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On the Formation of Coalitions to Provide Public Goods - Experimental Evidence from the Lab
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ABSTRACT

The provision of public goods often relies on voluntary contributions and cooperation. While most of the experimental literature focuses on individual contributions, many real-world problems involve the formation of institutions among subgroups (coalitions) of players. International agreements serve as one example. This paper experimentally tests theory on the formation of coalitions in different institutions and compares those to a voluntary contribution mechanism. The experiment confirms the rather pessimistic conclusions from the theory: only few players form a coalition when the institution prescribes the full internalization of mutual benefits of members. Contrary to theory, coalitions that try to reduce the free-riding incentives by requiring less provision from their members, do not attract additional members. Substantial efficiency gains occur, however, both along the extensive and intensive margin when coalition members can each suggest a minimum contribution level with the smallest common denominator being binding. The experiment thereby shows that the acceptance of institutions depends on how terms of coalitions are reached.

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1. Introduction

When countries got together in Copenhagen 2009 to negotiate a new climate agreement, diverging interest and strong free-riding incentives made it impossible to reach a meaningful way to address the challenge of providing the global public good greenhouse gas abatement. Countries struggled to debate the right way to move forward: to have negotiations involving all countries, to establish smaller clubs or coalitions that formulate their own agreements or just lower the requirements to achieve unanimous decisions.[1]

The problem of improving institutions to provide public goods is obviously more general. A large literature has evolved that considers donations and the private provision of public goods by individuals.[2] Common to this literature is the lack of enforcement mechanisms to internalize the external effects by public intervention. Instead agents (i.e. individuals or countries) have to voluntarily commit to contribute to the public good or to implement a specific institution. While most of the literature considers mechanisms that include *all* affected agents, many real-world examples hereby involve situations in which *subgroups* (coalitions) implement an institution to address the public good problem.

International agreements serve as one example: some countries may form a coalition to cooperate while others may free-ride on the coalition's efforts. Forming a coalition thereby involves (at least) two challenges: on the one hand, the institutional arrangements needs to attract members to the coalition (*extensive margin*). On the other hand, any given coalition should be able to internalize the mutual benefits among its members, i.e. increase the provision of the public good (*intensive margin*). In this paper, we compare the ability of different institutions to address these two issues. We thereby experimentally test theory on the formation of coalitions and compare the resulting provision level of the

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[1] The Economist.com commented: "Though there was a fair bit of mess involved, and their achievement was far from monumental, the leaders who turned up in Copenhagen seem to have made a difference by finding their way to a suboptimal deal rather than none at all." (from: "Copenhagen climate talks: Better than nothing", Economist.com, December 19th, http://www.economist.com/world/international/displaystory.cfm?story_id=15124802). Aldy and Stavins (2009) lay out different ways to implement future climate agreements.

[2] Following early work as summarized in Ledyard (1995), a large literature studies voluntary contributions to charities and explores mechanisms like rebates and matching (Eckel and Grossman, 2003), seed money (Andreoni 1998 and List and Lucking-Reiley 2002), auctions (Goeree et al. 2005) or raffles and lotteries (Morgan and Sefton 2000, Landry et al. 2006).

public good with those achieved by institutions that do not allow for the formation of subgroups, like a voluntary contribution mechanism.

Our experimental treatment is guided by a series of theoretical papers on coalition formation (Hoel 1992, Barrett 1994, Carraro and Siniscalco 1993) that were inspired by theories on cartel formation (d'Aspremont et al. 1983). These authors derive rather pessimistic predictions: as individual players (countries) have a strong incentive to free-ride on the provision of public goods by others, only a few countries are predicted to form a coalition. Consequently, no substantial efficiency gains compared to a voluntary contributions mechanism are predicted. Finus and Maus (2008) suggest that a coalition can attract more members by lowering the public good provision levels required from its members. That is, an institution that only partially internalizes the mutual benefits among its members, may be acceptable to more players and thereby generate efficiency gains. This leads to a trade-off between the extensive and intensive margin, i.e. between the number of players agreeing to the institution and the degree to which they internalize their benefits and provide the public good. We provide a first experimental test of this literature.

The extent to which different institutions are able to generate gains in the provision of the public good along the intensive and extensive margins has so far not received much attention in the experimental literature. McEvoy et al. (2008) experimentally evaluate the performance of coalitions in which members have the opportunity to violate their commitments and fund a third-party enforcer to maintain compliance. Contrary to theoretical predictions they find that member-financed enforcement decreases the average provision of the public good. Kosfeld et al. (2009) recently addressed the endogenous institution formation and show that agents are potentially able to voluntarily establish sanctioning institutions that improve the provision of the public goods, but are less likely to do so if subsets of players attempt to free-ride. Burger and Kolstad (2009) study the emergence of coalitions when agents have a discrete choice between contributing or not contributing to a public good and thereby cannot address the role of the intensive margin.

In our paper, we address the ability of three different institutions to attract members. They all involve an initial decision of players to join or abstain from the coalition. They differ in the way public good provision is required from members of the coalition: first, we consider a setting where coalition members are exogenously bound to fully internalize their mutual benefits. This treatment directly tests the coalition formation literature (e.g. Barrett 1994). Second, we consider if lowering the institutional requirements from coalition members, e.g. reducing the required public good provision level, can attract more members and thereby lead to efficiency gains (thereby testing Finus and Maus 2008). Third, we consider an institution in which members can each suggest a minimum public good provision level. The smallest suggested level is then binding for all members. This idea of players agreeing on the smallest common denominator closely follows many real world institutional arrangements. International agreements often codify uniform obligations among countries (Barrett 2003) and, since each participating country needs to sign and ratify the agreement, the player with the smallest proposal is pivotal. Any country can, however, voluntarily go beyond its obligations.

We compare these different institutions on coalition formation with institutions that involve all players: a voluntary contribution mechanism (VCM) and a mechanism in which *all* players are subject to the minimum proposal institution, i.e. participation is exogenous. Orzen (2008) studies the latter institution in a repeated four-person public good game and finds that it is very effective, often reaching full efficiency in the final period. All our treatments consider a payoff structure that is linear in the total public good provision, but non-linear in the individual contributions. This specification allows a direct test of the above mentioned coalition formation literature. At the individual level, it reflects increasing marginal provision costs to the public good which may arise from budget constraints, i.e. decreasing marginal utility from numeraire consumption.

