposals decreases with larger coalitions. The Spearman rank correlation between the average internalization ratio and the number of rounds is negative and significant for all the coalition games (at least $p < 0.10$ each).

The internalization ratio of the *binding* minimum in the coalition is defined as the ratio of the binding minimum contribution to the joint-payoff-maximizing level, $q^{\min}/(bk/c)$. On average, this ratio is 62% in *COALmin*, 109% in *COALqual_maj*, and 147% in *COALsimple_maj*, as illustrated in Figure 2 (left panel). Thus, while the qualified majority rule leads to an average minimum level near the collectively optimal level, the unanimity rule produces a minimum *below* that level and the simple majority rule produces a minimum *above* that level. Figure 3 shows the average internalization ratio of the agreed minimum conditional on the coalition size (solid line). The internalization ratios are relatively stable for coalitions including 2–6 members and they tend to be lower for larger coalitions. Interestingly, while the theoretical model described in Theoretical Background clearly fails to predict the individual minimum proposals in the voting stage,

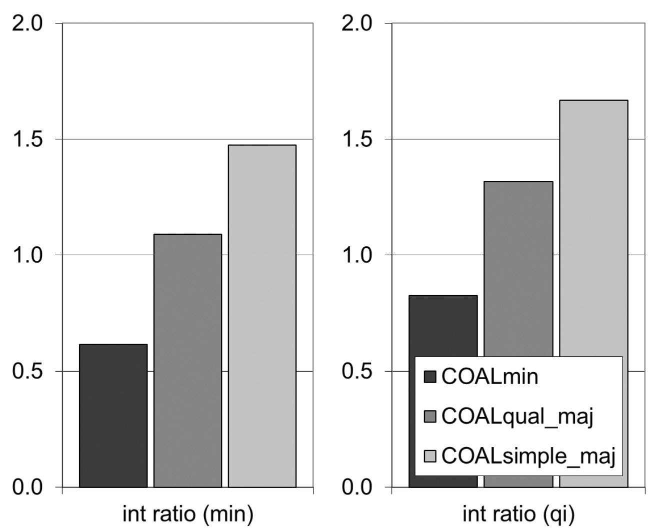

Figure 2. Average internalization ratio based on the agreed minimum contribution (left) and actual contributions (right).

[6] Contrary to theoretical predictions, leadership has been observed in several sequential public goods games (Gächter *et al.*, 2010; Güth *et al.*, 2007). Followers are found to respond positively to leadership but this reaction is often insufficient to compensate the leaders or to increase the overall efficiency substantially (Sturm and Weimann, 2008; Moxnes and van der Heijden, 2003).

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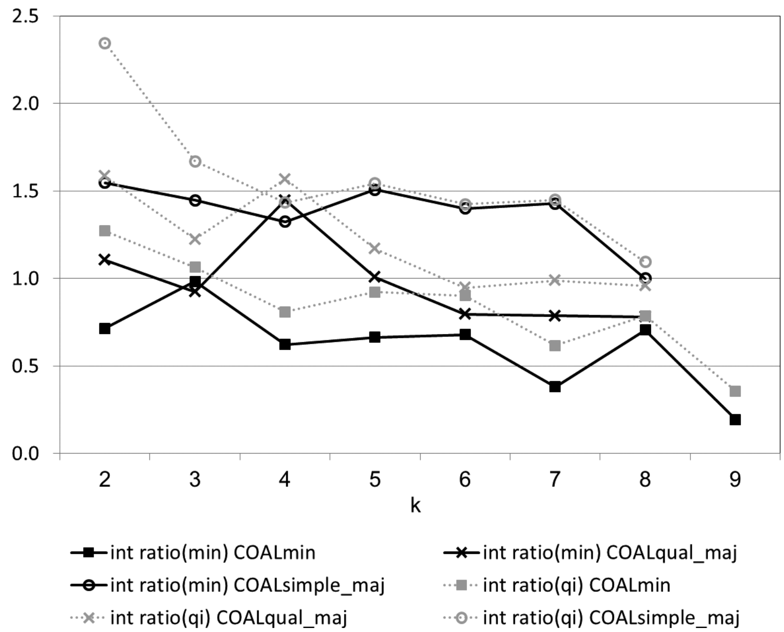

Figure 3. Average internalization ratio based on the agreed minimum (solid line) and actual contributions (dotted line) conditional on coalition size.

it serves as a good prediction in the participation stage; given joint-payoff maximization in the voting stage in *COALqual_maj*, the coalition size is not significantly different from the predicted $k = 3$ members (t-test, $p > 0.10$). Furthermore, the behavior observed in *COALmin* supports the suggestion of Finus and Maus (2008) that a lower effort level in the coalition can attract more members. According to their model, an internalization ratio of 62% would lead to a coalition consisting of $k = 5$ members, which is exactly what we observe (t-test, $p > 0.10$).

