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Voting on Thresholds for Public Goods: Experimental Evidence

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Abstract

Introducing a threshold in the sense of a minimal project size transforms a public goods game with an inefficient equilibrium into a coordination game with a set of Pareto-superior equilibria. Thresholds may therefore improve efficiency in the voluntary provision of public goods. In our one-shot experiment, we find that coordination often fails and exogenously imposed thresholds are ineffective at best and often counter-productive. This holds under a range of threshold levels and refund rates. We test if thresholds perform better if they are endogenously chosen, i.e. if a threshold is approved in a referendum, because voting may facilitate coordination due to signaling and commitment effects. We find that voting does have signaling and commitment effects but they are not strong enough to significantly improve the efficiency of thresholds.

Keywords: Provision of public goods, threshold, voting, experiments

JEL classification: H41, D72, C92

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1 Introduction

In some cases, public goods have a threshold, i.e. a minimal project size, for technological reasons - building half a bridge does not make much sense - but in other cases, the public good can be provided continuously - think of donations to start a community library. This paper investigates if introducing a threshold to a public good that does not have a specific threshold value for technological reasons can increase efficiency.[1] More specifically, we ask if such thresholds are more effective if they have been approved in a referendum rather than just imposed by some authority.

The issue we investigate is of potential relevance in both the small and the large. For example, consider a fundraising drive to start the community library. Will citizens donate more if the charity commits to a minimal size of the library than if the fundraising drive is started without any lower boundary for the size of the library? To provide an example from the other end of the scale, consider international agreements to abate greenhouse gases. Would nations be willing to contribute more to prevent global warming if the international agency commits to a minimum target for abatement? Are nations more likely to reach the threshold if they approved of the threshold in a referendum than if the threshold was suggested by some international organization? These examples illustrate that our study refers to situations in which potential contributors to the public good can be identified and, therefore, contributors can vote on the threshold but the central authority is weak and does not have the power to enforce contributions to the public good. In the examples above, the charity cannot force citizens to donate, the international organization cannot force sovereign states to reduce greenhouse gases. The mechanism we investigate is therefore a potential remedy to the free rider problem when no strong enforcement institution exists and when the players keep the full decision sovereignty on whether or not to contribute to the public good. All that is required is that an institution can credibly commit not to provide the public good if voluntary contributions are insufficient to meet the threshold.

The theoretical rationale for expecting that introducing a threshold increases efficiency is that a threshold transforms a public goods game with a unique and inefficient equilibrium into a coordination game with a set of additional equilibria in which all players are better off (Bagnoli and Lipman 1989). The intuition for why this transformation may increase efficiency is that a player's contribution can be essential for whether the public good is provided at all.[2] If a single player makes the difference between providing the

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[1] Threshold public goods are also called step-level, binary, discrete, lumpy, or provision point goods.

[2] Note that we investigate the effect of introducing a threshold in the sense of the minimal project size. In a situation without a threshold, the provision of the public good is continuous and proportional to the aggregate contributions. In contrast, in a situation with a threshold, the public good is provided if contributions meet or exceed the threshold but is not provided at all if the threshold is not met. If

public good at the threshold level versus none at all, he may find it in his best interest to contribute. However, this situation typically occurs if others make contributions such that the threshold is "almost" reached, i.e. if it is feasible (and not too costly) for a particular player to "make the difference". If others already contribute more than the threshold (and the public good is provided anyway) or if they contribute too little for a single player to make the difference between provision or not (i.e. the public good is not provided anyway), free riding is optimal for a self-interested player. Thus, thresholds only improve incentives to cooperate if players manage to solve a coordination problem.

The main focus of this paper is to investigate the effect of voting on thresholds, i.e. of choosing the level of the threshold in a vote. In particular, we ask if efficiency is higher (because coordination is more successful) when a threshold has been approved in a referendum rather than exogenously imposed. Our hypothesis is that strong electoral support for a threshold improves coordination because it serves to "signal" a willingness to contribute, i.e. widespread support is a reduced form of communication which shapes expectations. To illustrate, suppose that in a referendum all N voters support threshold level T. It seems plausible in a symmetric game (for reasons of focality and inequality aversion) to assume that, upon learning the result of the referendum, all players expect T to be reached and that all players contribute T/N.[3] In contrast, if only a small majority votes for T, players may hold the belief that some voters will contribute less than T/N each. This may result in contribution of more than T/N by player i (if he thinks he is essential) or in zero contributions (if he thinks aggregate contributions are too low such that his contribution would make a difference). Thus, the signaling effect is theoretically ambiguous and the efficiency-enhancing effect of voting on thresholds is a fundamentally empirical issue which can be systematically investigated only in the experimental laboratory (e.g. Falk and Heckman 2009). However, isolating the signaling effect is demanding even in the laboratory because psychological and statistical selection effects may add to the signaling effect. For example, those voting for threshold T may contribute T/N not because they think it is a best reply to what others do but because they feel committed to comply with a rule they supported. An additional effect results from statistical selection. If players are intrinsically more or less cooperative, and cooperative players tend to vote for higher thresholds, players with higher levels of cooperativeness will select into higher

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contributions exceed the threshold, the public good is again continuous and proportional to aggregate contributions, as in a situation without a threshold. This property is also called the "extended benefits rule" which tends to induce relatively high contributions compared to rules in which contributions beyond the threshold are simply wasted (no rebate) or returned (full rebate) to the participants. See Marks and Croson (1998) for a comparison of these rules and Spencer et al. (2008) for a systematic discussion of alternative rebate rules.

[3] This conjecture is supported by a substantial body of research on social dilemmas showing that under conditions of strategic uncertainty, group members tacitly coordinate their choice behavior by anchoring their decisions on rules of fairness (e.g. Allison et al. 1992, Suleiman et al. 2001).

thresholds.

We systematically test the hypothesis that approving of a threshold in a referendum improves the effectiveness of thresholds in a two-stage game for different threshold levels (low, intermediate or high) and for different refund rates (no, partial or full refund). In stage one, the players vote on implementing a threshold. The players know that if they accept, the public good will be provided only if their total contributions in stage two reach or exceed the threshold. In stage two, upon learning the outcome of the vote, the players make contribution decisions. If a positive threshold is approved, there is a set of equilibria in pure strategies where the threshold is exactly met. Because these equilibria Pareto-dominate the equilibrium of the standard public good game, it is a weakly dominant strategy to vote for the threshold in stage one. Variation of the threshold level is interesting because both benefits and costs of coordination increase with the threshold. Higher thresholds are more efficient if they are reached but players may be less confident that they can be reached, which increases the risk of "wasting" their contribution on a project that turns out not to be implemented.[4] Because of this trade-off, intermediate thresholds may be more efficient than high thresholds, and our experiment allows us to investigate if more ambitious thresholds are more or less efficient than low or intermediate thresholds. We also test the hypothesis at various refund rates (no, partial and full refund) in case the project is not realized. A refund provides partial or full insurance against the risk of "wasting" one's contribution on a project that is not realized. Clearly, such insurance reduces the cost of miscoordination, and we expect better coordination at higher refund rates.