Our experiment confirms the rather pessimistic conclusions from the coalition formation theory: only few players form a coalition and only minor efficiency gains relative to the VCM result when members are required to fully internalize their mutual benefits. Contrary to theory, coalitions that try to reduce the free-riding incentives by requiring less provision from their members, cannot attract additional members. That is, the predicted trade-off between intensive and extensive margin generally fails. However, substantial efficiency gains occur from larger coalition sizes when coalition members can each suggest a minimum contribution level with the smallest common denominator being binding. The experiment thereby shows that the way how terms of coalitions are reached matters for the acceptance of such institutions. That is, when agents have a possibility to influence the public good provisions requirements in a coalition, more agents are willing to enter the coalition. Our results are thereby in line with previous findings in the literature (e.g. Sutter et al. 2010, Tyran and Feld 2006) that show that endogenizing institutional features improves upon public good provision compared to exogenously implemented institutions.

However, not all players participate in the coalition. The coalition structure therefore suffers from manifesting inequality between insiders and outsiders and thereby lowers the willingness of coalition members to provide the public good. In contrast, the "smallest common denominator" structure frequently achieves close to efficient public good provision levels when it involves *all* players.

Our results have implications for public policy. Forming clubs or coalitions to provide public goods can be beneficial compared to just relying on voluntary contributions from everybody. However, the terms of institutionalizing the provision requirements from coalition or club members are crucial for the capacity to attract members: following an exogenous rule that specifies the required contribution levels from members (full or partial internalization of benefits) is less effective in inducing players to join the coalition than an institution that allows potential cooperators to endogenously determine the rules. If agents are only bound to the smallest common denominator, more players are willing to accept the coalition. While these institutions with partial coverage can thereby generate large efficiency gains, it appears worthwhile to explore an institutional setting in which *all* agents participate in making minimum proposals.[3]

This paper is structured as follows. Section 2 provides a short theory of coalition formation and public goods provision which generates the predictions for our experiment. We then report the experimental design in section 3, before we discuss our results in section 4. Section 5 finally concludes.

[3] The institution could formally be made incentive-compatible by requiring players to deposit a bond covering the level of their own minimum proposal. When the smallest common denominator is determined the difference between this bond and the binding minimum can be returned. Agents have an incentive to carry out their obligations in order to regain their deposit. For a possible implementation of such a deposit mechanism, see Gerber and Wichard (2009).

2. Theory and Predictions

We consider an economy that is populated by agents, $i = 1, ..., n$, with utility functions of the form

$$u_i = y_i + \gamma Q \quad (1)$$

where y_i is a numeraire, and $Q = \sum_{j=1}^{n} q_j$ represents the total provision level of the public good and γ denotes the (constant) marginal utility from the public good. Subjects can allocate their initial income w to personal consumption or public good provision q_i with the budget constraint given by

$$y_i + q_i^2 \leq w \quad (2)$$

The utility function given by (1) and (2) is standard in the coalition formation literature (Carraro and Siniscalco 1993, Barrett 1994).[4] We use this payoff structure to derive analytic predictions for our experiment. Throughout, we assume interior solutions which requires $w \geq n\gamma / 2$.

Voluntary contribution mechanism and social optimum

Individual utility maximization immediately yields the individual Nash provision level $q_i^{NE} = \gamma/2$ with the total contributions given by $Q^{NE} = n\gamma/2$. It should be noted that the Nash equilibrium involves dominant strategy such that each individual's actions do not depend on the provision levels chosen by the remaining players. The social optimum maximizes total payoff and is given by $q_i^{SO} = n\gamma/2$ and $Q^{SO} = n^2 \gamma/2$.

We now derive the equilibrium under the different coalition formation institutions. The standard coalition formation model (Carraro and Siniscalco 1993) involves two stages. In

[4] This specification deviates from a large part of the literature on voluntary public good provision which largely considers linear provision costs and implies a dominant strategy of giving zero in the Nash equilibrium such that any variance in the data could mistakenly be interpreted as altruism (Ledyard 1995). Differently, our non-linear structure generates positive Nash contributions.

the first stage, each subject decides about membership in the coalition. Let S be the set of players who are members of the coalition with k ($1 \le k \le n$) denoting its size. In the second stage, public good provision is chosen. Non-members are free to choose their public good provision level. Due to the assumed linearity of the public good, their payoff-maximizing decision does not depend on the coalition efforts and is again given by $q_i^{NC} = \gamma/2$. For the choice of public good provision by the members of the coalition, we compare different institutions.

Payoff maximizing coalition (COALfull)

If members of the coalition fully internalize their mutual benefits, the payoff-maximizing individual provision level given coalition size k is $q_i^C(k) = \gamma k/2$ for all members of the coalition.

Partial internalization of benefits inside the coalition (COALpartial)

We consider a setting where members of the coalition are not able to fully internalize their mutual benefits, but only internalize at a ratio of $\alpha \le 1$. That is, the provision level given coalition size k is $q_i^C(k, \alpha) = \alpha\gamma k/2$ for all members of the coalition. This institution has been suggested by Finus and Maus (2008).

Smallest common denominator inside the coalition (COALmin)

We finally consider an institution for negotiations inside the coalition where members of the coalition are requested to suggest a minimum public good provision level. After these minimum proposals $q_i^{\min}$ are received from all participating parties, the agreement will require all agents in the coalition to provide at least the smallest suggested level $\min_{j \in S} q_j^{\min}$. That is, agents are bound to provide $q_i \ge q^{\min} = \min_{j \in S} q_j^{\min}$. The individually payoff-maximizing provision level at this last stage is hence given by $q_i = \max\left[q^{\min}, \gamma/2\right]$. Note that this implies that it is weakly dominant to suggest a minimum provision level of $q_i^{\min} = k\gamma / 2$: this maximizes payoff if other players in the coalition suggest $q_j^{\min} \geq k\gamma / 2$, suggesting a smaller level would potentially lower the binding minimum and hence negatively affect all profits. However, there are other equilibria in weakly dominated strategies: any binding minimum $q^{\min} < k\gamma / 2$ is established as equilibrium if at least two players suggest that level while other players suggest a larger minimum.

This logic immediately implies that the minimum stage played for all players, i.e. in combination with a public good provision game, generates the efficient outcome in weakly dominant strategies. Thus, the following proposition holds:

Proposition 1

If all players are requested to suggest a minimum provision level and negotiations implement the smallest minimum level as a binding provision level, the social optimum is obtained in weakly dominant strategies.

In general, however, it is doubtful that all players participate in negotiations, we therefore compare the above institutions for negotiations with respect to the coalition size that they generate.