Contributions of Members and Non-members

The right panel in Figure 2 shows the internalization ratio based on the members' chosen contributions, $\sum_{i=S} q_i/(bk^2/c)$. With 83% in *COALmin*, 132% in *COALqual_maj*, and 167% in *COALsimple_maj* these ratios are higher than the ratios based on the agreed minimum because some members contribute more to the public good than the binding minimum. This is true even for the coalitions under the simple majority rule where the members have already negotiated a very high minimum level.

Figure 4 shows the average public good contributions of the coalition members and non-members. As expected, the non-members contribute clearly lower amounts than the members. Although the non-members in *COALqual_maj* and *COALsimple_maj* contribute slightly more to the public good than the non-members in *COALmin*, majority

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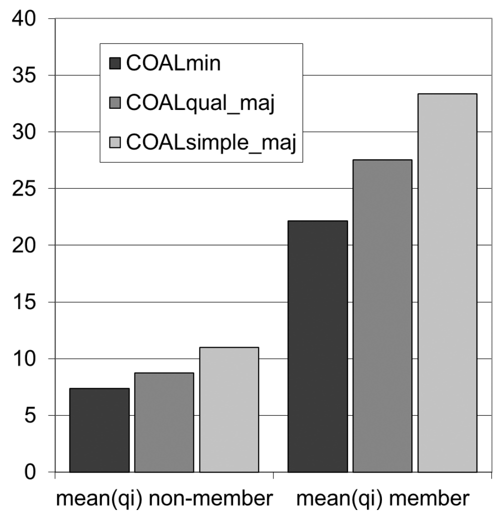

Figure 4. Average contribution levels among coalition members and non-members.

voting produces greater inequality between members and non-members. Under unanimity, the members' average payoff is 28% lower than that of non-members (889 *versus* 1.236); the inequality is thereby close to the predicted 26%. In contrast, under the simple majority rule members earn a payoff that is a remarkable 46% lower than the non-members' payoff (797 *versus* 1.478). Moreover, in the *COALsimple_maj* treatment, the members' payoff is significantly lower than the average payoff in the *VCM* treatment (Mann–Whitney test, $p < 0.05$). That is, on average, those who join the coalition under the simple majority rule are even worse off than those under unilateral decisions. This does not hold for members in *COALmin* and *COALqual_maj*. It is conceivable that the high inequality and the low payoff of the coalition members in *COALsimple_maj* might have a negative effect on the overall efficiency. The final result will therefore reveal the overall impact of the different voting schemes on the provision of the public good and welfare by comparing the average contribution and payoff levels in the coalition games and the VCM.

Overall Public Good Provision and Welfare

All the games perform better than predicted by theory, leading to higher average contribution and payoff levels (t-test, $p < 0.01$ each). The bird's-eye view of cooperation is provided in Table 4 and Figure 5, which present the average contribution and payoff levels across all the rounds for each treatment. The average contribution and payoff levels in the three coalition games exceed those in the standard voluntary contribution mechanism. A Mann–Whitney test shows that *VCM* gives lower contributions than *COALmin*, *COALqual_maj*, and *COALsimple_maj* ($p < 0.10, p < 0.10$, and $p < 0.01$,

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Table 4. Summary statistics of results.

Treatment	Total			First 5 rounds			Last 5 rounds		
	q	π	k	q	π	k	q	π	k
VCM	12.3	905.2		15.7	1098.4		8.9	711.9	
COALmin	14.8	1060.1	5.1	16.32	1160.1	5.3	13.4	960.1	4.8
COALqual_maj	15.7	1107.0	3.7	17.8	1200.6	3.9	13.6	1013.5	3.5
COALsimple_maj	18.9	1235.8	3.6	22.8	1430.4	4.0	15.1	1041.1	3.1

Note: $q =$ average contributions, $\pi =$ average payoffs, $k =$ average coalition size.