Our main findings are that thresholds are counterproductive if exogenously imposed and if less than full insurance is provided. When full insurance is provided, exogenous thresholds cease to be counterproductive and become merely ineffective as efficiency is the same with no, low or high thresholds. While higher thresholds are generally associated with higher contributions, the contributions often do not increase sufficiently to match the more ambitious thresholds. Higher thresholds induce the belief that others will more generously contribute which increases contributions somewhat, but these beliefs are excessively optimistic. As a result, contributions often fail to meet the threshold.

When thresholds are endogenously chosen in a referendum, we find that thresholds are more popular with full insurance and that intermediate thresholds are more popular than ambitious ones. Thus, voting patterns reflect the (anticipated) risk of coordination failure when a threshold is ambitious and insurance unavailable. We do find that approving of a threshold serves as a coordination device in the sense that expected contributions for chosen thresholds are higher than for imposed ones, and this effect is more pronounced

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[4] A reason might be that the set of asymmetric Pareto-efficient equilibria shrinks with increasing threshold levels.

if the threshold receives stronger support among other voters. However, these effects are weak and cannot significantly reduce the massive coordination failure we observe in our design. As a result, overall efficiency does not increase when participants choose a threshold compared to the case when it has been imposed. Thus, introducing a threshold - whether by fiat or in a referendum - is not an effective cure for the inefficiency in the provision of public goods in our framework.

The paper proceeds as follows. Related literature is discussed in section 2, section 3 explains the experimental design. In section 4 we further discuss the predictions and hypotheses. Section 5 reports the results, and section 6 concludes.

2 Related literature

Mounting experimental evidence shows that voluntary cooperation often results in inefficient outcomes absent institutional remedies (see Ledyard 1995, for a survey). Cooperation-enhancing institutions that have been studied in the lab include competition between teams (e.g. Reuben and Tyran 2009), punishment of free riding in the guise of informal sanctions (e.g. Fehr and Gächter 2000), redistribution (Sausgruber and Tyran 2007, Charness et al. 2006), or exclusion (Cinyabuguma et al. 2005). An obvious alternative to resolve the problem of voluntary contribution is to delegate power to a central authority with the competence to enforce contributions or to change incentives such that contributing is optimal for a self-interested player (e.g. through taxation, subsidies or matching grants). If such incentives are optimally set, it is matter of individual rationality to contribute optimally (e.g. Tyran and Feld 2006). There is an extensive literature on tax and subsidy mechanisms, in particular incentive-compatible mechanisms.[5] These studies are concerned with "pure" public goods problems, i.e. that have a unique free-riding equilibrium. An important difference to our approach is that such mechanisms require institutions that are able to enforce taxes and transfers between the players.

However, such institutions may not pre-exist but have to be created by players. A recent literature investigates the endogenous formation of institutions. For example, Kosfeld et al. (2008) show that a subset of players may successfully implement a costly

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[5] For a survey see Laffont (1987). The well-known Groves-Ledyard mechanism (Groves and Ledyard, 1977) levies a tax on choices with externalities on others; it yields an efficient level of the public good given that true preferences are revealed. For experimental tests of the Groves-Ledyard mechanism see Smith (1979), Harstad and Marrese (1981) and (1982), and Chen and Plott (1996). In the Falkinger mechanism the central authority sanctions negative and rewards positive deviations from the average contribution to the public good (Falkinger 1996). Falkinger et al. (2000) have shown in an experiment that the mechanism is capable to produce efficient levels of contributions. Andreoni and Bergstrom (1996) have proposed a similar approach and Kirchsteiger and Puppe (1997) provide a comparison of the two mechanisms.

organization to provide a public good. Gürerk et al. (2006) show that people may opt for an institution with sanctioning possibilities to protect themselves against free riding. Putterman et al. (2009) provide participants with a menu of tax bases, tax exemptions and tax rates to investigate if participants are able to select a combination that induces rational and self-interested participants to contribute efficiently in a standard public goods game (they overwhelmingly do). Tyran and Feld (2006) find that experimental subjects also tend to accept non-deterrent sanctions when deterrent sanctions are not available, and that such non-deterrent sanctions increase efficiency if they have been enacted in a referendum rather than imposed exogenously. Ertan et al. (2009) allow subjects to vote on the rules governing punishment. They observe that subjects disallow punishment of above-average contributions and that the institutional structure, which gets subsequently implemented in the vote, tends to increase efficiency. What is common to these approaches is that they all require the imposition of sanctions on free riders. In contrast, the threshold mechanism proposed in this study does not require any sanctioning institution.

The effects of exogenously imposed threshold levels have been extensively studied in the experimental literature, but not, to the best of our knowledge, the effects of endogenous thresholds. The previous literature tends to find rather mixed results on imposed thresholds. For example, the literature review of Croson and Marks (2000) shows that results of previous studies have varied widely with success rates ranging between 10% and 82%.[6] This meta-study shows that coordination tends to be more successful with a high ratio of total benefits of the public good to its costs [7], with higher refund rates and communication. Leadership contributions and other possibilities to choose sequentially also seem to increase the effectiveness of thresholds (e.g., List and Rondeau 2003, Cadsby and Maynes 1999, Coats et al. 2009). Controlled evidence from the field seems to support these findings (List and Lucking-Reiley 2002). Rondeau et al. (2005) report higher efficiency under a threshold mechanism when contributions below the target are fully refunded.

Closely related to our study are a field and lab experiment by Rondeau and List (2008) and a theoretical contribution by Gerber and Wichardt (2008). Rondeau and List (2008) investigate (among other things) the effect of introducing a threshold into a public good that does not have a threshold for technological reasons (a fundraising drive by the Sierra Club to provide environmental education) in a field experiment under conditions very similar to our lab study (contributions are fully refunded, i.e. $r = 1$ if the threshold is not met and the "extended benefit rule" that we use in all treatments applies). In

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[6] Our definition of a threshold as a minimum project size (allowing for project sizes exceeding the threshold) differs from some experimental studies surveyed in Croson and Marks (2000) which define the threshold as the only feasible project size.

[7] Note that we hold this ratio, which is also called the step return, constant at a level of 1.5 across all conditions.

line with our results, the authors find that a higher threshold level (USD 2500 vs. USD 5000) increased donations, but the increase was insignificant and donations (USD 945 vs. USD 1375) were in both cases clearly insufficient to meet the threshold. The authors also implement a one-shot game in the lab with thresholds levels at USD 22.50 vs. USD 45. Now, contributions increase significantly (USD 5.4 vs. USD 7.5) but the increase is again less-than-proportional compared to the increase in the threshold (39% vs. 100%). We infer from these numbers (the paper does not say) that the "success rate" must have fallen with the threshold level, i.e. that higher thresholds were counterproductive in this sense. Gerber and Wichardt (2008) suggest a mechanism to provide a public good in the absence of sanctioning institutions. In their two-stage game, the players choose to pay a deposit in stage one. The deposit is lost unless a player contributes to the public good. Hence, the deposit serves as a commitment device that renders contributing to the public good a dominant strategy.

3 Experimental design

Our design has 6 treatments which vary along 2 dimensions (see Table 1). We vary (i) whether thresholds T are imposed (EXO) or endogenously chosen in a majority vote (END) and (ii) the refund rate r across treatments. Each subject only participates in one treatment, i.e., a subject makes choices either in EXO or END and with only one of the refund rates. The numbers in parentheses in Table 1 show the number of participants in each condition. For example, we had 36 subjects participating in condition END0, which means that these subjects voted over threshold levels (END) and received no refund in case a threshold was not met ($r = 0$). The next two sections explain parameters and procedures in EXO and END, respectively.

