Combating climate change: Is the option to exploit a public good a barrier for reaching critical thresholds? Experimental evidence

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Combating Climate Change: Is the Option to Exploit a Public Good a Barrier for Reaching Critical Thresholds? Experimental Evidence*

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Abstract: The achievement of collective climate targets is hampered by a large number of factors. Most obvious is the conflict between self-interest and group interest at both the intra- and intergenerational level. Several experimental studies examine the effects of factors such as wealth heterogeneity, varying thresholds, or time discounting on the probability of achieving a collective climate target. In these experiments, participants act as a group and can invest money in a collective group account over a fixed number of rounds. If the group account is below a threshold after the last round, the members of a group usually lose a large proportion of their potential assets. However, in the real world, agents can not only invest in public goods, but also exploit them. We therefore study cooperation dynamics in a threshold climate change experiment in which group members can not only contribute money into their group account, but also take money out of it. We induce endowment heterogeneity by simulating the contribution decisions in the first rounds of the experiment and vary the loss rate between treatments. Our results show no significant differences between give and give-take treatments. Consistent with the results of previous studies, we find that with a lower loss rate, less groups reach the threshold.

JEL-Code: C92, D74, D81, H41, Q54

Keywords: climate change, experiment, public goods game, threshold public goods game, exploitation

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1. Introduction

Already by 2017, human activities had resulted in the warming of the global climate by about 1°C compared to pre-industrial levels. If the current rate of global warming is maintained, a global warming of 1.5°C will be reached between the years 2030 and 2052. Negative consequences of climate change are already evident in different regions and will increase significantly if global warming rises to 1.5 or even 2°C (IPCC, 2018). While investments aimed at effectively mitigating global warming are undertaken by individuals or groups of individuals, the rewards from climate-protecting investments benefit everyone. Consequently, there is a free-rider problem associated with climate protection. Individual actors have an incentive not to contribute to climate protection and to benefit from the efforts of others. At the same time, the collective benefit would be largest if investments are high enough so that catastrophic events can be avoided (Gollier and Tirole, 2017). Investments in climate protection are further characterized by the fact that the resulting benefits will largely be realized in the future. One of the key challenges facing humankind is therefore how to achieve intra- and intergenerational cooperation to combat climate change (Nordhaus, 2019).

The underlying decision situation can be described as a public good game (PGG) in which the entire world population forms the set of players (e.g., Milinski et al., 2008). Alternatively, one could argue that this decision situation resembles a group of countries engaged in climate negotiations (e.g., Tavoni et al., 2011). Individual contributions to the public good correspond to actions that reduce or limit CO_2 emissions.

In contrast to linear PGGs (see e.g., Zelmer, 2003; Ledyard, 1995), the social optimum in this global PGG does not consist in all actors investing the entire amount available to the public good. Rather, the problem of global warming can be modeled as a threshold PGG in which the public good is provided only if the sum of contributions exceeds a given threshold. For example, the goal of the Paris agreement is to keep the increase in global average temperature this century below 2°C compared to pre-industrial levels (United Nations, 2015). Based on this threshold, one could determine the aggregate contributions (i.e., worldwide reduction in CO_2 emissions) needed to reach the target.

The collective-risk social dilemma (CRSD, Milinski et al., 2008) is one variant of a threshold PGG. In the CRSD, a fixed number of participants interact over a finite number of rounds. Within each round, participants simultaneously choose their contributions. If the sum of contributions at the end of the last round exceeds a predefined threshold, every participant keeps her non-contributed wealth. Otherwise, each participant loses a fraction of her remaining wealth with a given probability.

In recent years, Milinski et al. (2011, 2008) and a number of related studies (Waichman et al., 2018; Brown and Kroll, 2017; Dannenberg et al., 2015; Jacquet et al., 2013; Tavoni et al., 2011) have used the CRSD or extensions of it to experimentally investigate under which conditions humans can succeed in preventing dangerous climate change. We will review these studies in section 2.

Countries[1] can contribute to climate protection by, for example, reducing their CO_2 emissions through investments in renewable energies or by enforcing stricter regulations. Climate-protecting actions have the characteristic that most of the benefits arising from them only become evident in the medium to long term (intergenerational). However, countries can also intensify the existing climate problem by, for example, clear-cutting forest areas to create space for new farmland (Mitchard, 2018; Rochedo, 2018) or exploiting new coal mining areas (Jakob et al., 2020; Blondeel and Van de Graaf, 2018). These kinds of climate worsening activities have the characteristic that they are implemented in order to boost short-term economic growth, independent of whether the threshold will be reached or not.

