Starting small toward voluntary formation of efficient large groups in public goods provision

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ABSTRACT

We test a mechanism whereby groups are formed voluntarily, through the use of voting. These groups play a public-goods game, where efficiency increases with group size (up to a limit, in one treatment). It is feasible to exclude group members, to exit one's group, or to form larger groups through mergers involving the consent of both merging groups. We find a great degree of success for this mechanism, as the average contribution rate is very high. The driving force appears to be the economies of scale combined with the awareness that bad behavior will result in exclusion or no admission. However, an important additional component is that it is possible for previous outsiders to later redeem themselves by becoming high contributors, typically in efficient large groups.

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1. Introduction

While achieving cooperation is beneficial or even critical for groups or societies, doing so may be problematic since individual incentives often conflict with socially efficient actions. Even if individuals feel inclined to help out, they may lose

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the taste for cooperating when they see other individuals not doing their share. The issue of how to successfully implement collective action when there is a prospect of such free riding is a vital topic in public economics.

Experiments have been used to investigate the provision of public goods since at least Marwell and Ames (1979). The basic idea is that each individual has an endowment to allocate between private goods and public goods, with a contribution to the public good creating more social surplus than a contribution to the private good. However, each individual only receives a fraction of the amount contributed, so that it is rational to allocate one’s endowment to private goods. The typical pattern in standard public-goods games is that of moderate initial contributions declining steadily over time. How can long-term efficiency be sustained?

One approach involves identification of individual contributions and voluntary punishment. While some studies show that the level of cooperation can be sustained fairly well, punishment inevitably involves sacrifice to lower the payoff of another individual (although it may nevertheless provide a net benefit). Punishment may also undermine altruistic cooperation or even backfire in form of anti-social punishment against individuals exhibiting pro-social behavior.²

An alternative approach is to allow the group in question to evolve endogenously, as with assortative matching.³ The notion that choosing partners can foster cooperation or contribution in the real world is potentially quite important. We follow this approach in our paper, providing and experimentally testing a more flexible and ‘realistic’ mechanism for voluntary group formation. Specifically, we start with small groups, combine features of exit and exclusion, allow groups to grow quickly with a merging stage, and also permit individuals who have been excluded to reform. Our intention is to demonstrate the effectiveness of this overall approach, in the hopes that this flexible mechanism can be adapted to a variety of environments. Indeed, the combination of these features leads to a very high contribution rate.

There are many real-world environments in which there are strong incentives to form large groups due to economies of scale. However, the expansion and exploitation of the potential size advantage is limited by the problem of solving the inherent free-riding problem, even under the condition of voluntary but restricted group association (among other organization issues). Producers’ cooperatives and firms with workforce participation have existed all over the world and in different stages of economic development (see Bonin et al., 1993; Dow, 2003, for example). Common examples of adjustment of membership and its size pertain to partnerships practicing law, medicine and accounting in advanced market economies.

One motivating example for our study, both for the type of mechanism and group dynamics and for the demographic magnitude on the lives of those in the society, is China’s rural collectivization movement in the 1950s. After the land reform that redistributed production means from the rich to the poor in late 1940s, the Chinese Communist Party experimented with promoting voluntary cooperation in form of mutual aid teams (MATs) among farmers, to exploit economies of scale. Attempts to begin with large-sized MATs failed miserably; following this initial failure, the Party recommended that MATs should start small with 3–5 households and repeatedly stressed that the formation was voluntary, in the hope that peasants would learn how to solve the induced incentive problems, develop mutual trust, and eventually merge into larger-sized MATs to exploit the full size of economies of scale (Shue, 1980). This voluntary phase of China’s rural collectivization movement was a great success. Since farmers had the right to exit, the potential free-riding problem must have been overcome for the MATs to stay together.⁴

Of course, the relevance of the issue goes far beyond this example. Field examples include joint ventures between research consortia and mergers between firms, where there are economies of scale involved. Municipal governments may also form larger groups for the purpose of sharing the cost of public goods. Business partnerships can involve exit, exclusion, and mergers, and typically start small. Cooperative corporate culture can be nurtured by starting small, as Weber (2006) shows experimentally with a coordination game. Co-authorship involves exit and exclusion and can even involve mergers on large projects. The matter of endogenous group-formation is fairly pervasive in the field and how to take advantage of scale economies while attaining efficient outcomes is an important question.

The implicit challenge for (experimental) economists is to provide evidence in this regard. We investigate whether starting small and allowing bi-directional movements of groups on a voluntary basis may indeed steadily foster mutual trust within the group, to fully exploit economies of scale in the large-size PG problem, in the manner of retreat and regroup. As Olson (1971, p. 36) put it, “The movement in and out of the group must no longer be ignored.” Of course, there are numerous potential sets of rules that implement the voluntary bi-directional movement feature in a regrouping mechanism, with our choice involving exit, inclusion, and mergers being one of these sets.

The basic structure of our mechanism for group evolution allows for an ebb and flow in a dynamic environment. In addition to exit, there are four key features of our design. One is that contributions are more valuable in larger groups. Another is the possibility of exclusion, which affords would-be cooperators insurance that they will be safe from would-be free-riders. One or both of the first two are present in a number of papers in the literature, such as Ehrhart and Keser (1999), Cinyabuguma et al. (2005), Page et al. (2005), and Ahn et al. (2008, 2009); we review this literature in detail in Section 2.