Table 1: Treatments of the experiment (number of subjects per cell in parenthesis)

	Refund rate		
Decision mode	0%	50%	100%
END	END0 (#Subj.: 36)	END50 (#Subj.: 36)	END100 (#Subj.: 36)
EXO	EXO0 (#Subj.: 36)	EXO50 (#Subj.: 33)	EXO100 (#Subj.: 33)

3.1 Imposed thresholds (EXO)

Treatments in EXO implement a standard version of the threshold public goods game (see Isaac, et al. 1989). Subjects are randomly assigned to groups of $N = 3$. We use "partner" matching, i.e. groups remain constant throughout the experiment. The subjects are endowed with $E = 20$ experimental points and decide how many of these point to keep or contribute to a public good. The payoffs are determined by

$$\pi_i = \begin{cases} E - c_i + \alpha \sum_j c_j, & \text{if } \sum_j c_j \geq T \\ E - c_i + r c_i, & \text{if } \sum_j c_j < T, \end{cases} \tag{1}$$

where π_i is subject i's payoff in points, c_i is i's contribution to the public good, and T is the threshold. If the sum of contributions within a group reaches or exceeds the threshold, each subject receives $\alpha = 0.5$ times this sum as payoff from the public good in addition to the amount kept, $E - c_i$. If the sum of contributions fails to meet the threshold, the public good is not provided and contributions are refunded at the rate r, with $0 \leq r \leq 1$. The parameter α is the marginal per capita return (MPCR) from the public good.

In EXO, participants make contribution choices for low ($T = 21$), intermediate ($T = 39$) and high ($T = 57$) thresholds. The case with $T = 0$ is a standard linear public goods game and serves as a control. The subjects make contribution choices for each of these thresholds in a randomized order. We provide no feedback about outcomes until the end of the experiment. We chose thresholds which are divisible by $N = 3$ to facilitate coordination, thus making equal contribution by all group members focal.

Each participant makes contribution choices given one refund rate, r. Refund rates vary the cost of contributing when the public good is not provided. For example, a value of $r = 0$ makes coordination failure costly because it implies that all contributions to the public goods are "wasted" if the threshold is not reached. In contrast, a value of $r = 1$ implies full insurance in the sense that contributions to the public good are fully refunded should the threshold not be met. Table 2 summarizes the parameters of the experiment.

Table 2: Parameters of the experiment

	Variable	Value
Endowment	E	20
Group size	N	3
MPCR	α	0.5
Threshold	T	$\{0, 21, 39, 57\}$
Refund rate	r	$\{0, 0.5, 1\}$

For each threshold level, participants make only one contribution decision. The one-shot nature of the game serves to investigate if participants are able to solve the difficult coordination problem absent any opportunities for communication, learning and experience.

For each threshold, subjects state their expectations on the contributions of others. The data on beliefs enables us to evaluate best-response behavior. Beliefs are elicited by rewarding a correct point prediction by an additional payment of 10 points. Point incomes from all choices are converted into money and paid out at the end of the experiment according to the exchange rate of 10 points = 0.8 Euros.

3.2 Voting on thresholds (END)

The END treatments are essentially the same as the EXO treatments except that participants vote on which threshold to implement before making contribution decisions. Voting is over pairs of thresholds T_L and T_H, with $T_L < T_H$. Participants vote on all 6 pair-wise comparisons of thresholds, i.e., $T_L = 0$ vs. $T_H = 21$, $T_L = 0$ vs. $T_H = 39$, ..., $T_L = 39$ vs. $T_H = 57$. To avoid sequence effects, we randomize the order of voting over subjects. Participants make conditional contribution decisions (i.e. according to the strategy method) for all possible outcomes of the vote.

More specifically, subjects make contributions for the case that zero, one, or two of the others in the group vote for T_H. Obviously, the outcome of the referendum may depend on the subject's own vote. For example, if a subject has voted for T_H, T_H is accepted for $H_{-i} \in \{1, 2\}$, while if the subject has voted for T_L, T_H is accepted only for $H_{-i} = 2$. The decision screen in the experiment accounts for this fact (see Appendix).

Applying the strategy method has the important advantage that we observe choices for all contingencies, including the cases that are not implemented. In particular, we can analyze how the contribution behavior depends on the subject's own voting and on other group members' voting choices. This rich data allows us to investigate the effects of voting choices on contributions - the main purpose of the paper - in great detail. For example, it allows us to disentangle the signaling and commitment effects discussed below. However, the use of the strategy method has the disadvantage to make choices more complicated - participants make 18 (6 votes × 3 cases) contribution choices in END compared to 4 contribution choices in EXO - and perhaps also more cognitively demanding.

In treatment END, participants state their beliefs about the contributions by others in the group after having made voting and contribution choices. Since the subjects make conditional contribution decisions, they also state beliefs conditional on all possible voting outcomes $H_{-i} \in \{0, 1, 2\}$. In addition, we ask subjects to state their beliefs regarding H_{-i}, i.e. the number of others' votes for the higher of the two thresholds, T_H.

In total, 210 (see Table 1) undergraduate students from the University of Innsbruck participated in our computerized (z-Tree by Fischbacher 2007) experiment. A session lasted approximately 45 minutes and the average subject earned Euro 10.2.[8]

4 Predictions and hypotheses

The game without a threshold ($T = 0$) has a unique inefficient equilibrium in which all participants contribute zero, $\sum_j c_j = 0$. The threshold public goods game with $T > 0$ has multiple pure-strategy equilibria (see e.g. Isaac et al. 1996). In addition to the inefficient free-riding equilibrium, there is a set of efficient equilibria that contains all feasible combinations of contributions along the mutual best response where the threshold is exactly met, $\sum_j c_j = T$. This set contains symmetric equilibria in which each participant contributes T/N and asymmetric equilibria in which participants contribute different amounts.[9] Because $\alpha N > 0$, equilibria involving positive contributions Pareto-dominate the zero-contribution equilibrium.[10]

Figure 1 illustrates individual best responses for the low ($T = 21$), intermediate ($T = 39$) and high ($T = 57$) threshold as a function of the sum of contributions by others in the group. The figure is drawn for $\alpha = 0.5$ and $N = 3$. For example, at $T = 21$, if others' contributions are below 10 points, the individual cost to meet the threshold exceeds the individual benefit from the public good. A rational and self-interested subject therefore contributes zero to the public good. If others contribute between 11 and 20 points, the best response is to contribute just as many points as needed to reach the threshold.[11] For others' contributions above 20 points, the best response is to contribute zero because his contribution is not essential for implementation of $T = 21$. The figure shows the analogous best response functions for $T = 39$ and $T = 57$.