The remaining question is in how far climate-damaging activities of individual actors motivate former climate-friendly actors to reduce their climate-friendly efforts or even carry out climate-damaging activities themselves. A further related question is how former climate-friendly actors behave when it becomes apparent that threshold values can no longer be reached at a certain point in time.

However, in all existing studies on the CRSD, participants only have the option of investing money to achieve the climate target. Yet, the above-mentioned examples on climate damaging activities illustrate that actors can not only free-ride but also actively exploit other actors' contributions. It is unclear whether the results from existing experiments also apply to situations in which exploitation is possible. Moreover, by neglecting the possibility to exploit, existing studies might lead to overly optimistic results.

Our experiment addresses this gap by examining the question how the dynamics of achieving the climate target change when there is a take option, in addition to the give option. The main

[1] Although we use the term countries in this study, it is equally applicable to smaller entities such as counties, organizations, or individuals.

research question of this paper is therefore whether the possibility of exploiting a public good and the observation of such behavior is a barrier to effective cooperation in the CRSD.

Our experiment consists of 20 rounds, though participants only make active contribution decisions in rounds 11 to 20. The experiment contains six treatments which differ according to participants' action sets, the potential loss rate, and participants' initial wealth distribution. In three Give-treatments (G-treatments), participants can only contribute non-negative amounts to the group account. In three Give-Take-treatments (GT-treatments), participants can either contribute non-negative amounts to the group account or withdraw amounts from it. We induce wealth heterogeneity by simulating the contribution decisions in the first 10 rounds of the experiment.

Our results show that the introduction of a take option makes it more difficult for groups to reach the threshold. In G-treatments, more groups reach the threshold than in the corresponding GT-treatments, although the effect is not significant. Consistent with previous literature, we find that a higher potential loss rate results in more groups reaching the threshold. We observe that groups with homogeneous wealth reach the threshold more easily than groups with heterogeneous wealth, but again, the difference is not significant. Taken together, our results show that extending the range of the action set to the negative domain and inducing heterogeneous wealth complicates coordination within a group.

The remainder of this paper is structured as follows: In section 2 we discuss the related literature. We describe the experimental design, procedures and hypotheses in section 3. In section 4, we present the results of our experiment. We discuss the results, point to a number of limitations and conclude in section 5.

2. Related Literature

2.1 The Collective-Risk Social Dilemma (CRSD)

As mentioned above, the CRSD was introduced by Milinski et al. (2008). In their experiment, groups of six participants play the CRSD for ten rounds. At the beginning of the game, each participant has an endowment of € 40. Within each round, participants simultaneously decide whether to contribute € 0, 2, or 4 into a group account.

All group members know that at the end of the ten rounds they will receive their non-contributed endowment only if the sum in the group account reaches or exceeds the threshold of € 120. On average, this threshold corresponds to a contribution of € 2 per participant and round. If the threshold is not reached after ten rounds, the non-contributed endowment will be lost with a probability of p=90% (T90), p=50% (T50), or p=10% (T10), depending on the treatment. Participants will not receive any payment in case of loss.

In case each participant contributes her fair share of € 2 per round, the threshold is exactly reached and each participant receives a payoff of € 20. This holds true for all treatments. However, if all participants free ride (i.e., invest nothing), the threshold is not reached. In this case, the expected payoff for each participant is € 40 * (1-p).

As the expected payoff from free riding decreases in p, one would expect that the threshold is reached more often when p is high. This is exactly what the results show. In T90, the threshold was reached by 5 of the 10 groups (mean € 118.2). Only one group reached the threshold in T50 (mean € 92.2) and no group reached the threshold in T10 (mean € 73.0). Although almost all participants in each treatment contributed € 2 in round 1, the willingness to contribute decreased in subsequent rounds, especially in T50 and T10.

2.2 Extensions of the CRSD

The CRSD has spurred a large and still-growing literature in which several extensions of the CRSD have been investigated. In this section, we discuss the extensions which are most relevant for our experiment, namely CRSDs in which participants have an operating fund and an endowment, and CRSDs with wealth heterogeneity. Other extensions of the CRSD investigate the effects of communication (Tavoni et al., 2011), uncertainty about the threshold (Dannenberg et al., 2015; Barrett and Dannenberg, 2014, 2012), heterogeneity in the expected loss (Brown and Kroll, 2017; Burton-Chellew et al., 2013), and heterogeneity in the wealth distribution and loss probabilities (Waichman et al., 2018).