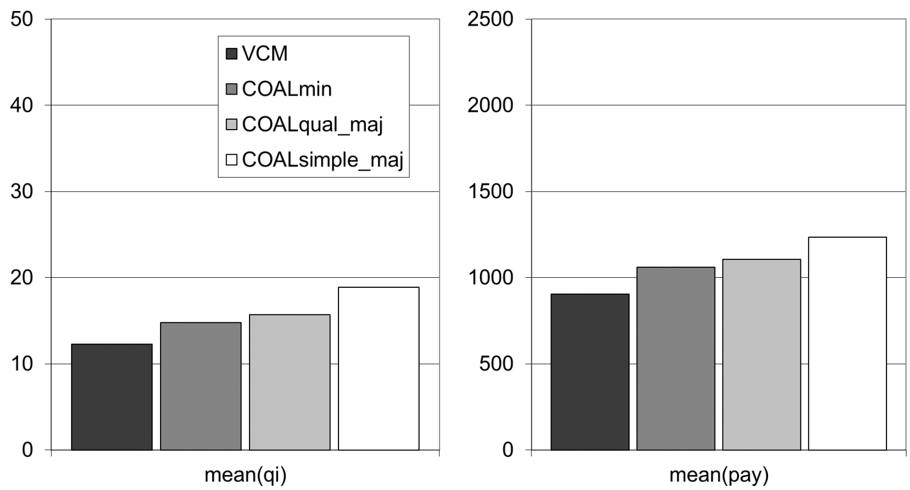

Figure 5. Average contribution and payoff levels.

respectively). Reducing the majority required to implement the minimum contribution level leads to small increases in the contribution and payoff levels. Testing among the coalition treatments shows that *COALsimple_maj* gives higher contributions than *COALmin* ($p < 0.10$). Identical comparisons follow for the average payoff levels.

Figure 6 shows the development of the average contributions for each treatment over time. The contributions in *VCM* decrease over time, which has also been observed in many other public good experiments (Ledyard, 1995; Fischbacher and Gächter, 2010). Though to a lesser extent, this downward trend is also observable for the three coalition games. Irrespective of the voting scheme, the possibility to form a coalition provides small benefits compared with the *VCM*. Comparing the average contributions and payoffs over the past five rounds shows that the differences between the *VCM* and the coalition games remain significant (Mann–Whitney test, $p < 0.01$ each), while there are no longer any significant differences among the coalition games. A series of linear regression models

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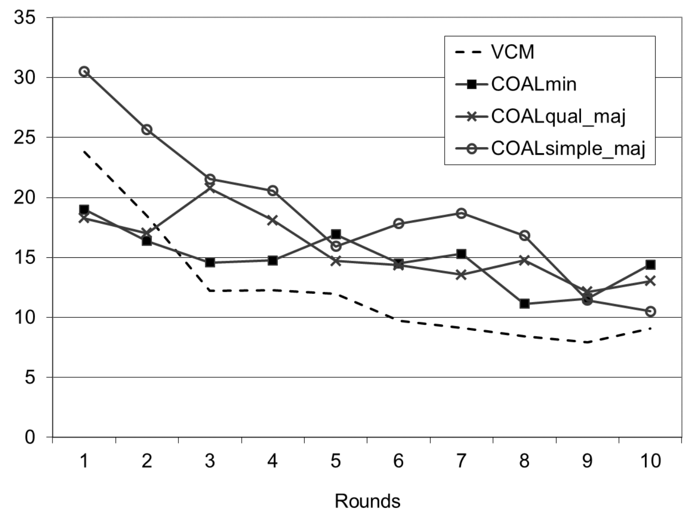

Figure 6. Average contribution levels over time.

Table 5. Linear regression of individual contributions.

Variables	Rd. 1–10 qi	Rd. 1–10 qi	Rd. 6–10 qi
COALmin	2.551**	2.551**	4.520***
	(1.012)	(1.012)	(1.372)
COALqual_maj	3.360**	3.360**	4.698***
	(1.687)	(1.687)	(1.467)
COALsimple_maj	6.644***	6.644***	6.194***
	(1.664)	(1.664)	(1.268)
round6_10		−5.451***	
		(0.807)	
Constant	12.30***	15.02***	8.858***
	(0.616)	(0.782)	(0.595)
Observations	4000	4000	2000
Clusters	40	40	40
Wald chi2	20.05***	58.56***	58.56***

Note: Random effects estimation, robust standard errors in parentheses (clustered at group level), significance *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Definition of variables: qi = subject's contribution; *COALmin* = 1 if subject plays in the *COALmin* treatment, 0 otherwise; *COALqual_maj* = 1 if subject plays in the *COALqual_maj* treatment, 0 otherwise; *COALsimple_maj* = 1 if subject plays in the *COALsimple_maj* treatment, 0 otherwise; round6_10 = 1 for the last five rounds, 0 for the first five rounds.