In treatment END, the game is solved by backward induction. If a majority in a group votes for a positive threshold over the "zero threshold", this decision transforms a social dilemma game with a unique inefficient Nash equilibrium into a coordination game with a set of Pareto-superior equilibria. It is therefore a weakly dominant strategy to vote for

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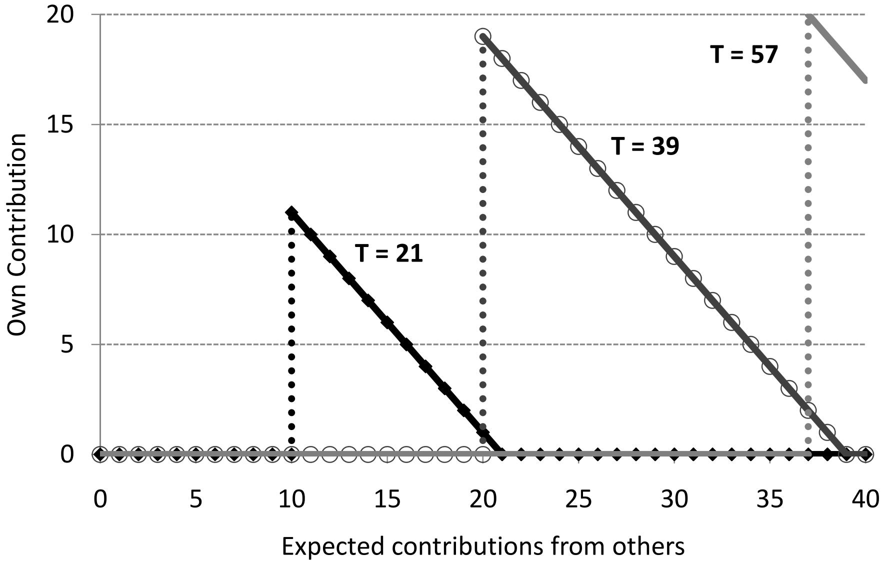
[8] Subjects were recruited via Email. Those with experience in public good experiments were excluded from the recruitment. The subjects were randomly assigned to treatments. We check proper understanding of the instructions (which are available from the authors on demand) in a series of control questions. The sessions did not start before all participants answered these questions correctly.

[9] Note that the equilibria are given by $\sum_j c_j = 0$ plus $\sum_j c_j = T$, with the additional restriction that none of the subjects contributes more than 10 points at $T = 21$ and 19 points at $T = 39$.

[10] Note that for $r = 1$, there is a larger set of inefficient equilibria. These equilibria obtain when an efficient equilibrium is not feasible, i.e., $E < (\sum_j c_j - c_i)$, and subject i is indifferent between contributing zero or any positive amount to the public good.

[11] Note that the figure only serves illustrative purposes. In the experiment subjects contribute integer numbers as points to the public good.

Figure 1: Best response as function of the sum of others' contributions for $T \in \{21, 39, 57\}$



a positive threshold if the alternative is a zero threshold. Matters are more complicated when the vote is between two positive thresholds $T_L > 0$ and $T_H > 0$ because (empirically debatable) assumptions about the equilibrium selection in the contribution stage of the game must be made. Unless otherwise stated, we will therefore restrict our analysis to the decisions between $T_L = 0$ and $T_H > 0$. The within-subject variation of the threshold nevertheless enables us to evaluate which threshold level is most popular and to compare this to the empirically optimal threshold.

In our one-shot design participants cannot learn from experience and the risk of miscoordination is therefore high. As illustrated in Figure 1, higher thresholds are associated with higher critical levels triggering positive contributions by rational and self-interested players. Since $\alpha N > 1$, the set of equilibria with higher thresholds contains equilibria that Pareto-dominate all equilibria with lower thresholds. This fact may make these equilibria more focal and ease the coordination problem. At the same time, if the threshold is high, the cost of miscoordination and thus deviating from equilibrium is also high. The net effect is therefore indeterminate and the question of which threshold level is more efficient is fundamentally empirical.

We hypothesize that voting improves efficiency by reducing the risk of miscoordination. Our hypothesis is based on three arguments. First, the number of votes for a threshold may provide a signal for others' cooperativeness. Second, voting may be determined by subjects' beliefs about others' behavior as well as their personal characteristics such as social preferences or cognitive skills. If such characteristics are relevant also for the behavior in the game, voting may give rise to selection effects that influence the outcome of the game. Finally, a subject who votes in favor of a threshold may feel committed to also contribute to the successful provision of the public good. It is important to note that these arguments do not univocally support a positive effect on efficiency. For instance, voters may vote strategically and send misleading signals. Moreover, depending on the expected contributions with and without a threshold, a signal of contributions from others can increase, decrease or leave unchanged optimal contributions (see Figure 1). The effect of approving a threshold in a referendum is thus theoretically indeterminate and therefore fundamentally an empirical issue.

5 Results

Section 5.1 presents the results for exogenous thresholds. Our main findings from this analysis are that exogenous thresholds are at best ineffective (with full insurance, i.e. $r = 1$) and most often (in all other cases) counterproductive. Thus, exogenous thresholds do not increase efficiency in our experiment. The counterproductive effect is most pronounced with the most ambitious threshold ($T = 57$). While higher thresholds tend to induce higher expectations and somewhat higher contributions, the increase in contributions is usually insufficient to reach the more ambitious threshold as shown in section 4.2. For example, when increasing the threshold by a factor of 2.7 from $T = 21$ to $T = 57$ with partial refund ($r = 0.5$), we find that expectations increase by a factor of 1.6, and contributions only increase by a factor of 1.4, falling clearly short of the required factor 2.7 in this example. The consequence is that the success rate, i.e. the percentage of cases in which the threshold is reached falls from 73% to 27%, and efficiency measured by average payoffs falls by 23%.

Section 5.3 shows that voting on thresholds does not improve efficiency of thresholds. Again, expectations and contributions increase with chosen thresholds, but the increase falls short of what is required to meet the more ambitious threshold. To continue the example in the previous paragraph with moving from $T = 21$ to $T = 57$ with partial refund ($r = 0.5$), efficiency falls in END by 19% which is in the same ballpark as the drop observed in EXO (23%). To explore the reasons for this result, we discuss voting behavior and the effects of voting on expected and actual contributions.

5.1 Results in EXO

In EXO the main variables of interest are the "success rate" at a given threshold, i.e. whether subjects manage to coordinate on the Pareto-superior equilibria of the game and how efficiency is related to various threshold levels. In addition, we are interested in how these effects interact with the refund rate.

Figure 2 shows that average contributions monotonically increase with the threshold at all refund rates. For example, in EXO0 with no refund (upper left panel of Figure 2), average contributions are 6.4 without a threshold ($T = 0$), and increase to 8.3 ($T = 21$), 12.4 ($T = 39$), and 14.5 with the most ambitious threshold ($T = 57$). Pairwise tests reveal significance ($p < 0.05$) in 16 out of 18 cases.[12]

Figure 2 also suggests that contributions are higher with a full refund (EXO100) than with partial or no refund. For example, at $T = 57$, contributions in EXO100 are 18.4 vs. 14.2 in EXO50 and 14.5 in EXO0. These findings are in line with the conjecture that lower refund rates increase the cost of miscoordination which makes the participants more reluctant to contribute. These differences are significant at p-values of $p = 0.021$ and $p = 0.076$ (two-sided Wilcoxon ranksum test).[13]

Figure 2: Average contributions by threshold and refund rate in treatment EXO

Figure 3 shows efficiency as measured by the average payoff in points by threshold. The figure reveals that the payoffs tend to fall with thresholds with no (EXO0) and partial (EXO50) refund, and this drop is particularly pronounced for the most ambitious