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² See Fehr and Gächter (2000), Masclan et al. (2003), Fehr and Rockenbach (2003), Fehr et al. (2007) and Herrmann et al. (2008).
³ Sober and Wilson (1998), Frank (1988), and Bergstrom (2002) show that cooperative behavior can survive if it entails advantages over selfish behavior; these advantages can include an improved chance of being matched with like-minded individuals and a better chance of avoiding undesirable elements of the population, Sethi and Somanathan (2003) provide a survey of theories of assortative matching.
⁴ For detailed discussion of the role of exit in the 1950s Chinese agricultural MATs with reference to economic theory, see Lin (1990) and Puttermann and Skillman (1993) among others. Hinton, 1966 Appendix A1 provides further discussion related to this issue.
However, all of these previous mechanisms have some gaps that we feel inhibit the degree of realism. In fact, a major methodological motivation for, and contribution of, our current design is that previous experimental studies by Ehrhart and Keser (1999) and Ahn et al. (2008, 2009) do not realize the scale economy of the public-goods provision when group size is fully endogenous. One novel feature of our mechanism is implementing mergers between groups, rather than allowing a group to merely add one individual at a time. This facilitates a more efficient process for combining existing cooperative groups within the time constraints of a laboratory experiment; it also allows groups to not only shrink, but also to grow rapidly because their ‘cooperative’ looks attractive to other groups. Another novel feature is that our design facilitates successful ‘redemption’, whereby individuals who were initially excluded or fenced off from seed groups later have high contribution rates as members of efficient, large groups.

Our experiment has two treatments with voluntary group-formation. Individuals play a public-goods game for three periods, with ID numbers showing individual contributions. We then allow exit, exclusion, and merger in three steps (described in Section 3). Three periods of play follow with the new groups, with this process continuing until 15 periods have been played. We have two such 15-period segments, with new ID numbers for the second segment, thus allowing a fresh start. Each ‘society’ is comprised of nine individuals, who are initially randomly matched into three groups with three members in each group. In our first treatment, the value of the marginal unit of contribution increases with group size, so that larger groups are more efficient so the social optimum is achieved with full contributions in the grand coalition. Our second treatment is identical to the first except that, in order to explore the effect of social efficiency on behavior, we only increase the group’s return from contributions up to a group size of four. In both of these treatments, we provide friction to growth through the hurdle of having the marginal per-capita return (MPCR) of contributing decrease with increasing group size.

Our results are striking with endogenous group formation. We see considerable exit and exclusion, particularly in early rounds. The high level of contribution persists in each segment while subsequent voting for group members is expected. When the value of contributions increases for all increased group sizes, large and stable groups form. With this value increases only up to a group size of four, contributions are only slightly lower, but the smaller groups and considerably greater instability lead to lower efficiency.

The remainder of this paper is organized as follows. We describe the previous literature in Section 2 and the experimental implementation in Section 3. We present the experimental results in Section 4 and offer a discussion of our results in Section 5. We conclude in Section 6.

2. Previous literature

Early experimental studies (e.g., Marwell and Ames, 1979; Isaac and Walker, 1988) focused on patterns in provision rates and on investigating the influence of group size on public contributions; in these studies, the group remains fixed for the duration of the experiment. Since these early studies, much experimental literature suggests that a key impediment to sustaining high contribution rates is the presence of ‘bad apples.’ It seems that individuals are particularly sensitive to uncooperative behavior, perhaps in the same way that individuals are considered to experience losses more strongly than gains. Thus, one possible approach is to enable would-be cooperators to avoid these free riders and join with like-minded individuals.5

We first discuss papers that allow individuals to choose groups, at least after an initial start. Ehrhart and Keser (1999) were the first to consider a public-goods game with endogenous group-formation. Nine individuals were randomly placed into three initial groups and played the game. Each individual was then told the sizes and average contributions for each group, and could unilaterally decide, at a fixed cost, to switch groups or to form a new (one-person) group. However, although there was considerable movement, this device had limited success. Without exclusion or an entry restriction, the pattern is one of more cooperative individuals being on the run from free riders, who constantly chase them.

Ahn et al. (2008, 2009) investigate the effect of entry and/or exit restrictions. They essentially change two elements of the Ehrhart and Keser (1999) design. First, entry and/or exit may be restricted, subject to simple majority voting of the group. Second, instead of the common linear payoff function, they use a non-linear one, in which investing in the group account has a cost that is a cubic function of the amount invested; the latter paper adds a quadratic congestion cost.

There are three treatments in each paper, which involve different entry/exit rules: free entry/exit, restricted entry with free exit, and free entry with restricted exit. Ahn et al. (2008) shows that restricted entry increases contribution, but overall efficiency is lower compared to other treatments, due to the smaller group sizes around 6 (maximum = 12, optimum = 9), with a declining trend by adding more entrants. In addition, the ratio of the average contribution to the optimal contribution is also declining over time, reminiscent of the standard decay phenomenon. In Ahn et al. (2009, Fig. 3), earnings drop dramatically in groups of more than 6 members, with negative average earnings for the largest group sizes. The main insight is that restricted entry can get individuals into relatively well-performing 6- or 7-person groups; however, it fails to sufficiently

5 For a discussion of the earlier work in this area, see Ledyard (1995).
In Table 1, Group returns and MPCR in the Main treatment, by group size.

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exploit the desirable scale economies, as larger groups do not perform well once they grow this far. In comparison, our design achieves highly efficient social outcomes.

In Cinyabuguma et al. (2005), sessions began with 16 individuals in one group. After each round, there was a vote on whether to expel individual group members, who were then irreversibly banished to a “fringe group” of undesirables who played a public-goods game with a lower endowment; thus, the group size can only decrease. There is significant expulsion, with an average of about 1/6 of the original group relegated to the fringe over the course of a session. Their results demonstrate that punishment in form of exclusion can greatly enhance cooperation in the main group, though without a chance for the outcasts to later re-join the main group. On the other hand, however, one cannot draw straightforward conclusions about its effect in more realistic setups, such as real-world cooperatives where groups typically start small and grow in size over time, with viable alternatives to the current membership.

A different approach to group re-formation considers the effect of assortative matching under fixed group sizes. The first paper (despite its later publication date) is Gunnthorsdóttir et al. (2007), who sort the individuals involved (without telling them) into high and low contributing groups of fixed size of four and find similar results, with bifurcations in the contribution level. They observe benefits in this segmentation for the high contributors.

Page et al. (2005) have four 4-person groups (initially randomly assigned) who play 20 rounds of a public-goods game. After every 3 periods, there is a regrouping where each individual can provide costly ratings for any number of the other 15 individuals based on the public information about everybody’s average contribution. The four individuals with the strongest mutual preferences form the first group. This procedure then determines the second and third groups, with the leftovers forming the last group. The average contribution improves from 38% in the baseline to 70%, but with decay due to free-riding in the leftover group.