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Table 6. Linear regression of individual payoff levels.

Variables	Rd. 1–10 pay	Rd. 1–10 pay	Rd. 6–10 pay
COALmin	154.9***	154.9***	248.2***
	(58.95)	(58.96)	(82.22)
COALqual_maj	201.9**	201.9**	301.6***
	(94.02)	(94.03)	(90.03)
COALsimple_maj	330.6***	330.6***	329.2***
	(76.16)	(76.17)	(66.19)
round6_10		−290.7***	
		(41.57)	
Constant	905.2***	1.051***	711.9***
	(42.69)	(48.20)	(42.32)
Observations	4000	4000	2000
Clusters	40	40	40
Wald chi2	20.49***	63.05***	29.89***

Note: Random effects estimation, robust standard errors in parentheses (clustered at group level), significance ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.
Definition of variables: pay = subject's payoff; *COALmin* = 1 if subject plays in the *COALmin* treatment, 0 otherwise; *COALqual_maj* = 1 if subject plays in the *COALqual_maj* treatment, 0 otherwise; *COALsimple_maj* = 1 if subject plays in the *COALsimple_maj* treatment, 0 otherwise; round6_10 = 1 for the last five rounds, 0 for the first five rounds.

confirms that all three coalition games perform better than the *VCM*, leading to higher contributions and payoffs. The differences become more pronounced towards the end of the experiment (see Tables 5 and 6).

CONCLUSIONS

This study adds to the experimental literature on the voluntary formation of coalitions to provide public goods. The participants in the experiment have the possibility to form a cooperative coalition to provide the public good while non-members may freeride on the coalition's effort. The effectiveness of any such coalition crucially depends on its ability to attract members and to implement a sufficiently high effort level to provide the public good. The aim of this paper is to shed light on the negotiation process within the coalition that determines the effort level and, thereby, affects the incentives to join the coalition. Different voting schemes are implemented in the coalitions to determine their effort levels, namely unanimity, qualified majority voting, and simple majority voting. The resulting public good provision and payoff levels are compared with those achieved by the traditional *VCM*.

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The experimental results provide further evidence of the beneficial effects of coalition formation. All the coalition formation games outperform the traditional *VCM*, leading to higher public good provision and welfare. Theory suggests that the voting scheme does not matter for the outcome. As long as the coalition members choose the dominant strategy by maximizing the joint payoff, only a few players are expected to join the coalition. At first sight, in line with theoretical predictions, the experiment shows that a change in the voting scheme implemented in a coalition does not significantly change the public good provision level and welfare. However, changing the majority required to determine the terms of an agreement alters the depth and breadth of cooperation. Coalitions under the unanimity rule are relatively large and implement moderate effort levels, while coalitions with majority votes implement high effort levels but attract only a few participants.

Though the coalition members make similar minimum proposals under all the voting rules, the pivotal players, whose minimum proposals form the binding minimum, differ between voting schemes. While coalitions under the qualified majority rule implement a minimum contribution near the predicted joint-payoff-maximizing level, coalitions under simple majority implement a minimum above that level and coalitions under unanimity choose a minimum below that level. This lower effort required from the members under unanimity keeps the coalition relatively large with on average half of all the players being in the coalition throughout the game. The experimental results hereby confirm that the terms of institutionalizing the requirements from a coalition are crucial to the capacity to attract participants (Finus and Maus, 2008). Lowering the effort level within the coalition leads to a higher and more stable participation rate. It furthermore leads to less inequality, as the burden of the provision of the public good is shouldered by more users, which may enhance the long-term acceptance of the institution.

The theoretical coalition formation literature mostly assumes that agents are purely self-interested.[7] The experimental studies provide some insight into the consequences arising from real (and possibly other-regarding) preferences. As already pointed out in the introduction, the experimental literature in this field is in need of further development and therefore the picture is still incomplete. Promising areas for further research include, for instance, asymmetric actors, endogenous institution design, and non-compliance. The coalition formation experiments so far show that people in the lab do not always act in line with the theory. Similar to the standard public goods games, the institutions typically perform better in the lab than in theory. The present experiment on coalition formation indicates that subjects have quite different views on what the coalition should do. Pure self-interest cannot explain all the observed behavior; it rather seems that a significant share of people are willing to forego money in order to pursue a goal beyond own payoff maximization. However, for all that, the experimental subjects are far away from the social optimum. The grand coalition is never implemented, perhaps because the subjects lack the possibility to prevent the formation of smaller coalitions. Relative to the difference between the fully cooperative outcome and the non-cooperative outcome, the average efficiency gain in all the coalition games is 29–38%, which decreases to 17–24% in

[7] Exceptions are for instance Lange and Vogt (2003) and Lange (2006).