Membership game

All these institutions for deciding the provision level inside the coalition lead to specific incentives of agents to join the coalition. Consequently, different coalition sizes may result. Specifically, we can denote the total payoff to members of the coalition given a coalition size of k and institution I by $\Pi^C(k, I)$, the payoffs to non-members by $\Pi^{NC}(k, I)$. Using the terminology from cartel and coalition formation literature (d'Aspremont et al. 1983, Carraro and Siniscalco 1993, Barrett 1994), a coalition of size k is externally stable if no player outside the coalition has an incentive to join, i.e. if

$\Pi^{NC}(k,I) > \Pi^{C}(k+1,I)$.[5] The coalition is internally stable if no member has an incentive to leave, i.e. if $\Pi^{C}(k,I) \geq \Pi^{NC}(k-1,I)$.

For the institutions *COALfull* and *COALpartial* we can restate known results from the literature:

Proposition 2

A coalition that is internally and externally stable satisfies $k \leq \frac{2+\sqrt{3-2\alpha}}{\alpha}$ *but* $k+1 > \frac{2+\sqrt{3-2\alpha}}{\alpha}$.

The proof involves straightforward comparison of payoffs which follow from (1) and (2).

For the standard coalition game (*COALfull*) in which the coalition fully internalizes their mutual benefits ($\alpha = 1$), this implies that only 3 agents form the coalition ($k = 3$). Figure 1 shows how the predicted size of stable coalitions depends on α. The decreasing relation corresponds to a trade-off between intensive and extensive margins: For example, coalitions of $k = 6$ players could be stabilized for $\alpha = 0.5$ while only 3 players form a coalition when mutual benefits are fully internalized. The increased coalition size can thereby also generate efficiency gains, i.e. increases in total payoff to all agents and in the payoff to the average coalition member. The example of $k = 6$ and $\alpha = 0.5$ illustrates this result: compared to the $k = 3$ solution when $\alpha = 1$, the same total provision level results while the provision efforts are being distributed across more players. Due to the increasing marginal provision costs, gains in total payoffs result.

We now consider the institution in which members can make their minimum suggestion (*COALmin*). Since the weakly dominant strategy in the subgame following the membership decision involves full internalization of mutual benefits, the only subgame

[5] We assume that a player would join the coalition if he or she is indifferent as this increases payoffs to all other agents.

perfect equilibrium in weakly dominant strategies equals the $k = 3$ result in *COALfull*. However, it is not clear that agents choose the weakly dominant strategies in the minimum stage. Therefore, less than full internalization could result. As a result, different coalition sizes could be stabilized. For example, the grand coalition is stabilized when players choose the following subgame-perfect strategies: (i) all agents coordinate on the full internalization in the grand coalition, while (ii) in all smaller coalitions players suggest the minimum contribution at the Nash level ($q^{\min} = \gamma / 2$).[6]

Proposition 3

In the coalition game in which negotiating parties agree to implement provision obligations at the smallest minimum level suggested by a member of the coalition, the social optimum in a grand coalition (as well as any other coalition size) can be stabilized in a subgame perfect equilibrium. The only equilibrium in weakly dominant strategies corresponds to the standard coalition game in which three members fully internalize their mutual benefits.

3. Experimental Design

We designed an experiment to test the different institutions on coalition formation to provide public goods. The treatments involved different institutions to implement a ten-person public good game. The payoff function for each player was given by $\pi_i = -q_i^2 + \gamma Q = -q_i^2 + \gamma \sum_{j=1}^{n} q_j$ with $\gamma = 10$, $n = 10$ and $q_i \in [0,...,100]$ and was common knowledge.We begin with the traditional *VCM* as a control treatment. Three coalition formation treatments introduced a first "coalition stage" in which subjects needed to decide on participating in the institution. Decisions to join a coalition were made simultaneously and independently. Following this coalition stage, subjects played their contribution game. In treatment *COALfull*, the members' contributions to the public good were exogenously fixed at the level that internalized their respective mutual benefits

[6] Coalitions that do not include all players may complicate coordination. This could for example be caused by inequality concerns (e.g., Fehr and Schmidt 1999, Lange and Vogt 2003).

onto each other, while in treatment *COALpartial* they only internalized 50% of their mutual benefits, i.e. $\alpha = 0.5$. Non-members in both treatments were free to set their contributions at any level. Treatment *COALmin* introduced an intermediate stage: after being told the number of subjects in the coalition, all members of the coalition negotiate about the minimum contribution that each member should contribute to the public good (minimum stage). Negotiations take the form that all participants simultaneously and independently proposed a minimum amount between 0 and 100. The smallest proposed amount then became the binding lower limit for the contributions of all coalition members. Members were informed about *all* proposed minimum amounts (arranged in descending order). Non-members did not make any decision in this stage and were only informed about the coalition size. In the contribution stage, members and non-members chose the amount of their contributions to the public good. While non-members could freely choose their contributions, members' contributions were bound to provide at least the binding minimum. Finally, we implemented a treatment *VCMmin* in which *all* subjects took part in the negotiation about a minimum contribution. Players first simultaneously and independently proposed a minimum amount between 0 and 100. The smallest proposed amount then became the binding lower limit for the contributions of all players. Players were informed about all proposed minimum amounts (arranged in descending order). In the contribution stage, all players simultaneously and independently determined the amount of their contribution to the public good which had to be equal or greater than the binding minimum. Table 1 summarizes the key features of our experimental design and the number of participants in each session. The experiment was run in May and July 2009 at the MaxLab laboratory at the University of Magdeburg, Germany. In total, 500 students participated in the experiment, whereby 100 subjects took part in each treatment. No subject participated in more than one treatment. Sessions lasted between 60 and 90 minutes. For each session, we recruited 20 subjects. Each subject was seated at linked computer terminals that were used to transmit all decision and payoff information. We used z-tree (Fischbacher 2007) for programming. Once the individuals were seated and logged into the terminals, a set of instructions and a record sheet were handed out. Experimental instructions included several numerical examples and control questions in order to ensure that all subjects understood the games. The sessions each consisted of 12 rounds, the first two being practice. The subjects were instructed that the practice rounds would not affect earnings. At the beginning of the experiment subjects were randomly assigned to groups of ten. The subjects were not aware of whom they were grouped with, but they did know that they remained within the same group of players throughout the rounds (partner matching). At the end of the experiment, one of non-practice rounds was chosen at random as the round that would determine earnings with an exchange rate between Euro and token of 1:100. On average, a subject earned €10.68 in the games. Additionally, all subjects received €1.00 as show-up fee.[7]

4. Experimental Results

Our experimental design enables us to test our theoretical predictions regarding public good contribution levels across different institutions. We craft the results summary by both pooling the data across all periods and reporting treatment differences in the first five and last five periods. We later explore the effects of time on contribution schedules in more detail.