Croson et al. (2006) also study endogenous excludability, but with a fixed and exogenous rule, in three different experimental games. The individual who contributes the least is automatically excluded from receiving any of the group’s payoffs; this leads to higher contribution rates in the public-goods game and the best-shot game, with a smaller increase in the minimum-effort game. This is essentially a competition among the four individuals in a group, where the optimal outcome for an individual is to be the second-lowest contributor.

Finally, Weber (2006) finds that slowly building groups, after first establishing cooperative behavior in 2-person groups, can be effective in achieving high rates of contribution in the minimum-effort game with large groups (up to 12 individuals). Here it seems important for groups to first establish a norm and grow slowly. In the working-paper version (Weber, 2005), a ‘manager’ selected at random from all individuals can grow the group endogenously; managers who try to simultaneously add multiple individuals to the group in the early stages have a notable lack of success in achieving good outcomes in the larger groups.

3. Experimental implementation

We conducted our experiments in November of 2005 at the University of California, Santa Barbara, with individuals recruited from a campus-wide list of (primarily) undergraduate students who had previously indicated interest in participating in paid research experiments. No one had any experience with public-goods or voting experiments.

In Treatment 1 (hereafter the “Main” treatment), we conducted four laboratory sessions with a web-based program; there were nine individuals in the first session and 18 in each of the remaining three sessions, for a total of 63 individuals in this treatment. The average income in these sessions (of about 90 min in length) was approximately $21, including a $5 show-up fee. Our supplemental, printed sample instructions are presented in Appendix A2.

In this treatment, nine individuals in each ‘society’ were initially placed into three groups of three, who then played a public-goods game for three periods. Each individual was endowed with 25 tokens to be allocated between a private account and a public account. The social benefit of an allocation to the public account depended on the group size, as shown in Table 1. We determined the group return by using the 4-person MPCR of 0.4 as the standard, leading to a group return of 1.6 for the.

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6 We would like to mention that these papers do have the feature by which individuals who have been denied entry could try again later. However, unlike successful redemption in our design, adding such individuals does not seem to lead to higher contribution levels or benefits for the society; in fact, it is possible that the decrease in contributions for larger groups may be the result of adding too many such individuals and ‘poisoning’ the group.

7 Other studies on the topic of group formation in the public-goods game include Riedl and Ule (2002), Coricelli et al. (2004), Brosgol et al. (2005), and Önes and Puterman (2007). See also Gunnthorsdóttir et al. (2010a,b). We apologize to the authors of relevant non-cited studies for our omission.
Thus, incumbents were chosen to re-start two rounds later. The game was designed to have a unique solution: the grand coalition of the group containing all individuals. 8

A regrouping round with two stages follows the three periods of PG actions:

Stage 1: Every individual decided whether to unilaterally exit the group and, if he or she chose to stay with the group, then cast a yes or no vote on every other group member. If strictly more than 50% of the voters chose to exclude an individual who had not chosen to exit, that individual was expelled from the group.

Stage 2: At this point there were a number of groups, group remnants, and (voluntary or expelled) ‘free agents’. Each of these entities then decided whether it wished to merge with each of the other entities. A merger happened if and only if at least 60% of the members of each entity wish to merge with the other entity. Our algorithm for performing group mergers began by considering whether the two largest groups (with ties broken randomly) wished to merge. If not, the mechanism considered the desires of the largest group and the third-largest group regarding a merger. This continued until a merger was achieved, at which point the process began again with the new two largest groups, etc. Ultimately, the process continued until no more mergers could be made. This means that an individual might be involved in more than one merger within the same merger stage. Any leftover singles were formed into new groups, depending on how many singles remained. If there was exactly one single at the end of this process, he or she remained unattached. The instructions provide the details of this process.

Throughout the game, we provided the minimum level of salient information to make decisions. In each of the three PG game periods, they were only informed of the group total that, together with one’s own contribution level, determined one’s payoff in that period. On the Stage 1 screen of the regrouping round, each individual learned about the per-period average contribution of each other individual (by identification number) in one’s current group in those three periods, as well as the group average in other groups. On the Stage 2 screen, the group average for each transitional entity was made known to everyone. Feedback about contributions was necessarily limited to the past three periods, since the contribution of an individual in a group was not divulged to those outside the group.

The new groups then played three periods of the public-goods game, followed by a regrouping round, with the same rules. There were voting rounds after the first four sets of three periods, with 15 periods overall in the segment. We then re-formed societies (except in the first session) with new identification numbers randomly assigned; a new 15-period segment was started with three 3-person groups formed at random in each society. 9 Thus, in each session there were 30 periods of play in the public-goods game and eight voting rounds. Treatment 2 (hereafter the “Capped Efficiency” or “Capped” treatment) isolates the influence of efficiency considerations on contributions and group size. This treatment was identical to the Main treatment, with one important exception: the group return from contributions was capped at 1.6, so that this return was identical for all groups with four members or more. So the optimal composition is either the grand coalition or one group of four and one group of five. Our purpose here was to see how groups form in the presence of more sharply declining returns to group contributions; this permits a stress test of returns on contributions and group formation. We had three sessions in this treatment (six societies), each with 18 individuals. The average income in these sessions was approximately $18, including a $5 show-up fee. Table 2 shows the social benefit of an allocation to the public account; there is no direct efficiency incentive to form groups larger than size four.

Table 2

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4-person group. We increased (decreased) this factor by 10% for each additional individual added to (removed from) the group, except that the factor for a solitary individual was 1.8

A regrouping round with two stages follows the three periods of PG actions:

Stage 1: Every individual decided whether to unilaterally exit the group and, if he or she chose to stay with the group, then cast a yes or no vote on every other group member. If strictly more than 50% of the voters chose to exclude an individual who had not chosen to exit, that individual was expelled from the group.