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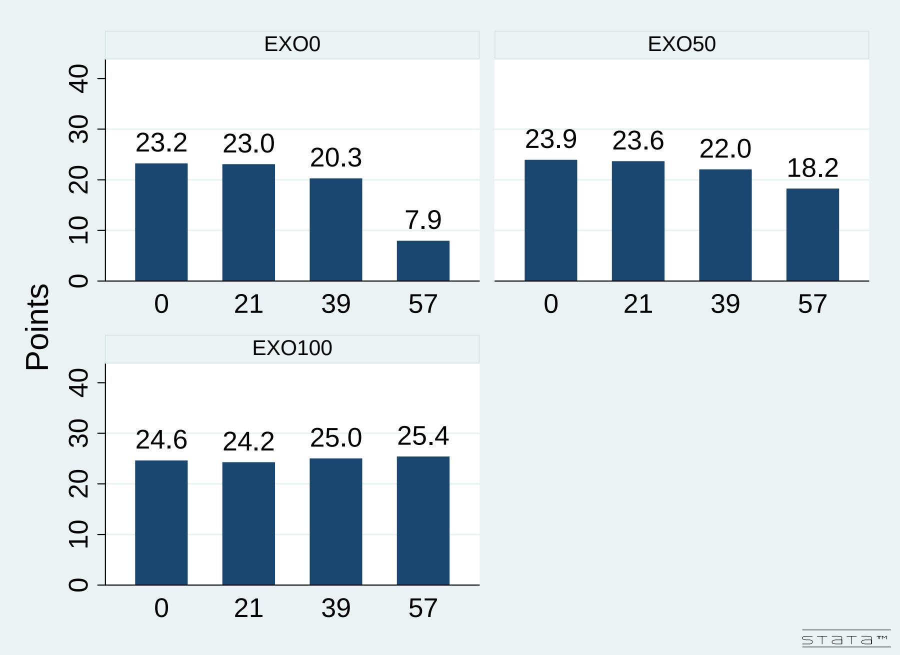
[12] We use a two-sided Wilcoxon signed rank test. The two insignificant comparisons are thresholds 39 vs. 57 in EXO0 and 0 vs. 21 in EXO100.

[13] Contributions in EXO0 and EXO50 are no significantly different: $p = 0.682$.

threshold. In these treatments, average payoffs at $T = 57$ are significantly lower than those for $T \in \{0, 21, 39\}$ (at p-values $p < 0.05$). With full refund (EXO100), average payoffs are essentially constant across thresholds and the threshold level has therefore virtually no impact.

Figure 3: Average payoff by threshold and refund rate in treatment EXO



We conclude that exogenously imposing a threshold does not increase efficiency and ambitious thresholds are counterproductive absent full insurance in our design. The reason for these findings is that while contributions do increase with the threshold level, the increase is often insufficient to match the increase in the threshold.

Table 3 (upper panel) shows the “success rate”, i.e. the share of groups who manage to reach or surpass the threshold. With zero or partial refund, low success rates are particularly costly because contributions are wasted in this case. The table shows that the average success rate decreases dramatically with the size of the threshold, whereas it clearly increases with the refund rate. Regressing individual payoffs on a constant, the own contribution, and indicator variables for the thresholds and refund rates reveals (i) significantly lower payoffs under a high threshold than under zero threshold and (ii) significantly higher payoffs under a partial and full refund than under no refund ($p < 0.05$). Yet, even a modest threshold under full refund does not improve efficiency compared to the standard linear public goods game (see EXO100 in Figure 3).

Table 3: Success rates by treatment

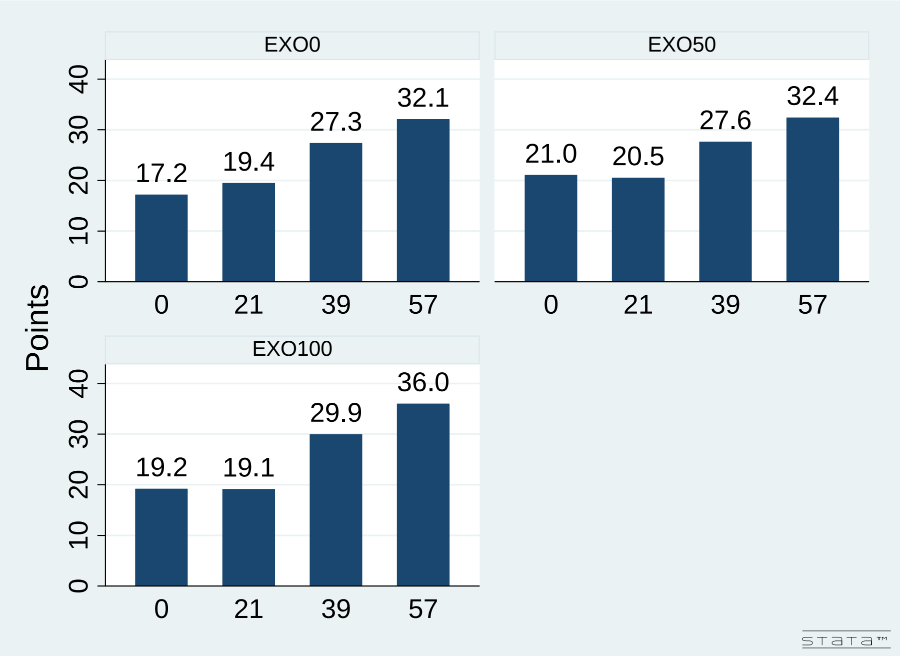
		EXO0	EXO50	EXO100	*avg.*
	21	0.75	0.73	0.82	*0.76*
Threshold	39	0.58	0.55	0.82	*0.65*
	57	0.17	0.27	0.55	*0.32*
	avg.	*0.5*	*0.52*	*0.73*	*0.53*
		END0	END50	END100	*avg.*
	21	0.45	0.67	1.00	*0.68*
Threshold	39	0.38	0.62	0.73	*0.57*
	57	0.10	0.36	0.64	*0.46*
	avg.	*0.35*	*0.58*	*0.76*	*0.57*

5.2 Discussion of results in EXO

Why do the subjects increase their contributions with the threshold as shown in Figure 2 despite the fact that this behavior does not increase, and often reduces, their payoffs? The answer to this question comes in three parts. The first part is that the threshold level provides a signal about others' contributions. If met, a high threshold improves the efficiency of the Pareto-superior equilibria. For some of these equilibria, a subject may rationally expect high contributions from others. At the same time, if the threshold is high, the cost of miscoordination and thus deviating from equilibrium is also high. This argument might induce lower expectations. A priori, the direction of the signal is therefore not clear. Figure 4 shows that subjects expect higher contributions by others if the threshold is high. The figure shows the subjects' average expected contributions per threshold and treatment. This observation indicates that the prospects of reaching the good equilibria of the game was more salient in participants' minds than the cost of miscoordination.