Table 2 provides mean contribution and payoff levels for each of our treatments and Figure 2 provide a graphical depiction of the data. The first panel presents the average contribution levels across treatments and the second reports the resulting payoff average levels. As can be seen from the table and figures, contribution levels in the standard coalition game *COALfull* do not exceed those in the *VCM* (12.1 vs. 12.3). Average contributions in the *COALpartial* treatment are smaller (8.5) such that the hypothesized efficiency gains did not materialize. Combining the coalition formation framework or the VCM with a minimum stage, however, increases average contributions (14.8 and 22.1).

These differences are confirmed by a series of Mann-Whitney tests with the average contribution by one group across all periods is taken as the unit of observation: *VCM* gives larger contributions than *COALpartial* (1% significance), less than the *COALmin* (10% significance), and less than *VCMmin* (10% significance). The standard coalition

[7] Overall, 9 out of 500 subjects earned negative payoffs in the games. In these cases, payoffs were cut off at zero and the subjects only received the show-up fee.

model *COALfull* performs worse than *COALmin* and *VCMmin* (5% and 10% significance, respectively). Identical comparisons follow for the average payoff, i.e. the efficiency level of the respective institutions (see also Table 2). We can therefore formulate the following result:

> *Result 1: Average contribution and payoff levels in coalition formation game do not exceed those in the voluntary contribution mechanism (VCM) if the coalition fully internalizes their mutual benefits. If the coalition partially internalizes the mutual benefits, average contributions and payoffs are even lower than those in the VCM. If negotiations among coalition members are facilitated through a smallest common denominator rule, average contributions to the public good increase. The smallest common denominator rule best facilitates public good provision when involving all agents.*

Further evidence for Result 1 can be found through a series of linear regression models as illustrated in Table 3. Averaged across all periods, the minimum institutions (*VCMmin* and *COALmin*) perform significantly better than the *VCM* (1% significance), while the partial internalization in the coalition formation structure leads to less contributions (1% significance).

Figure 3 indicates that the contributions in the *VCM* are decreasing over time, they are smaller in the last 5 periods than in the initial 5 periods (see also Table 2). This downward trend which has been observed in many other experimental settings primarily for linear public goods is, however, significantly less pronounced for all coalition structures. In *VCMmin*, contributions increase over time. This effect is due an increase in the proposed minimum contribution levels. As suggested by the theory, some (but not all) groups are able to coordinate on the optimal contribution level (see Figure 4).

Furthermore, when concentrating on the last 5 periods, the coalition structure *COALfull* performs better than the *VCM*. A Mann-Whitney test confirms that *COALfull* leads to larger contributions than *VCM* in the last 5 periods (10% significance). This suggests that predictions from the theory hold: the coalition formation structure which internalizes all the coalition members' benefits provides small benefits compared to the voluntary contribution mechanism. However, the partial internalization of benefits in *COALpartial* does not provide any positive effect. Exactly the same comparisons result for the payoff levels. These findings are confirmed by regression results depicted in Tables 3 and 4.

In the following, we will have a closer look at the cause of the differences. For this, we consider the number of agents who join the coalition. Figure 5 indicates the crucial differences. While the coalition in the standard coalition formation treatment (*COALfull*) include on average close to the predicted three members (3.50), this number is even slightly less in *COALpartial* (3.22). Formulating less strict provision levels in the coalition therefore does not reduce free-riding incentives in a way that more agents join. This result directly puts into question the empirical relevance of the theoretical result by Finus and Maus (2008). A reduced requirement along the intensive margin therefore does not trigger the predicted gains along the extensive margin. The average coalition size increases, however, when agents are allowed to make their own proposals for the minimum provision in the coalition: in *COALmin* we obtain an average coalition size of 5.07 which is significantly larger than the one for the other two treatments (Mann Whitney, 1% significance; further evidence in Table 5).

> *Result 2: The number of agents in the coalition is close to the theoretical prediction in the standard coalition formation game. An exogenous reduction in the provision levels required when joining the coalition does not enlarge the coalition. An institution in which coalition members can suggest their own minimum with the smallest suggested level being binding triggers the entry of more agents.*

Result 2 potentially provides an interesting feature of the acceptance of institutional requirements. In the *COALmin* treatment, agents can impact the coalitions' provision efforts *after* observing the number of coalition members, i.e. the number of potential cooperators. This implies that they are not bound to a specific provision level just by showing their intent to join the coalition.[8] As a consequence, the "costs" of joining are smaller such that we should expect more agents to join. Result 2 is consistent with recent

[8] For example, this can be relevant if players are inequality-averse and want to avoid large payoff inequalities between free-riders and coalition members (see e.g. Fehr and Schmidt 1999).

findings in the literature that endogenously determined institutions are better accepted than exogenous rules (Sutter et al. 2006, Tyran and Feld 2006). The important question is, however, what level such coalition can agree upon.

A sensible measure to assess the provision level in the coalition is the internalization ratio, i.e. the ratio of chosen provision effort of the coalition compared with the level that fully internalizes the mutual benefits of coalition members ($\sum_{i \in S} q_i / (k^2 \gamma / 2)$). On average the ratio is given by 83% for the *COALmin* treatment and thereby lies in between levels in *COALfull* and *COALpartial* as illustrated in Figure 6.[9] The internalization ratio does depend, however, on the size of the coalition. We depict this internalization ratio in Figure 7 for the different coalition sizes in *COALmin*. Figure 7 shows that the ratio based on the average suggested minimum, the binding minimum, as well as the eventually chosen level are decreasing in the coalition size k. This is confirmed by a linear regression model as reported in Table 6.

> *Result 3: When negotiations in the coalition are institutionalized by each coalition member making a minimum proposal with the smallest suggested level being binding, the extent to which mutual benefits are internalized is decreasing in the size of the coalition.*

Result 3 shows a trade-off between intensive and extensive margin for the endogenously formed coalition. We can furthermore compare the internalization ratio given by the binding minimum with the ratio needed to stabilize a given coalition size as derived in section 2 (dashed line in Figure 7, see also Figure 1). Interestingly and surprisingly, the binding minimum ratio (int_min) follows closely the levels that are necessary to stabilize coalitions of the respective size.