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Treatment 3 (hereafter the “Baseline” treatment) features fixed groups, in order to establish that our subject pool shows similar behavior in the standard game to what has been observed previously. There were three sessions with 18 individuals in each. In each session, individuals were randomly assigned to a 3-person, a 6-person, or a 9-person group for a 15-period segment. We chose these group sizes to obtain observations from small, medium and large groups. Each group simultaneously played the same public-goods game as in our main treatment, except that there was no regrouping round. Consequently, each individual was informed of only the group total in one’s group. 10 After the first segment, we randomly re-assigned individuals to new groups, so that the composition of groups varied across segments. Average income in these 45-min

8 More precisely, the payoff for an individual with contribution level x in a size-n group with group total contribution level X is π = (25 − x) + 1.322(1 + 0.1)2−2X/N, for n = 2, 3, . . . , 9. Consequently, if a potential newcomer were to contribute at least ((10−n)x)/11n < (X/n) while all incumbents maintained their current level, then the latter’s payoffs would not decrease in the larger new group.

9 We chose to have a re-start, as an individual might get locked into a situation that is difficult to escape during a segment, but instead would receive a fresh start in the second segment. In the second segment, we re-mixed the individuals from the two societies in the first segment for at least two reasons. First, by comparing the patterns of behavior across the two segments, we can assess how much was learnt in the first segment. Second, mixing the groups across segments also helped to avoid the resumption of the behavioral patterns from the first segment.

10 We are indebted to Charles Holt for adapting his Veconlab software to make this possible.
sessions was about $13, including a $5 show-up fee. Clearly there are differences from the other treatments across multiple dimensions, but here we intended to show that the subject pool did not behave unusually in a standard public-goods game.

Our experimental design is rather complex, so that one might naturally be concerned about a lack of comprehension. However, as we shall see, the experimental patterns are very strong. This suggests that individuals understood at least the general framework fairly well, since the observed behavior is so systematic and non-random.

Our experimental methodology represents a “top-down approach,” in that our design simultaneously changes many elements from previous studies. This differs considerably from the standard “bottom-up” approach in which only one element of a design is changed. While the top-down approach does not facilitate identification of the importance of each separate element, real-world systems often have complementary or synergistic factors, in which case the research strategy of isolated manipulation of one factor at a time may greatly delay discovery of the system-based causal relationships. The logical next methodological step is to tease out whether this set of features is what is minimally required for similar success in social outcome, as well as concerns of how manipulation of individual features may affect the results. We provide a detailed discussion of the benefits of the top-down approach, as well as the reasoning behind our design choices for information flows, exclusion, and mergers, in Appendix A3 (Burton-Chellew and West, 2012; Croson, 2001; Davis and Holt, 1993; Milgrom and Roberts, 1994; Sääksvuori, 2013; Tiebout, 1956; Van Regenmortel and Hull, 2002; Yang et al., 2009).

4. Experimental results

In this section, we first analyze our data at the group level. In Section 4.1, we present descriptive statistics and some simple tests; in Section 4.2 we offer analysis of individual behavior, as well as regressions regarding the determinants of exit, exclusion, and merger choices. We then consider redemption in Section 4.3.

4.1. Descriptive statistics and simple tests

Fig. 1 illustrates the average contribution rate over time.\textsuperscript{11} We see that our mechanism induces high contribution levels in the Main and Capped Efficiency treatments, with a notable decrease in the last voting period of a segment. The average contribution profiles over time are remarkably similar for these treatments, with a 5–10 percentage point difference in contributions across these treatments in every period range except the last one; overall, the contribution rate in the Main treatment (excluding the last voting period and singles) is 90.9%, while the contribution rate in the Capped Efficiency treatment is 83.9%. Thus, when the multiplier increases with group size (at least up to groups of size four), we observe a very high contribution rate. While the difference in contribution rates in these treatments is modest, it is statistically significant ($p = 0.029$, with the natural one-tailed test) on a Wilcoxon ranksum test using session-level data for median contributions.\textsuperscript{12} Note the end-game effect in both the Main and Capped Efficiency treatments in periods 28–30 (and echoed in periods 13–15).\textsuperscript{13}

\textsuperscript{11} We exclude unmatched individuals (singles) from the calculations, as their contribution choices are arbitrary without any payoff consequences. There were only 24 such singles cases out of 1170 contributing decisions in total, or about 2%. Thus, even assuming a zero-contribution rate for these singles would not affect the results substantially.

\textsuperscript{12} Using the median as a statistic minimizes the weight placed on outliers. The median contribution was 25 in each of the four Main treatment sessions and was less than 25 in each of the three Capped Efficiency sessions. An alternative test uses the mean contribution in each session, finding $p = 0.057$, one-tailed test.

\textsuperscript{13} While in theory we should observe unraveling all the way back to the beginning, it is more the norm than the exception in experiments to see unraveling only in the last period or two of finite-horizon experiments.
In the Baseline treatment, we see the familiar pattern of a moderate initial rate of contribution, followed by a severe decline over time. The contribution rate is highest in the 3-person game, intermediate in the 6-person game, and lowest in the 9-person game; the differences in contribution rates across fixed groups are largest in the beginning and diminish over time.\textsuperscript{14} Endogenous group formation clearly generates a far higher contribution rate than in any of the fixed-group treatments. Making pairwise comparisons between each treatment, the Wilcoxon–Mann–Whitney ranksum test (see Siegel and Castellan, 1988) of session-level data indicates statistical significance at $p = 0.029$ (one-tailed test) in each case for the Main treatment versus the Baseline and $p = 0.050$ in each case for the Capped treatment versus the Baseline.

Since group size is endogenous in our design, we examine how each 9-individual society evolves over time.\textsuperscript{15} In the Main treatment, group size grows steadily over the course of the first 15-period segment; group sizes are larger in the second segment. Overall, the most common endogenous decompositions were the grand coalition and an 8-individual group with an unmatched single; in the second segment the grand coalition was the most common endogenous group. The pattern for the Capped treatment is quite different, with the most frequent endogenous decomposition having subgroups of size 2, 3, and 4. We observe no real trend toward increasing group size, perhaps because there is no direct incentive to form a group with more than 3 others.