The second part of the answer concerns the subjects' reaction given their beliefs. Table 4 shows that about a third (34% to 36%) of all subjects choose exact best responses (=BR) to their expectations. The numbers in parentheses indicate that a sizeable fraction of subjects within this class hold focal beliefs, i.e., beliefs about others' contribution equivalent to $\frac{2}{3}T$. Between 51% and 65% of subjects contribute more than their best response (>BR). This high share of "overcontributing" subjects can be explained by three factors. First, subjects overcontribute to avert the risk of not reaching the threshold. Second, since the contributions can have positive externalities on others within the group, subjects may also overcontribute due to social preferences. Finally, there may be decision errors. However, since only few subjects contribute less than the best response (<BR) the explanatory power of unsystematic decision errors is limited. The observation that

Figure 4: Average *expected* contributions by threshold and refund rate in treatment EXO



many subjects hold focal beliefs to which they choose a best response, and the fact that many subjects overcontribute given their beliefs explains why an increase in expected contributions (see Figure 4) translates into an increase in own contributions (see Figure 2).

Table 4: Number of subjects in EXO who contribute exactly (=BR), less than (<BR), and more than (>BR) best response towards own belief

	Threshold	=BR	 BR	#obs.
EXO0	$T = 21$	11 (6)	2 (0)	23 (6)	36
	$T = 39$	12 (7)	4 (1)	20 (2)	
	$T = 57$	16 (8)	3 (1)	27 (2)	
EXO50	$T = 21$	12 (8)	0 (0)	21 (0)	33
	$T = 39$	12 (10)	4 (1)	17 (0)	
	$T = 57$	15 (8)	2 (1)	16 (0)	
EXO100	$T = 21$	10 (7)	2 (1)	11 (1)	33
	$T = 39$	13 (11)	1 (0)	19 (0)	
	$T = 57$	11 (8)	1 (0)	21 (2)	

Note: In parenthesis is the number of subjects who expect focal contributions (i.e., $\frac{2}{3}T$).

The third part of the answer is that, despite the positive effects of thresholds on expected contributions, coordination often fails. The most likely explanation is that expectations are imprecise and biased. The data shows a vast variation in the difference between expected and actual contributions: averaged over all thresholds and treatments, the standard deviation of this difference is 14.4 points. In addition, subjects tend to overestimate others' contributions. On average, the subjects expect others to contribute 2.1 points more than they actually do contribute ($p = 0.001$, Wilcoxon signed rank test). These figures do not come as a surprise given the findings in the previous literature. With best response functions that are kinked and decreasing for important ranges of expectations, coordination is difficult especially in the one-shot game. In fact, Isaac et al. (1989) reported success rates similar to ours' for the first period of the repeated game.

5.3 Results in END

This section reports the results for the endogenous treatments. We first ask which threshold is most popular. We then explore how voting affects choices and efficiency in the game.

Voting and aggregate outcomes: Table 5 shows acceptance of the higher of the two thresholds in each pairwise vote by treatment. The numbers in parenthesis show aggregate acceptance rates. In END0 and END50, the low threshold $T = 21$ is clearly the most popular as it is the unique majority winner. In all pairwise comparisons, a majority of voters prefer $T_H = 21$ and $T_H = 39$ over $T_L = 0$, and it prefers $T_L = 21$ over $T_H = 39$ and $T_H = 57$. This result suggests that the subjects anticipate the risk of miscoordination at a high threshold. Indeed, when this risk is eliminated ($r = 1$), the majority winner is $T = 57$ in END100.

Table 5: Individual (aggregate) acceptance in percent for T_H ($T_H > T_L$)

	END0	END50	END100
0 vs. 21	56% (58%)	56% (50%)	69% (58%)
0 vs. 39	53% (67%)	61% (58%)	72% (83%)
0 vs. 57	31% (25%)	39% (33%)	64% (75%)
21 vs. 39	44% (50%)	31% (42%)	64% (58%)
21 vs. 57	44% (42%)	31% (33%)	67% (75%)
39 vs. 57	36% (17%)	31% (25%)	56% (58%)

Despite the support for positive thresholds, voting does not increase aggregate efficiency. Figure 5 shows efficiency as measured by aggregate payoffs in the endogenous treatments.[14] The figure shows that endogenously selecting a threshold does not matter

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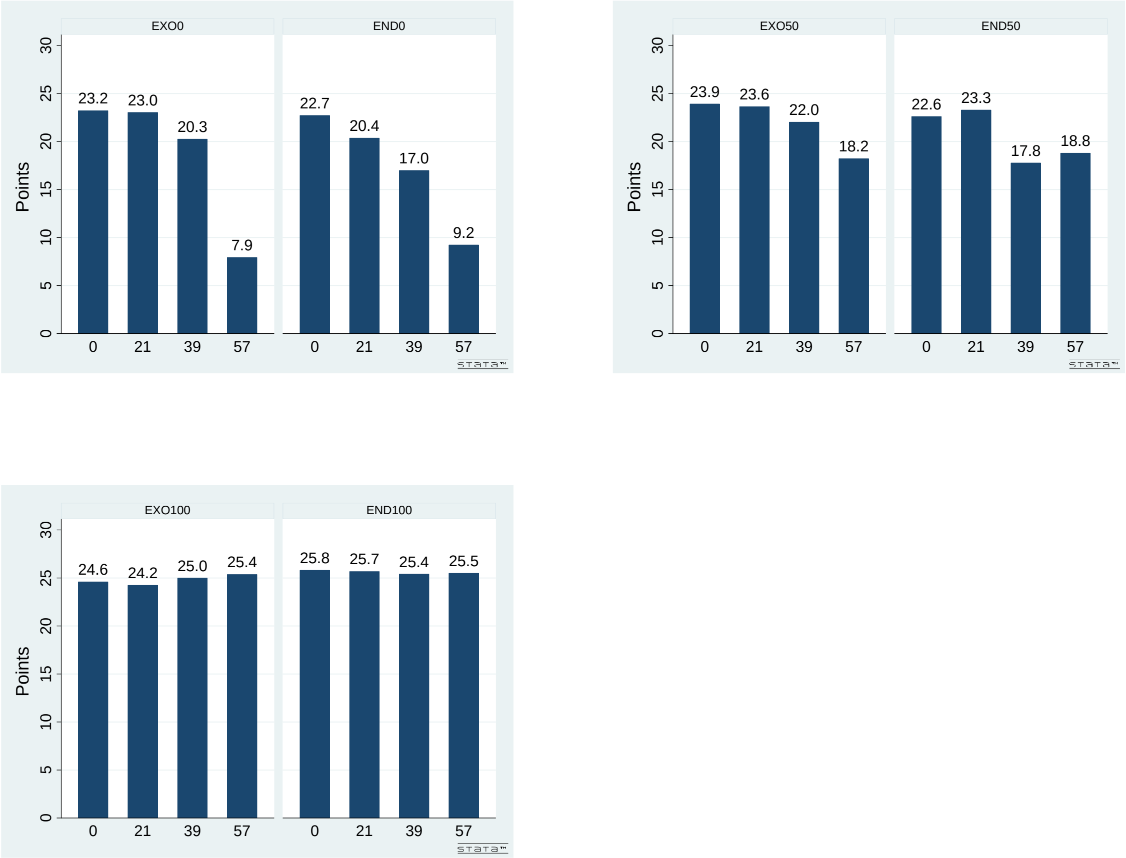
[14] In principle, contributions may not only depend on the outcome of the vote but also on the baseline

Figure 5: Average payoff by threshold and refund in treatments EXO and END



for payoffs.[15] As before, the reason for this outcome is that subjects often fail to reach the threshold (see Table 3, lower panel). We now explore the effect of voting in more detail.