Milinski et al. (2011) is the first study in which participants have an operating fund and an endowment. The authors examine the effect of intermediate climate targets and wealth heterogeneity on group cooperation. As in Milinski et al. (2008), participants interact in groups of six for ten rounds and the threshold is € 120. Contributions to the group account are paid out of the operating fund, which should mimic participants' wealth which they can use to cover their living expenses. In contrast to Milinski et al. (2008), participants receive their remaining amounts from the operating fund after the end of the experiment, even if the threshold is not reached. The endowment does not change during the game but will be lost with a probability of 90% at the end of the game if contributions fall short of the threshold. The endowment can be seen as assets that are negatively affected by medium- and long-term climate changes.

Within this setting, Milinski et al. (2011) study the effect of wealth heterogeneity by distinguishing between “rich” and “poor” participants. "Rich" participants have an operating fund of € 40 and an endowment of € 60, while "poor" participants have € 20 and € 30, respectively. Treatments with exclusively "rich" participants, with exclusively "poor" participants, and with a mixed number of three "rich" and three "poor" participants are tested. The results show that all "rich" groups, no "poor" group, and 60% of the mixed groups managed to reach the threshold. Interestingly, "rich" and "poor" participants in the mixed groups showed no different contribution behavior than in the groups with only "rich" or only "poor" participants.

Using a similar experimental setting, Jacquet et al. (2013) investigate the effect of time-dependent discounting on contribution behavior. In their experiment, the non-invested operating fund is paid out to the participants directly after the experiment. In case the threshold is reached, the endowment of 45 € is paid out after one day (treatment 1), after seven days (treatment 2), or it is invested in planting oak trees (treatment 3). If a group falls short of the threshold, the group members’ endowments are destroyed with a probability of 90%. While in treatment 1, 7 out of 10 groups reached the threshold, only 4 out of 11 groups managed to reach the threshold in treatment 2, and none of the 11 groups in treatment 3.

In a review article, Dannenberg and Tavoni (2016) compare the results of experimental climate change games with the results of related studies from evolutionary game theory. Based on the findings of the reviewed studies, Dannenberg and Tavoni (2016, p. 95) come to the general conclusion “…that the expected loss of crossing the threshold and uncertainty about the threshold are the most important determinants of collective action. The threshold’s role as a catalyzer of cooperation is hindered when uncertainty and especially ambiguity about its location is introduced. Wealth inequality and the credibility of the pledges constitute further difficulties.”

The results from Milinski et al. (2011) and from Brown and Kroll (2017) provide no clear evidence for a negative effect of wealth heterogeneity. However, the findings of Tavoni et al. (2011) and Burton-Chellew et al. (2013) suggest that with wealth heterogeneity, groups are less likely to reach the threshold. In contrast to these results, Waichman et al. (2018) find that heterogeneities can facilitate coordination. Although the main contribution of our study is the extension of participants' action sets by allowing negative contributions, we also conduct treatments with homogenous and heterogeneous operating funds.

2.3 Related Literature on Give and Take-Options

Our experimental design is also related to experimental studies that investigate the effect of extending participants' action sets in PGGs and dictator games. Starting with Andreoni (1995), a number of experimental studies (Gächter et al., 2017; Dufwenberg et al., 2011; Park, 2000; Sonnemans et al., 1998) have shown that cooperativeness is higher in positively framed PGGs than in negatively framed public bad games. For a repeated PGG, Khadjavi and Lange (2015) show that average contributions in a treatment that allows both positive (give) and negative (take) contributions are not significantly different from a strategically equivalent pure give treatment. However, the effect of a simultaneous give-take option has not been studied yet in a CRSD.

Krupka and Weber (2013), Bardsley (2008), and List (2007) conduct dictator games in which the dictator can either give or take away money from the recipient. In Krupka and Weber's (2013) standard dictator game, dictators are endowed with US$ 10 and recipients with US$ 0, and dictators can give between US$ 0 and US$ 10. In a "bully" variant, both dictators and recipients are endowed with US$ 5 each, and dictators can choose between giving up to US$ 5 or taking up to US$ 5. Note that both decision situations are strategically equivalent because they have the same number of actions which result in the same set of outcomes. Two results are striking: First, the equal split, in which both the dictator and the recipient receive US$ 5 each, occurs more often in the "bully" variant. Second, allocations in which the recipient receives less than US$ 5 are more frequent in the standard dictator game. Moreover, Krupka and Weber (2013) conduct an additional experiment in which they elicit norms about the social appropriateness of the different actions from the standard and "bully" dictator games. The appropriateness ratings are in line with the results. That is, in the "bully" variant, the equal split is perceived as more appropriate than in the standard dictator game, and taking money is perceived as less appropriate than giving money, even though both actions lead to identical payoffs.