The frequency of various group sizes is revealing: There were 26 groups of size four in the Capped treatment (counting each group in each period separately), compared to only one in the Main treatment. On the other hand, while there were 46 groups of size six or greater in the Main treatment, there were only seven such groups in the Capped treatment. A related issue is the stability of the groups, here defined as whether a group stayed intact in the subsequent period. Overall, 78% of groups with four or more individuals in the Main treatment stayed intact, versus 43% in the Capped treatment. Groups larger than size five were always unstable in the Capped treatment; in contrast, groups with more than five members were stable 75% of the time in the Main treatment. Table 3 summarizes frequencies of exit and merger in large groups.

We also consider the relationship between one’s own contribution rate and one’s earnings: Does cooperation pay? This is the basic evolutionary question (and assortative-matching issue) to be answered; it is answered positively in Page et al. (2005), Gunnthorsdottir et al. (2007) and Yang et al., 2007, among others. Of course, holding one’s group size and the contributions of others in the group constant, the higher the contribution, the lower the profit. But it is obvious that contributions are a critical determinant of the size and character of one’s (endogenous) group. In the Main treatment (excluding unmatched individuals and final voting periods), we obtain a Spearman coefficient between one’s contributions and one’s earnings (using average data for each individual as a single observation) of 0.5223, with $p = 0.000$; in the Capped treatment, the Spearman coefficient is 0.5786, again with $p = 0.000$.\textsuperscript{16} In Appendix E, we show the visual relationship between average contributions and earnings for each individual.

We turn now to the effect of capping potential efficiency gains at a group size of four. The results are clear concerning the number of large groups in each of these treatments. Session-level data show that the number of large groups was higher in each of the four sessions of the Main treatment than in any of the three sessions of the Capped Efficiency treatment. The Wilcoxon–Mann–Whitney ranksum test gives statistical significance at $p = 0.029$ (one-tailed test). Thus, larger groups do not tend to form when there is no payoff advantage for the larger groups.

The results regarding the effect of capping efficiency on contribution rates are more mixed. Recall the strong similarity in Fig. 1 in the contribution profiles over time for the two endogenous treatments, with a rather modest difference in contribution rates in nearly every voting period. Once again, the ranksum test can be performed using each society as one observation. The purest test uses data from the first segment, as there has been no interaction between societies. However, the data from the second segment has the advantage of perhaps better representing settled behavior. The Wilcoxon–Mann–Whitney test

\textsuperscript{14} Note that the contribution rate is very similar for the fixed 3-person group and the initial 3-person groups in the endogenous treatments in the first three periods, while contribution rates diverged thereafter. This suggests that behavior is learned over time.

\textsuperscript{15} Detailed decomposition results are shown in Tables B1 and B2 of Appendix B. Tables C1 and C2 in Appendix C shows group sizes and mergers and decompositions over time for each society in each treatment.

\textsuperscript{16} In this paper, we round the $p$-value to three decimal places.
yields \( p = 0.069 \) using society averages in Segment 1 and \( p = 0.018 \) (one-tailed tests) using society averages in Segment 2.\(^{17}\) Nevertheless, the difference in rates across treatments is modest; the mechanism achieves a high level of contributions even when the potential efficiency gain is much smaller.

### 4.2. Detailed analysis on group formation

#### 4.2.1. Exit

Each individual faced the exit decision at most eight times and exit was chosen only rarely, 8.9% (16.5%) of the time in the Main (Capped) treatment. The Wilcoxon ranksum test on individual exit rates finds a significant difference (\( p = 0.003 \)) across treatments. The higher exit rate in the Capped treatment is consistent with the lower degree of stability in this treatment.

While there is much heterogeneity with respect to the circumstances when one chooses to exit from one’s group, there is nevertheless a clear overall relationship between the choice to exit and one’s contribution relative to the group average. Individuals chose to exit from a multi-person group significantly more often when their contribution exceeded the group average.\(^{18}\) There is also a clear and significant individual-level relationship on whether the average contribution of the other multi-person groups exceeded that of one’s own group and exit, with individuals more likely to exit when the average contribution of the other groups was higher.\(^{19}\)

Table 4 shows the determinants of exit choice, in random-effect probit regressions excluding decisions by singles. In both treatments and in all specifications, the difference between one’s own and the average ingroup contribution is a significant factor: the bigger this difference, the more likely that exit will be chosen. When contributions in one’s own group are low, one might be tempted to look elsewhere. In this respect, the average contribution for the other existing groups is also a statistically significant determinant of exit. In addition, there is an attraction to the maximum average contribution of the other groups, as there is a large coefficient for this term in specifications (3) and (6), as well as a high degree of significance.\(^{20}\)

#### 4.2.2. Exclusion

Turning next to exclusion patterns, if one has chosen to stay with the group, but is unhappy with some group members’ choices, one might consider exclusion. Each individual made exclusion decisions about each individual in one’s group in (up to) eight voting periods. Each individual made an average of 33 decisions about whether to exclude an individual group member in the Main treatment and 17 such decisions in the Capped treatment. Eighty-three out of 117 individuals (71%) chose exclusion at least once (excluding instances when the individual voting for exclusion was the minimum contributor). Exclusion was chosen in 18.7% (6.0%) of the decisions in the Capped (Main) treatment, so that each individual chose to exclude another group member about 3.3 (2.0) times.\(^{21}\) Again, the higher exclusion rate in the Capped treatment is consistent with

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\(^{17}\) A similar approach that instead uses the average contribution of the median contributor in each society as one observation also finds significance: \( p = 0.051 \) (0.001) for one-tailed tests of the data from segment 1 (2).

\(^{18}\) Fifty-four unique individuals (of 117) chose to exit at least once (excluding the last voting period). Thirty-four individuals chose to exit more frequently when their contribution was higher than the group average, compared to 12 individuals who chose to exit more frequently when their contribution was lower than the group average; the binomial test establishes that this difference is significant \((Z = 3.24, p = 0.001)\).

\(^{19}\) Of the 54 individuals who chose to exit from a multi-person group at least once, 43 chose exit more frequently when the average contribution of the other groups was higher, while eight chose exit more frequently when this contribution was lower; the binomial test establishes that this difference is significant \((Z = 4.90, p = 0.000)\).