In particular, the internalization ratios for coalitions that comprise more than 3 players are smaller than 1 (t-test, 1% significance). That is, the coalitions do not fully internalize the benefits of their members. We can only speculate about the reasons: on the one hand, if agents are inequality-averse, they may want to avoid unfavorable payoff differences to free-riders and therefore suggest a lower minimum. On the other hand, it may be more

[9] Note that the internalization ratio is exogenously fixed at 1 in *COALfull* and 0.5 in *COALpartial*.

complicated for larger coalitions to coordinate onto the optimal provision level as they are more susceptible to single players suggesting a small binding minimum.[10]

Decision to enter the coalition

We now have a closer look at the determinants of individual decisions to enter a coalition. One of the most important theoretical results is that the incentives to leave the coalition are the larger, the larger the coalition size is. In Table 5 we show results from a probit estimation model which explains the decision to join the coalition by the individual's decision in the previous period as well as by the lagged coalition size. We see that the individual's decision is largely driven by his or her behavior in the previous period (1% significance). The likelihood of joining the coalition is not significantly influenced by the coalition size in the previous period. Additionally, players in the *COALmin* treatment are more likely to join the coalition (1% significance).

For players in *COALmin*, the internalization ratio based on the binding minimum is also decisive: the larger this internalization ratio in the past period, the smaller is the likelihood of an agent joining the coalition (5% significance).

> *Result 4: In COALmin, subjects are the less likely to join a coalition, the stricter the provision requirements, i.e. the larger the internalization ratio based on the binding minimum in the previous period.*

Decision on minimum levels

We have shown the benefits of institutions that allow agents to first submit a minimum suggestion, before the smallest one will be binding for all agents. In the *VCMmin* treatment this allows agents to step by step coordinate to larger provision levels of the public good. In the *COALmin* treatment this allows agents to condition the coalition efforts on the information on how many agents stay outside the coalition. The implied

[10] This is similar to the effects in *VCMmin* where only some groups are able to coordinate (see Figure 4) while others do not achieve larger provision levels as some players consistently make suboptimal minimum suggestions, i.e. do not play the weakly dominant strategy.

reduction in the "risk" of being exploited by free-riders when joining the coalition allows larger coalitions to build which generate larger provision levels of the public good.

A distinct prediction from the theory is that agents in both minimum treatments have a weakly dominant strategy to suggest the minimum which fully internalize the mutual benefits. We have already seen that this full internalization does not occur in our experimental results. We therefore finally address the question how agents' minimum suggestions evolve over time. Theory would predict that agents' minimum suggestions should move upward: those who propose a larger level than others have no effect on the binding level. By adjusting downwards, they only can bring down the binding minimum which would hurt their and other players' payoffs. Those who suggested the binding level would have incentives to increase their suggestion since this can only benefit them and others. To test these adjustments over time, we define a variable "change_qimin" which reflects the difference between a player's minimum suggestion in the current and in the previous period. Table 7 presents the results from a linear regression model. We regress the change in the suggested minimum on the individuals' minimum suggestion in the previous period, the previously binding minimum, and a dummy variably which takes the value one if and only if the agent was a pivotal player in the previous period, i.e. if his or her minimum suggestion was binding. For both treatments, agents adjust their proposals upwards (constant is positive, 1% significance). This adjustment is smaller for subjects who already have submitted larger proposals in the previous periods. In the *COALmin* treatment we see that in particular pivotal players adjust their proposal upwards.

> *Result 5: On average, subjects are adjusting the minimum proposals upwards over time.*

This effect is particularly important since agents' provision levels of the public good are (as predicted) highly sensitive to the required minimum. In fact, 40% of contribution decisions in *VCMmin* and 65% of decisions in *COALmin* are exactly at the binding minimum level. It is therefore evident that those players whose suggestion forms the binding minimum have a large effect on the total provision level of the public good.

5. Conclusions

Not just the failure of climate negotiations in Copenhagen has revealed that forming institutions to secure the provision of global public goods is a complicated endeavor. The success of an institution to overcome free-riding incentives depends on two interlinked challenges: on the one hand, the institutional arrangements need to attract signatories, i.e. coalition members (*extensive margin*). On the other hand, any given coalition should be able to internalize the mutual benefits from the public good among its members (*intensive margin*).

In this paper, we tested different institutions with respect to their ability to succeed along these two dimensions. Our experimental results show, one the one hand, that institutions that exogenously force members to fully internalize their mutual benefits generate a rather low participation rate, just as theoretically predicted. The resulting provision levels of the public good do hardly go beyond the ones achieved by a purely voluntary contribution mechanism. On the other hand, lowering the degree of internalization of benefits within the coalition does not attract more members and, accordingly, cannot generate efficiency gains.

We further showed that institutions that allow members to *endogenously* determine the terms of the agreement may attract more members. We thereby add to the recent literature on beneficial endogenous choices of rules in social dilemma situations (e.g. Sutter et al. 2010, Tyran and Feld 2006). In particular, we show the success of a very simple negotiation rule: each coalition member can suggest a provision level, knowing that the smallest suggested level is binding for all coalition members: this rule generates larger coalition sizes and average contributions. Efficiency gains therefore result along the extensive margin. This generates a clear tradeoff between extensive and intensive margin: the larger the (endogenously determined) requirements from coalition members were in the previous period, the less willing subjects are to enter the coalition, i.e. the negotiations.

The principle of the smallest common denominator reflects many real world institutional arrangements which often implement uniform obligations. Coordination on large provision levels, however, does not always happen and also requires time: the largest benefits from coordinating on larger minimum proposals occur in the last periods.

However, despite the relative success of the smallest common denominator rule in our experiment, experience from the field (e.g. Barrett 2003) shows that such rules may not necessarily imply strong agreements. Reasons may involve the heterogeneity of countries with respect to wealth as well as to costs and benefits from the public good which may aggravate the coordination on a uniform binding minimum. The experimental investigation of the impact of such heterogeneities on coalition formation and on the performance of the different institutions and their possible adjustments are fruitful areas of further research.