Signaling: As contributions are essentially driven by expected contributions, voting may make a difference if the voting outcome effectively signals others' contributions. In the left panel of Figure 6 we plot subjects' expected contributions by others' voting behavior.[16] The figure shows averages over all refund rates and has been constructed as follows. We consider the three pairwise votes between $T_L = 0$ and $T_H \in \{21, 39, 57\}$, where T_H has been accepted by the group. To keep the aggregate voting outcome constant, we concentrate on the cases where the decision maker plus at least one of the other subjects

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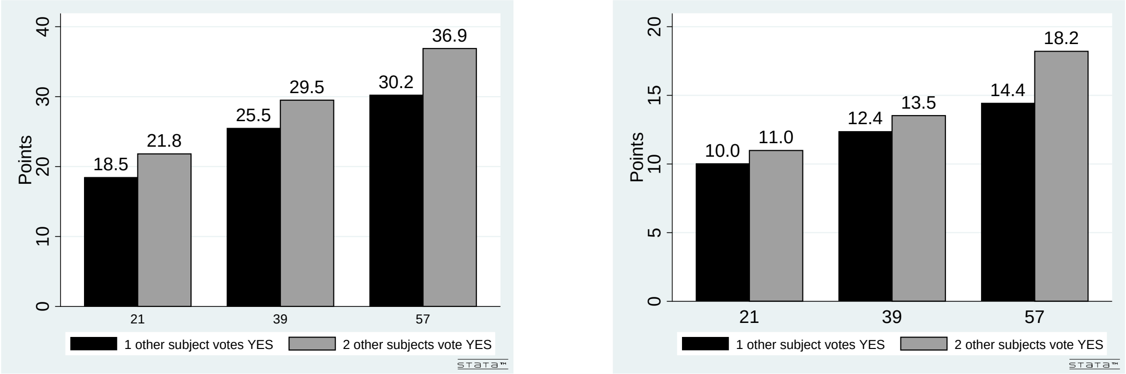
option in the voting choice. To assure a constant default for the voting decisions, Figure 5 only shows data for voting choices between $T_L = 0$ and $T_H > 0$. However, the overall picture remains the same if we also include the data for choices between $T_L > 0$ and $T_H > 0$.

[15] We ran 12 pairwise comparisons across treatments for all 4 thresholds and 3 refund rates. These tests show no significant results, with only one exception: for $T = 39$ payoffs are smaller in END50 than in EXO50 ($p = 0.059$, according to a two-sided Wilcoxon rank sum test).

[16] Remember that we have elicited expected and own contributions conditional on the voting behavior of others in the group (see section 3).

Figure 6: Expected (left) and own contributions (right) and others' voting



in the group have voted for $T_H > 0$. The bars show average expected contributions from others (between 0 and 40 points) according to whether one or two other subjects have voted for T_H.

The results indicate a significant signaling effect of others' voting. On average over all decisions, an additional vote for T_H from the group increases expected contributions by 4.5 points. In addition, the effect increases with the threshold. For $T_H = 21$ the additional vote signals higher contributions by 3.3 points; for $T_H = 39$ and $T_H = 57$, the respective numbers are 4.0 and 6.6 points.[17]

The right panel of Figure 6 shows a subject's own contribution by others' voting. While the effects are less pronounced for contributions than for expectations, an additional vote for T_H significantly increases subjects' contributions. The average contribution increases by 1.8 points. Calculated separately by threshold level, for $T_H = 21$, $T_H = 39$, and $T_H = 57$, the respective numbers are 1.0, 1.1, and 3.8 points. Except for $T_H = 39$ ($p = 0.120$), these effects are significant at $p < 0.05$. Note that these results are not trivial. According to the best response (see Figure 1), an increase in the expected contributions does not necessarily translate into actual contributions. On the other hand, it is important to note that the positive signalling effects of voting are insufficient to increase the efficiency of subjects' play.

Selection and commitment: Voters who approve of a positive threshold may do so because they expect sufficiently high contributions from others. If so, voters would rationally select into a threshold regime according to their expectations. To evaluate this argument empirically, Figure 7 compares the average expected as well as the average own contributions between YES- and NO-voters. The figure has been constructed analogously to 6. However, to keep constant the aggregate voting outcome, we now only consider the

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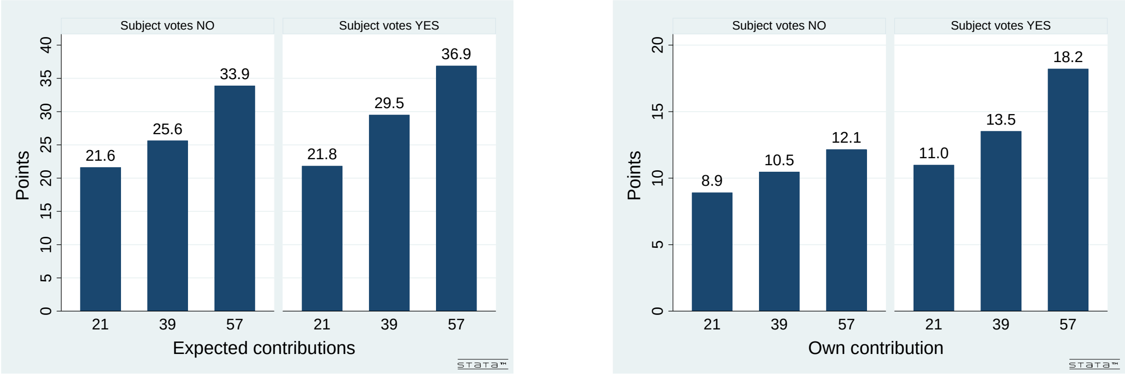
[17] All these effects are significant at $p = 0.000$ according to a two-sided Wilcoxon signed rank test.

Figure 7: Average expected (left) and own contributions (right) by vote



cases where two of the other voters in the group have voted for T_H.

The left panel of Figure 7 shows that YES-voters, i.e. those who themselves approve of the high threshold, expect slightly higher contributions from others than NO-voters. However, the difference in expectations is small and insignificant for $T_H = 21$ ($p = 0.990$) and $T_H = 39$ ($p = 0.252$). The only significant effect occurs for $T_H = 57$ ($p = 0.012$). At least for a high threshold, this observation indicates that subjects' approval is partially due to fact that they expect high contributions from others.