\(^{20}\) A reviewer points out that how the maximum contribution (as well as the average contribution) in other groups affects one’s decision about exiting most likely depends on one’s own contribution, since low contributors have little chance of getting into a high-contributing group. However, the fact that own contribution is included the first independent variable may help to control for this issue. Adding another term for own contribution in the regression seems problematic and we feel that the first independent variable is quite important.

\(^{21}\) The Wilcoxon ranksum test on individual exclusion rates finds that these differ across treatments \((p = 0.000)\).
Table 5
Determinants of exclusion choice.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>(1) Main</th>
<th>(2) Main</th>
<th>(3) Main</th>
<th>(4) Capped</th>
<th>(5) Capped</th>
<th>(6) Capped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other’s contribution</td>
<td>–0.208** [0.015]</td>
<td>–0.121** [0.017]</td>
<td>–0.109** [0.018]</td>
<td>–0.202** [0.016]</td>
<td>–0.140** [0.017]</td>
<td>–0.129** [0.018]</td>
</tr>
<tr>
<td>Ingroup minimum</td>
<td>1.832*** [0.180]</td>
<td>1.153*** [0.289]</td>
<td>1.349*** [0.145]</td>
<td>0.828*** [0.178]</td>
<td>1.647*** [0.185]</td>
<td>1.144***</td>
</tr>
<tr>
<td>Contribution less</td>
<td>0.825*** [0.287]</td>
<td>0.543*** [0.420]</td>
<td>0.196*** [0.435]</td>
<td>3.364*** [0.337]</td>
<td>1.647*** [0.386]</td>
<td>1.144***</td>
</tr>
<tr>
<td>than one’s own</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.977*** [0.329]</td>
<td>0.543*** [0.420]</td>
<td>0.196*** [0.435]</td>
<td>3.364*** [0.337]</td>
<td>1.647*** [0.386]</td>
<td>1.144***</td>
</tr>
<tr>
<td># Observations</td>
<td>2089</td>
<td>2086</td>
<td>2086</td>
<td>958</td>
<td>931</td>
<td>931</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in brackets. “Ingroup minimum” and “Contribution less than one’s own” are dummy variables taking values of 0 or 1. ** Significance at the 1% level.

the lower degree of stability in this treatment. The minimum contributor was almost always one of the excluded parties. Overall, excluding votes by the minimum contributor, 85% of the exclusion votes were for the minimum contributor.

Table 5 reports the results of random-effects regressions vis-à-vis the decision of whether or not to exclude another group member in the eight voting rounds. We see quite strongly that an individual is more likely to vote to exclude another group member the lower that member’s contribution; this is the case in both treatments and all specifications. In addition, one’s own contribution plays a role – if the other individual’s contribution is less than one’s own, exclusion is considerably more likely. Finally, one is considerably more likely to exclude someone from the group if that individual’s contribution was the least in the group.

4.2.3. Merging
Once all exit and exclusion choices were made, one chose whether to merge with other groups. The overall rate of voting to merge (excluding choices by singles and in the last voting period in each segment) was 42.0% in the Main treatment and 26.9% in the Capped treatment.

Fig. 2 shows the distribution of the individual rates of voting to merge. The difference in individual rates is highly significant with the Wilcoxon test (Z = 5.14, p = 0.000). Merging is less attractive when the efficiency gains from larger groups are capped. Indirectly, this may also indicate that individuals in the disciplinary effect expected from the threat of exclusion.

Since we have a number of observations of positive and negative merge choices for each individual, we can perform useful individual regressions for the merge choice. To examine the motivation to merge, we construct a variable that reflects on whether a possible merger looks profitable, as rational individuals would prefer merger with another group if they expect to profit from such merger.23 As the first benchmark for comparison, we consider that one would only consent to a merger if the expected payoff (assuming existing contribution averages) in the next round is higher than both one’s payoff in the current round and the expected one for his or her current intermediate group for the case of no merger at all.

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22 We eliminate ties in the regressions involving the ingroup minimum, so some observations are dropped.

23 This variable only applies in voting periods other than the last one in a segment, as these exhibit significant unraveling while the others do not.
Table 6
Determinants of merger choice.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Dependent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
</tr>
<tr>
<td>Outgroup contribution</td>
<td></td>
</tr>
<tr>
<td>0.127***</td>
<td>0.139***</td>
</tr>
<tr>
<td>[0.010]</td>
<td>[0.010]</td>
</tr>
<tr>
<td>Outgroup size</td>
<td></td>
</tr>
<tr>
<td>0.245***</td>
<td>0.217***</td>
</tr>
<tr>
<td>[0.041]</td>
<td>[0.043]</td>
</tr>
<tr>
<td>Own group contribution</td>
<td></td>
</tr>
<tr>
<td>−0.037***</td>
<td>−0.073***</td>
</tr>
<tr>
<td>[0.013]</td>
<td>[0.010]</td>
</tr>
<tr>
<td>Own group size</td>
<td></td>
</tr>
<tr>
<td>−0.061***</td>
<td>−0.030</td>
</tr>
<tr>
<td>[0.030]</td>
<td>[0.036]</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
</tr>
<tr>
<td>−2.965***</td>
<td>−2.174</td>
</tr>
<tr>
<td>[0.192]</td>
<td>[0.274]</td>
</tr>
<tr>
<td># Observations</td>
<td></td>
</tr>
<tr>
<td>1147</td>
<td>1147</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td></td>
</tr>
<tr>
<td>−560.13</td>
<td>−548.58</td>
</tr>
</tbody>
</table>

Standard errors are in brackets.
*** Significance at the 5% level.
** Significance at the 1% level.