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Table 1: *Summary of experimental design*

Treatment	Stages	Coalition structure	n	γ	α	No. of subjects
VCM	contribution	no	10	10		100
COALfull	membership contribution	yes	10	10	1	100
COALpartial	membership contribution	yes	10	10	0.5	100
COALmin	membership minimum contribution	yes	10	10		100
VCMmin	minimum contribution	no	10	10		100

Table 2: *Summary statistics for all treatments*

Treatment	q	π	k	eff
		Total		
VCM	12.3	905.2		0.21
COALfull	12.1	959.3	3.5	0.24
COALpartial	8.5	727.1	3.2	0.12
COALmin	14.8	1060.1	5.1	0.29
VCMmin	22.1	1418.6		0.47
		First 5 periods		
VCM	15.7	1098.4		0.31
COALfull	13.3	1030.1	3.7	0.27
COALpartial	9.0	766.1	3.1	0.14
COALmin	16.3	1160.1	5.3	0.34
VCMmin	16.8	1187.9		0.35
		Last 5 periods		
VCM	8.9	711.9		0.12
COALfull	10.9	888.5	3.2	0.20
COALpartial	7.9	688.1	3.3	0.11
COALmin	13.4	960.1	4.8	0.24
VCMmin	27.5	1649.2		0.58

Notes: q = average contributions, π = average payoffs, k = average coalition size, eff = average efficiency defined as $(\pi - \pi^{NE})/(\pi^{SO} - \pi^{NE})$ with π^{NE} =475 and π^{SO} =2500

Table 3: *Linear regression of public good contributions for all treatments*

VARIABLES	All per. qi	All per. qi	Last 5 per. qi
COALfull	-0.202	-2.420***	2.016***
	(0.578)	(0.796)	(0.780)
COALpartial	-3.826***	-6.702***	-0.950
	(0.578)	(0.796)	(0.780)
COALmin	2.551***	0.582	4.520***
	(0.578)	(0.796)	(0.780)
VCMmin	9.833***	1.046	18.62***
	(0.578)	(0.796)	(0.780)
per6_10		-6.880***	
		(0.796)	
per6_10_COALfull		4.436***	
		(1.126)	
per6_10_COALpartial		5.752***	
		(1.126)	
per6_10_COALmin		3.938***	
		(1.126)	
per6_10_VCMmin		17.57***	
		(1.126)	
Constant	12.30***	15.74***	8.858***
	(0.409)	(0.563)	(0.551)
Observations	5000	5000	2500
R-squared	0.111	0.158	0.252

Notes: Standard errors in parentheses, significance *** p<0.01, ** p<0.05, * p<0.1.
Definition of variables:
qi = subject's contribution,
COALfull = 1 if subject played in the *COALfull* treatment, 0 otherwise,
COALpartial = 1 if subject played in the *COALpartial* treatment, 0 otherwise,
COALmin = 1 if subject played in the *COALmin* treatment, 0 otherwise,
VCMmin = 1 if subject played in the *VCMmin* treatment, 0 otherwise,
per6_10 = 1 for the last five periods, 0 for the first five periods,
per6_10_*treatment* = interaction term of time dummy and treatment dummy.

Table 4: *Linear regression of payoff levels for all treatments*

VARIABLES	All per. pay	All per. pay	Last 5 per. pay
COALfull	54.16	-68.28	176.6***
	(34.06)	(47.30)	(46.48)
COALpartial	-178.1***	-332.3***	-23.77
	(34.06)	(47.30)	(46.48)
COALmin	154.9***	61.70	248.2***
	(34.06)	(47.30)	(46.48)
VCMmin	513.4***	89.52*	937.3***
	(34.06)	(47.30)	(46.48)
per6_10		-386.5***	
		(47.30)	
per6_10_COALfull		244.9***	
		(66.89)	
per6_10_COALpartial		308.6***	
		(66.89)	
per6_10_COALmin		186.5***	
		(66.89)	
per6_10_VCMmin		847.8***	
		(66.89)	
Constant	905.2***	1,098***	711.9***
	(24.09)	(33.44)	(32.87)
Observations	5000	5000	2500
R-squared	0.083	0.117	0.185

Notes: Standard errors in parentheses, significance *** p<0.01, ** p<0.05, * p<0.1.
Definition of variables:
pay = subject's payoff level,
COALfull = 1 if subject played in the *COALfull* treatment, 0 otherwise,
COALpartial = 1 if subject played in the *COALpartial* treatment, 0 otherwise,
COALmin = 1 if subject played in the *COALmin* treatment, 0 otherwise,
VCMmin = 1 if subject played in the *VCMmin* treatment, 0 otherwise,
per6_10 = 1 for the last five periods, 0 for the first five periods,
per6_10_*treatment* = interaction term of time dummy and treatment dummy.

Table 5: *Probit estimation of decision to join the coalition for all coalition treatments*

VARIABLES	All coal ci	COALmin ci
ci_lag	1.169***	1.381***
	(0.0565)	(0.0979)
k_lag	0.0249	-0.0167
	(0.0213)	(0.0286)
meanqi_lag	-0.00658	
	(0.00627)	
COALpartial	-0.0391	
	(0.0685)	
COALmin	0.241***	
	(0.0687)	
int_ratio_min_lag		-0.236**
		(0.103)
Constant	-0.875***	-0.480***
	(0.0842)	(0.170)
Observations	2700	900

Notes: Standard errors in parentheses, significance *** p<0.01, ** p<0.05, * p<0.1.
Definition of variables:
ci = 1 if subject joined the coalition, 0 otherwise,
ci_lag = 1 if subject joined the coalition in the previous period, 0 otherwise,
k_lag = coalition size in the previous period,
meanqi_lag = mean group contribution in the previous period,
COALpartial = 1 if subject played in the *COALpartial* treatment, 0 otherwise,
COALmin = 1 if subject played in the *COALmin* treatment, 0 otherwise,
int_ratio_min_lag = previous period internalization ratio based on the binding minimum.

Table 6: *Linear regression of internalization ratios for COALmin*

VARIABLES	COALmin int_ratio_min
k	-0.0725***
	(0.00901)
period	-0.0166***
	(0.00544)
Constant	1.115***
	(0.0615)
Observations	1000
R-squared	0.063

Notes: Standard errors in parentheses, significance *** p<0.01, ** p<0.05, * p<0.1.
Definition of variables:
int_ratio_min = internalization ratio based on the binding minimum,
k = coalition size,
period = period.

Table 7: *Linear regression of the adjustment in the individual minimum proposal* q_i^{min} *over time (*q_i^{min} *in current period minus* q_i^{min} *in previous period) for COALmin and VCMmin*

VARIABLES	COALmin change_qimin	VCMmin change_qimin
qi_min_lag	-0.349***	-0.363***
	(0.0625)	(0.0283)
q_min_lag	-0.236**	0.0118
	(0.0949)	(0.0317)
pivot_lag	5.174*	-0.477
	(2.785)	(1.515)
Constant	15.86***	18.28***
	(2.915)	(1.405)
Observations	344	900
R-squared	0.237	0.201

Notes: Standard errors in parentheses, significance *** p<0.01, ** p<0.05, * p<0.1.
Definition of variables:
change_qimin = subject's minimum proposal minus proposal in the previous period,
qi_min_lag = subject's minimum proposal in the previous period,
q_min_lag = binding minimum in the previous period,
pivot_lag = 1 if subject suggested binding minimum in the previous period, 0 otherwise.