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the final round. The chief cause is the inevitable link between coalition performance and participation, as described above, which illustrates the importance of considering these two requirements jointly. In this respect, the experimental results support the view that under certain circumstances first-best solutions are not available, thereby bringing second-best solutions to the table that do not aim at coalition performance but rather try to transform the underlying game (Barrett, 2003).

APPENDIX

Experimental instructions for the *COALmin* treatment (translated from German)

INSTRUCTIONS

Welcome to the Magdeburg Experimental Laboratory MaXLab!

Please read these instructions carefully and should you have any questions please signal us by opening the door or a show of hands. In the laboratory experiment you are taking part in, you can win money depending on your decisions and the decisions of your fellow players. Your payout from the experiment will be calculated in LabDollars (LD). The conversion rate between € and LD is *1:100*, i.e., 100 LD are € 1. All your decisions made the experiment will remain *anonymous*. Only the experimenter will know your identity, but your data will be treated confidentially.

RULES OF THE GAME

Now you will learn more about the rules of the game you will be participating in. Altogether *10 players* take part in the game, so besides you there are 9 more players. Every participant faces the same decision making problem. Your task in the game, and also your fellow players' task, is to decide how many points (between 0 and 100) you would like to contribute to a *joint project*. Your *payout* will be calculated as follows:

$$\begin{aligned}\text{Your payout} &= -(\text{your contribution to the project})^2\\ &\quad + 10 \cdot (\text{sum of all contributions of all players to the project}).\end{aligned}$$

Example. If all other players have contributed an amount of 90 points to the project and you contribute an amount of 10 points, then your payout will be

$$-(10)^2 + 10 \cdot (10 + 90) = 900\,\text{LD}.$$

If, however, all other players contribute a total amount of 50 points and you do not contribute anything, your payout will be

$$-(0)^2 + 10 \cdot (0 + 50) = 500\,\text{LD}.$$

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To simplify the calculation of your payout, you will find an excel-file called "*Simulator*" on your screen. You can enter your contribution and the *average* contribution of all other players and so quickly determine your payout.

There are *two stages* in this game. In *stage 1* you can decide whether you want to become a member of a coalition, i.e., if you want to join a coalition or not. Should you decide that you want to join a coalition you additionally can decide which amount should be the *minimum amount* each member of the coalition should contribute to the project. Also all other members of the coalition can state their desired minimum amount. The members will be informed about the proposals for the minimum amount of all members. If you are member of a coalition, *stage 2* will be to decide for yourself which amount you want to contribute. In this decision the *smallest* minimum amount of all members will form your *lower* limit of contribution. If you have decided not to join a coalition, *stage 2* for you will be to state your contribution to the project without any limitation.

The game consists of *10 separate rounds* in each of which you will play the same two-stage game. The nine other players you will interact with will be the same in every round. If the experiment is complete you will receive the *payout of one of the rounds* in € (according to the conversion rate stated above). The round to be paid out will be determined *randomly*. This means you should behave in *each* round as if it were the round relevant for payout. In the beginning, *two trial rounds* will be played which are *not relevant for payout*. Independent of the course of the game you will receive € 1 for your participation.

CONTROL QUESTIONS

If you have read the instructions and do not have any questions, please answer the following control questions (hint: use the simulator).

1. Please assume your contribution to the project is 10 points and the average contribution of all the other players is 15 points. How much LD will be your payout of this round?
   My payout is ___________
2. Please assume the average contribution of all other players is 5 points, which of the following amounts will result in the highest payout for you?
   O 5 points O 10 points O 20 points O 30 points
3. Please assume you want to maximize your payout, does it make sense to not contribute at all (meaning zero points) to the project?
   O yes O no
4. Please assume you and three other players have joined a coalition and all members have stated the following minimum contribution: 4, 88, 22, 56. In which range does your contribution to the project have to be?
   More than or equal ___________ and less than or equal ___________.
5. Is it possible that a member of a coalition has to contribute more than he proposed as his minimum contribution?
   O yes O no

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6. Please assume all players chose the same amount, which of the following contributions results in the highest payout for all players (please check the according box)?
   O 10 points O 30 points O 50 points O 70 points O 100 points

If you have answered all questions, please signal us. We will then check your answers. The game begins when all participants in the experiment have successfully completed the test.

Good luck in the experiment! The MaXLab-Team

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