Let \( n' \) be the original group size before exit/exclusion, \( n \leq n' \) the intermediate group size, \( m \) the merger partner’s size, \( f \) the group-return function, \( D_{excl} \) the dummy for exclusion, and \( X_k \) the total average contribution level of the respective group of size \( k \). We define the variable \( S \), which reflects the expected earning difference from merger success and failure.

\[
S = \frac{f(n + m) \cdot (X_n + X_m)}{n + m} - (1 - D_{excl}) \max \left\{ \frac{f(n)X_n}{n} , \frac{f(n')X_{n'}}{n'} \right\} - D_{excl} \cdot 25
\]

We make the conservative assumption here that individuals have a rather myopic perspective, in that they only consider payoffs in the next round.\(^{24}\) If we ignore the possibility of exclusion, the above formula can be simplified as follows:

\[
S = \frac{f(n + m) \cdot (X_n + X_m)}{n + m} - \max \left\{ \frac{f(n)X_n}{n} , \frac{f(n')X_{n'}}{n'} \right\}
\]

We regress separately for each individual the decision of whether to merge, using \( S \) as the independent variable. The coefficient on \( S \) is negative in only four cases, clearly far from random behavior. Eighty of these regressions find a positive coefficient for \( S \) that is significant at the 5% level (no negative \( S \) coefficients are significant).\(^{25}\) Thus, the expectation of future profit clearly drives the decision to merge, at least for most individuals.

The median estimated coefficient for \( S \) is 0.235. Of course the size of the coefficient varies considerably across the population. \( S \) shows the distribution of these coefficients. Table 6 shows the aggregate-level (at the group level) determinants of the merger decision in simple regressions. A merger is more attractive if the other group has made higher contributions; further, the larger the other group, the more interest in merging with it. These forces are quite significant and strong.

\(^{24}\) Note that in case of exclusion (i.e., \( D_{excl} = 1 \), merger failure at the ensuing stage would (per game rules) send the excluded into an involuntary and random group of 1–3 persons. Thus, \( D_{excl} 25 \) reflects the pessimistic view of staying single in this case. Note also that if \( n = 1, f(n)X_n/n = 25.\)

\(^{25}\) This reflects a binomial test of the hypothesis that individuals are more likely to choose to merge when \( S \) is positive.
addition, the lower the average contribution in one’s own group and the smaller is one’s group, the more attractive a merger is for the members of the group.26

4.3. Redemption

A novelty of our design is that it allows individuals who have been excluded from a group due to bad behavior, to reform, as evinced by a pattern of small initial contributions and larger contributions in late rounds.27 Such individuals presumably would have been permanently excluded in studies featuring irreversible exclusion, but are often subsequently able to join large groups. We feel that reversible exclusion is a more accurate representation of the field environment than is permanent exclusion, given that individuals typically tend to relent or renegotiate.

Approximately 20% of all individuals achieved redemption, with a higher redemption rate in the Main treatment.28 Thus, providing the possibility for individuals who have made early mistakes to later join a group that is successfully cooperating enables many to become productive members of society. We present each individual’s contributions over time and classification with respect to redemption in Appendix D (Tables D1 and D2).29,30

If these individuals were excluded irreversibly, it would greatly impact social efficiency. For example, if three individuals from a 9-person society were permanently excluded, there would be at best a 6-person group and a 3-person group formed from those who were banished. This gives an average multiplier of 1.776; in a 9-person group made feasible with redemption, the multiplier is 2.577. Thus, the potential social efficiency with redemption is 45% higher than otherwise. In short, a non-grim-trigger strategy seems a desirable feature.31 As a final note, exclusion appears merely a small issue in the Main treatment with 7 cases total for 14 societies, while it is more of a problem in the Capped Efficiency treatment, with 20 cases for 12 societies.

5. Discussion

5.1. Relevant factors for the success of the mechanism

Our mechanism is successful in achieving a high rate of contribution. In the Main treatment, we find a strong tendency toward forming large, full-contribution groups, thus promoting a high degree of efficiency; group sizes are smaller in the Capped Efficiency treatment, but the contributions remain fairly high. We often see the grand coalition formed in the Main treatment, even though we start with small building blocks and have only a few voting rounds to get there.

While we cannot be certain, it is our sense that two main elements appear to drive our results. First, increasing returns to scale seem needed for large and inclusive groups to form; if these are capped at a group size less than the number of members in the society, there is less stability and lower relative efficiency. Since the presence of economies of scale may be a natural feature for public-goods problems in general, it is important to deal with truly endogenous group sizes. Second, the exclusion option provides would-be cooperators the means to protect themselves against more ‘selfish’ individuals in their group. A belief that a grand coalition or other large group will form may suppress one’s inclination toward free-riding from the start; the much higher starting average rate of contribution in the second segment is support for the view that individuals form such beliefs. While cooperation is more valuable in larger groups, there is at least some congestion, so that the MPCR does drop with increasing group size, unlike the other studies with exclusion.32 Thus, in a certain sense our design represents a more difficult test for sustaining cooperation, as the burden increases with group size and it has been found that contributions decrease as the MPCR decreases (see Gächter and Herrmann, 2009, for a survey).

A critical element for our results is that free-riders are not able to exploit cooperators on a long-term basis. Several studies (including Fischbacher et al., 2001; Fischbacher and Gächter, 2010) demonstrate that many individuals are conditional cooperators, who make large contributions until and unless other members of the group make small or no contributions.

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26 Simple aggregate probit regressions clustered by individual show that the coefficient of S is significant (Z = 14.96 and Z = 17.76 in the Main and Capped Efficiency treatments, respectively). We used S for the regressions for each individual (Fig. 3) to avoid having too many independent variables for the limited number of observations per individual.
27 Maier-Roigaud et al. (2010) provide an in-depth summary of the related notion of ostracism.
28 If we define redemption as having contributed 50% or less in either the first or second voting rounds in the first segment and at least an 80% average in the four non-final voting rounds in the second segment, then 7 of 63 individuals in the Main treatment and 13 of 54 individuals in the Capped Efficiency treatment (20 of 117 overall) achieved redemption; with a definition involving 60% and 90%, this becomes 16 of 63 and 9 of 54, respectively (and 25 of 117 overall).
29 We note that the history provided to individuals is limited to the contributions from the last three periods and from the three periods comprising the previous voting round. This shorter history may facilitate redemption, since observers can only focus on recent behavior and not on earlier transgressions.
30 We consider redemption over both segments, but it is true that considering reform within one’s original society avoids learning effects. If we adapt the definition in footnote 26 to just the first segment, Appendix D still shows 9 cases of redemption (14.2%) in the Main treatment and 6 cases of redemption (11.1%) in the Capped treatment.
31 While we note that Ali and Miller (2010) show theoretically that when individuals interact on a social network, permanent ostracism is unsustainable; on the other hand, temporary ostracism achieves the maximal gains from trade that can be achieved by any sub-game perfect equilibrium.
32 We note that we are not claiming that the impact of increasing group size on group returns and stability is monotonic, as coordination and other problems are likely to multiply with really large groups. It is an empirical question regarding the size of the optimal; in fact, we were a bit surprised that 9-person groups survived so well.
Our endogenous group-formation treatments allow conditional cooperators to avoid free-riders, and thus to sustain large contributions. In addition, a non-myopic free-rider may well cooperate strategically, as it rapidly becomes apparent that contributing nothing will very likely lead to being unmatched (or matched involuntarily with other undesirables), with an average payoff near 25. Even if one has selfish preferences and understands the equilibrium if everyone has such preferences, own-payoff-maximization may require full contribution, given expectations that a sufficient number of others will contribute.