Figure 1: *Internalization factor α needed to stabilize a given coalition size*

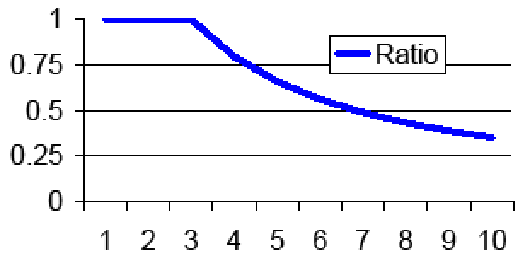


Figure 2: *Average contribution and payoff levels for all treatments*

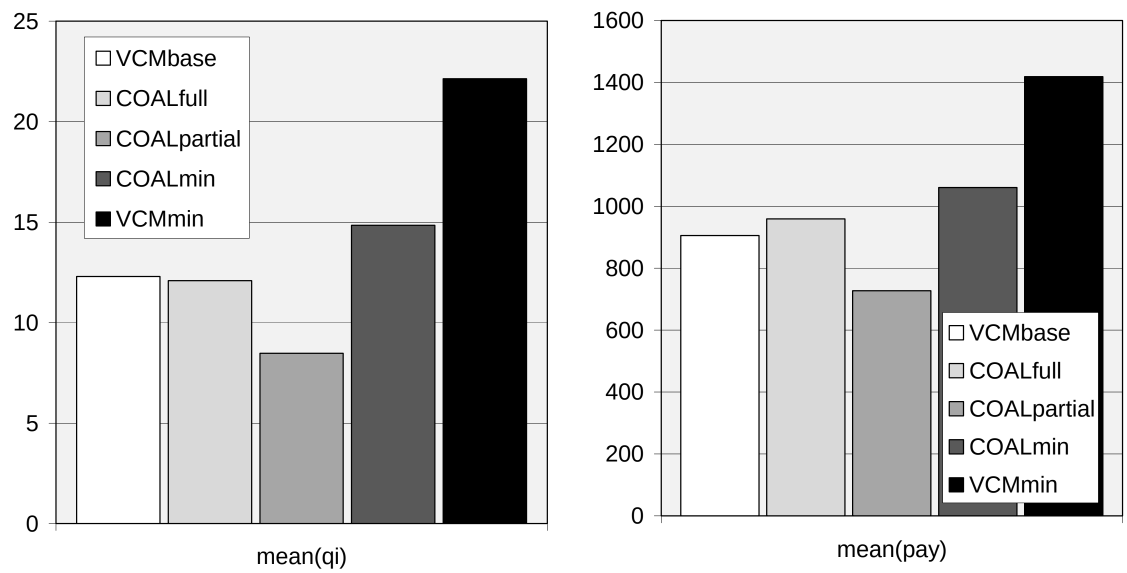


Figure 3: *Average contribution for all treatments over time*

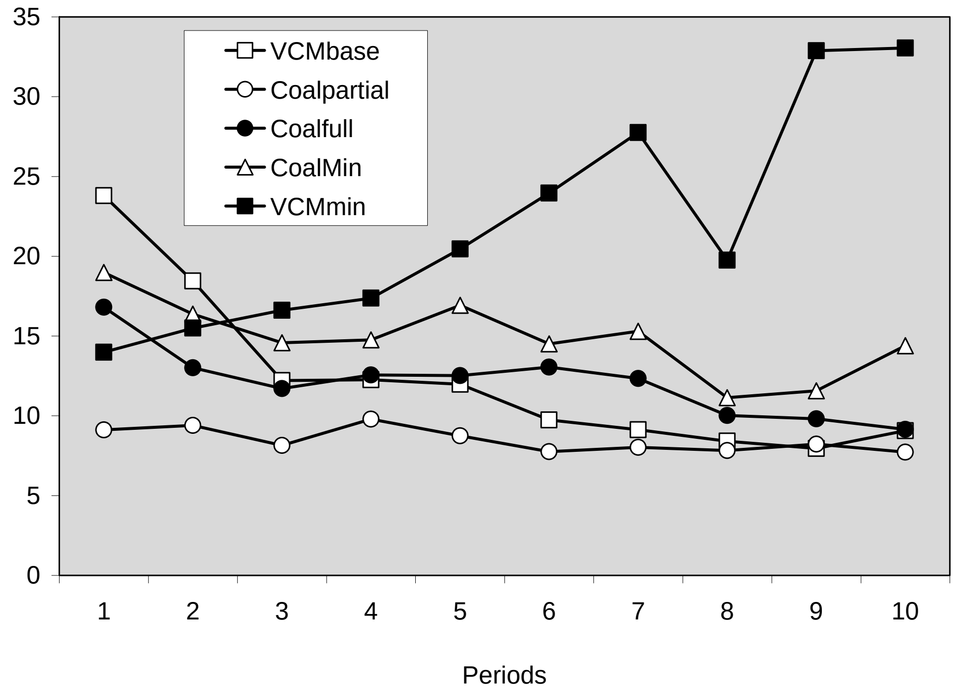


Figure 4: *Binding minimum in VCMmin for each group over time*

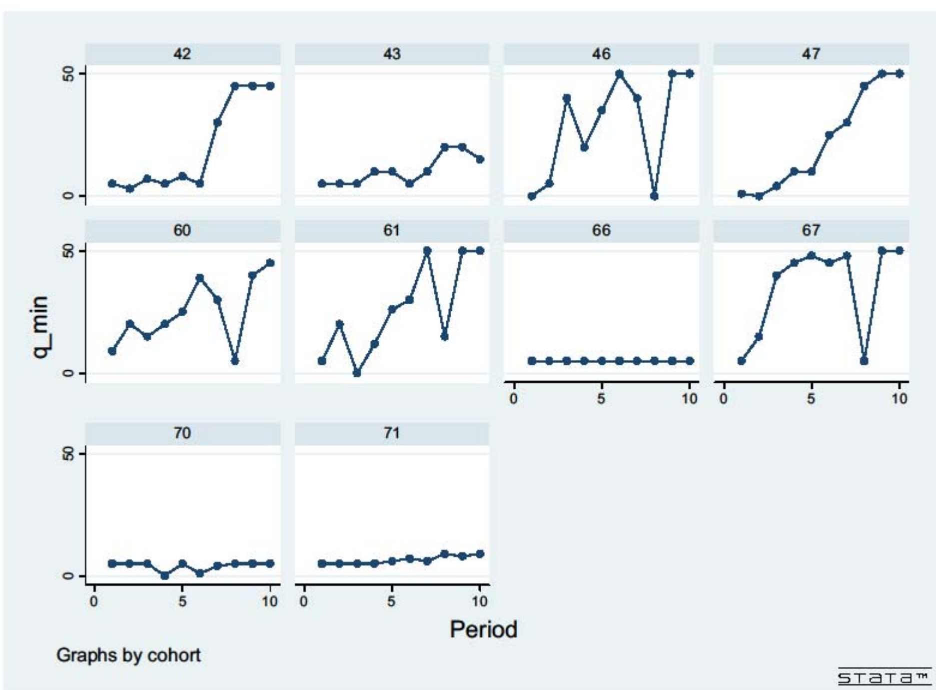


Figure 5: *Average contribution levels among coalition members and free-riders as well as average coalition size across treatments*

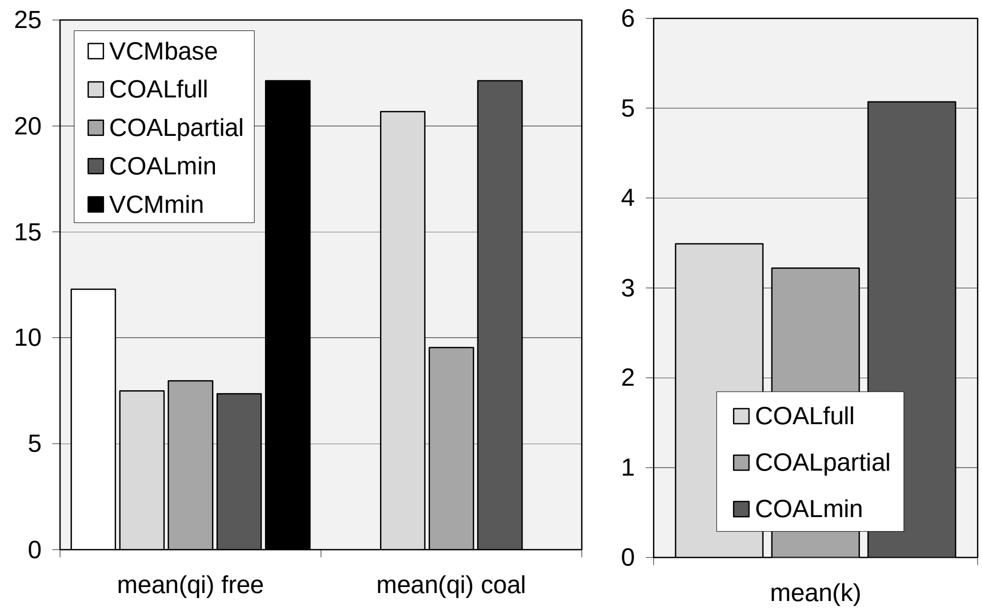


Figure 6: *Average internalization ratios conditional on coalition size.*

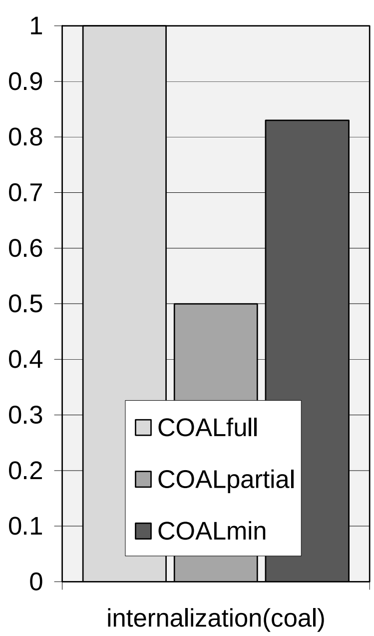
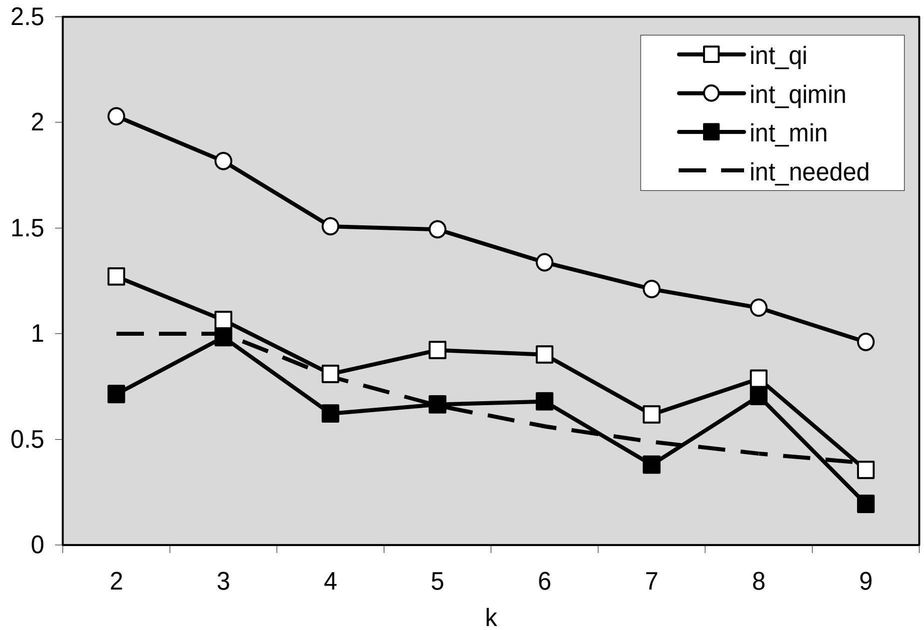


Figure 7: *Average internalization ratios conditional on coalition size in COALmin: suggested minimum ratio (int_qimin), binding minimum ratio (int_min), chosen fraction of mutual benefits that are internalized in coalition (int_qi); the dashed line (int_needed) shows the internalization ratios theoretically required to stabilize the respective coalition size.*



Appendix

Experimental instructions for the *COALmin* treatment

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 you would like to contribute to a **joint project**. Your **payout** will be calculated as follows:

Your payout = $-$(your contribution to the project)^2 + 10·(sum of all contributions of all players to the project)

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:

$-(10)^2 + 10\cdot(10+90) = 900$ LD

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

$-(0)^2 + 10\cdot(0+50) = 500$ LD

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 maximise 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

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