Selection into a threshold level may happen due to heterogeneous social preferences. To obtain a measure of cooperativeness, we let the subjects to play a one-shot standard linear public goods game prior to playing the threshold public goods game. The payoffs were determined according to $\pi_i = E - c_i + \alpha \sum_j c_j$, without mention of any threshold. The subjects did not receive feedback on the outcome of this choice until the end of the entire experiment. The parameters and procedures were the same as the ones described above. Using the individual-level contributions from this game as a proxy for the subjects' cooperativeness, we find no correlation between this variable and voting.[18]

In addition to selecting into a threshold level, subjects may raise their contributions because they feel committed to their vote. The right schedule of Figure 7 shows the average own contribution conditional on the subject's vote. It shows that YES-voters contribute more than No-voters for $T_H = 21$ ($p = 0.063$), $T_H = 39$ ($p = 0.042$), and $T_H = 57$ ($p = 0.001$). While both effects seem to partially play a role, the relatively large effect of the voting behavior on the own contributions suggests that the commitment effects dominate any selection effects. Further support for this conjecture comes from analysis of best-response behavior. Presumably, subjects who choose a threshold

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[18] A linear probability model including a constant, the refund rate, and the threshold the subjects' contributions to the public good does not explain any variation: the estimated parameter is 0.001 at $p = 0.684$.

based on their expectations are more likely to choose contributions in accordance with their best response. This link is broken if a subject raises own contributions because of a commitment with the own vote. To test, we calculate the difference between own contributions and the best response towards expected contributions from others. We find that NO-voters deviate by less from their best response than YES-voters (2.76 vs. 5.78 points, $p = 0.030$), thus providing further evidence for a commitment effect.

6 Discussion and conclusion

We have studied the effect of introducing a threshold into a public goods game by voting. A priori, this is a promising approach when there is no predefined threshold for technological reasons, participants can be identified (and can vote) but where there's no central authority with the power to enforce contributions or punish non-compliance. Examples range from the small (e.g. a fund-raising drive to start a community library only if a sufficient amount is raised to buy some minimal number of books) to the large (e.g. a voluntary agreement of nations to reach a minimum abatement of greenhouse gases).

We find that accepting a threshold has significant signaling and commitment effects, but these effects are insufficient to improve the efficiency of public-good provision in our design. In both endogenous and exogenous conditions, participants in our experiment are challenged to solve a difficult coordination problem absent previous experience, opportunities for communicating or learning from mistakes within the game, and in a rather complex (we use the strategy method) and context-free (we use neutral wording in the presentation of the situation to participants). These design aspects suggest that we provide a demanding test for the efficiency-improving effect of voting on thresholds. However, our design can also be considered to be favorable for coordination since the players were symmetric, i.e. the endowments, costs of contributing and benefits from the provision of the public good were the same for all participants, and the symmetry was common information. In addition, the thresholds to choose from were divisible by N which should have made equal contributions to reach the threshold focal. In most naturally occurring examples such as donations for a community library or greenhouse gas abatement on a global level, players are not symmetric. For example, in the context of abatement, some countries are large (i.e. their emissions are large) and some are poor (i.e. their opportunity cost of abatement is high), and to some both or neither applies. In this situation, coordination can be expected to be more difficult than in our experiment because equal contributions are neither focal nor fair.

In summary, we provide the first study to show that introducing thresholds, both imposed or approved in a referendum, is no sure cure for the inefficient voluntary provision of public goods when no other, more intervention-intense, mechanism is available. An interesting alley for further research is to investigate the robustness of this result by adding more context (e.g. in a field experiment), allowing for learning (e.g. in a repeated laboratory experiment), making contributions sequentially, or by adding opportunities for communication.

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Appendix: Decision Screens

Voting screen:

1 von 6

Verbleibende Zeit [sec]: 14

Phase 1

Abstimmung 1:

Alternative A: 0
Alternative B: 21

Stimmen Sie für Alternative A mit einer minimalen Projektgröße von 0 oder Alternative B mit einer minimalen Projektgröße von 21?

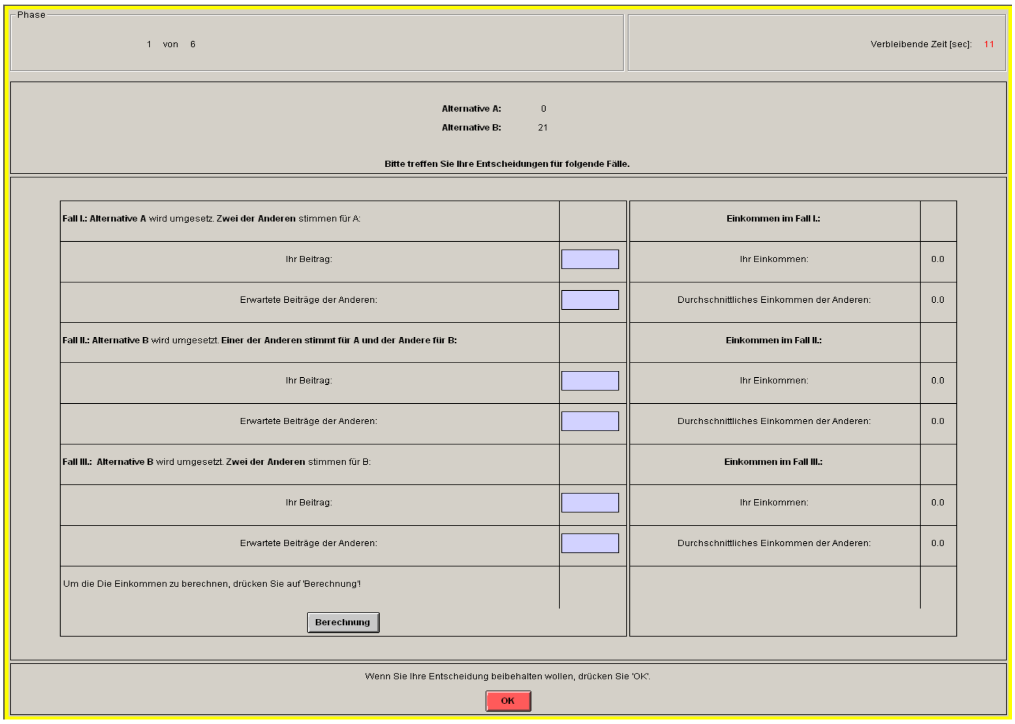
Alternative A ○ ○ Alternative B

Abstimmungsverhalten der Anderen:

Was erwarten Sie: Wieviele der anderen beiden Gruppenmitglieder stimmen für Alternative A?

Bestätigen Sie Ihre Entscheidungen mittels 'OK'.

Decision screen:



1 von 6

Verbleibende Zeit [sec]: 11

Alternative A: 0
Alternative B: 21

Bitte treffen Sie Ihre Entscheidungen für folgende Fälle.

Fall I.: Alternative A wird umgesetz. **Zwei der Anderen** stimmen für A:		**Einkommen im Fall I.:**	
Ihr Beitrag:		Ihr Einkommen:	0.0
Erwartete Beiträge der Anderen:		Durchschnittliches Einkommen der Anderen:	0.0
Fall II.: Alternative B wird umgesetzt. **Einer der Anderen stimmt für A und der Andere für B:**		**Einkommen im Fall II.:**	
Ihr Beitrag:		Ihr Einkommen:	0.0
Erwartete Beiträge der Anderen:		Durchschnittliches Einkommen der Anderen:	0.0
Fall III.: Alternative B wird umgesetzt. **Zwei der Anderen** stimmen für B:		**Einkommen im Fall III.:**	
Ihr Beitrag:		Ihr Einkommen:	0.0
Erwartete Beiträge der Anderen:		Durchschnittliches Einkommen der Anderen:	0.0
Um die Die Einkommen zu berechnen, drücken Sie auf 'Berechnung'!			

Wenn Sie Ihre Entscheidung beibehalten wollen, drücken Sie 'OK'.