Individuals base their current actions on what they expect the future to be, and particularly on how their own actions may affect this future. The precise conditions under which a purely selfish individual should choose cooperation over free-riding will depend on beliefs, but cooperation will not be so rare given the payoff attraction of large groups. The outlook of the efficiency potential of large groups, combined with the expectation of such groups forming, makes current risky actions worthwhile and cooperation is sufficiently safe-guarded by the severe impact of exclusion. Thus, we see behavior in our setting as being primarily determined by a combination of non-myopic own-payoff maximization and conditional cooperation.

5.2. Types

We perform an analysis of the contributions by each individual after the last vote in each segment, as this provides insight into the underpinnings of the observed behavior. Appendix F shows the contributions for each individual and group in periods 13–15 and 28–30. We classify each individual on the basis of his or her contributions and those of the others in the group.

Fig. 4 shows the results of our classification. Individuals are unconditional cooperators (U) if they persist in making high contributions even after observing other members of the group making low contributions in these last three periods. In some cases (U/C), individuals never observe low contributions and so we cannot distinguish between whether they are unconditional or conditional cooperators. In other cases (C/S), individuals cooperate until they observe low contributions and then make low contributions themselves; here we cannot distinguish between conditional cooperation and strategic behavior. Classification S refers to strategic individuals, who choose low contributions before observing anyone else doing so. Finally, some individuals (O) either did not fit into any of these classifications or were single.

We see that there are many individuals in each of these classifications. The overall proportions are 24.4%, 23.1%, 20.5%, and 25.2% for U, U/C, C/S, and S types, respectively (6.8% of all individuals were classified as O). There is a shift toward

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33 Chaudhuri (2011) surveys the literature on conditional cooperation and social norms in public-goods experiments.

34 For example, consider an individual with selfish preferences in an n-person group at the beginning of the penultimate voting round of a segment, who is pondering whether to free ride or to stick to the norm. Free riding leads to expulsion. Thus his or her average per-period payoff in this case is: $(25 - f(n) \times (n - 1)/n + 25$. If one postpones free-riding to the last voting period while sticking to full contribution in the penultimate voting round, then one expects an average payoff of $25 - (25 - x \times f(n) \times (n - 1)/n + 25$, where $x$ denotes the aggregate % of contribution from other group members. For the individual to not free-ride in the penultimate voting period, the first expression must be no greater than the second. In the Main treatment, $x$ must be greater than 31% (50%) if one is in a 9-person (4-person) group. In the Capped treatment, $x$ must be greater than 57% (50%) for these group sizes. There is a greater incentive to stick to the full-contribution norm within large groups in earlier rounds.

35 See Charness and Yang (2008) for a precise definition of “efficiency potential.”
more strategic behavior in the second segment of the session. The proportion of unconditional cooperators was largely unchanged across segments, the proportion of conditional/unconditional cooperators drops dramatically, the proportion of conditional stratégique individuals increases substantially, and the proportion of strategic individuals nearly doubles. The behavior in the second segment may be a better indicator, since there is experience from the first segment. In any event, a sizeable proportion of the individuals, perhaps 35–50%, appear to be conditional cooperators and another sizeable proportion of the population, perhaps 30–40% are strategic. Since conditional cooperators can protect themselves from free-riders (strategic types), these would-be free-riders pursue their self-interest by making large contributions until the last periods and thereby exploiting the scale economies.

6. Conclusion

Can a completely voluntary regrouping mechanism solve the free-riding problem in a PG environment with moderate economies of scale? We provide a mechanism that finds a great degree of success for this mechanism, with the average contribution rate quite high in two treatments with endogenous exit, exclusion, and merger; this contribution rate is slightly (but significantly) smaller in the second treatment, where we cap the social value of a contribution, so that there is no additional efficiency advantage to forming a large group.

Our design offers safeguards that make it difficult for myopic free-riders to seriously interfere with the efforts of conditional cooperators. Driving forces appear to be economies of scale combined with the awareness that bad behavior will result in being expelled from a group and/or being unable to join another. We also feel it is useful for established groups to have a possibility of merging for their mutual benefit; in our design, mergers serve as a complement to the scale economy and we find that cooperative groups can grow quickly. A critical element is the greater efficiency in larger groups, while another very helpful element is the insurance for would-be cooperators that they will be able to ward off would-be free-riders, within a voluntary group formation mechanism. Finally, the possibility of redemption (reversible exclusion) makes it possible to achieve a substantially higher degree of social efficiency.

Ours is an approximation of how groups (and groups of groups) can evolve, adapted so it is manageable for conducting experiments while preserving the essential features. The mechanism differs from those in previous studies with respect to being fluid and dynamic; we provide a general and flexible platform to address both increases and decreases in endogenous size. Change is a prominent feature of society, and allowing both inflows and outflows between and among groups seems a better representation of the environment in the field.

Acknowledgements

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Appendix A-F. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2014.03.005.

References


36 The respective comparisons are 26.5% versus 22.2%, 34.2% versus 12.0%, 15.4–25.6%, and 17.1–33.3%.
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