3. Experimental Design and Hypotheses

3.1 Experimental Design

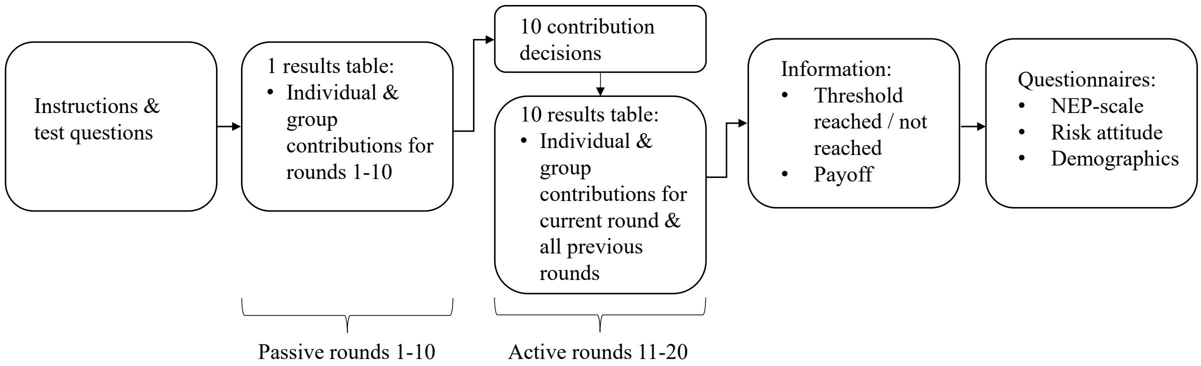

Figure 1: Sequence of the experiment.

Our experimental design is shown in Figure 1. Our experiment is a CRSD with N=6 participants per group and T=20 rounds. After the instructions (Appendix A.1) and test questions, there are ten passive rounds followed by ten active rounds of the CRSD (described in detail below). Starting at the end of round 10, participants are informed about all group members' contributions within each round, each group members' aggregate contribution, and the value of the group account (see the results table in the experimental instructions in Appendix A.1). In addition, all participants receive information on the remaining operating fund of each group member up to the current round, and the average contributions of each group member up to the current round. To ensure anonymity, all participants are given a pseudonym. The pseudonyms correspond to the names of moons and dwarf planets from the solar system and are retained by the participants throughout the entire experiment. At the end of round 20, participants are told whether the threshold is reached or not and receive information on their final payoff. The experiment ends with a post-experimental questionnaire on environmental and risk attitudes and demographic characteristics. In the following, we describe each part of the experiment in more detail.

Contribution decisions in rounds 1-20: Within each round $t = (1, \ldots, T)$, all participants simultaneously chose their contributions c. Let $c_{i,t} \in A_i$ denote the contribution of participant i in round t. At the beginning of round 1, the group account is empty, i.e. $C_0 = 0$. Let $C_t = \sum_{i=1}^{n} \sum_{\tau=1}^{t} c_{i,\tau}$ denote the value of the group account at the end of round t. Let $OF_{i,t}$ denote participant i's operating fund at the beginning of round t. Since contributions are paid out of the operating fund, the operating fund evolves according to $OF_{i,t+1} = OF_{i,t} - c_{i,t}$. The initial value of the operating fund is given by $OF_{i,1} = 160$.

We denote participant i's endowment by $e = 120$. The initial endowment is the same for all participants and does not change during the game, hence we can omit all subscripts. If, at the end of the game, the group account equals or exceeds the threshold $S = 480$, the endowment is unaffected. Otherwise, a fraction p of the endowment is destroyed. Note that p is not a probability but a fixed loss rate.[2] Since initial endowments are identical, the expected value of the endowment at the end of the game is identical for all participants.

At the end of the game, each participant's payoff consists of her operating fund (OF_i) minus her contributions over all 20 rounds plus an additional payoff (i.e., the endowment), which depends on the value of the group account. Equation (1) summarizes the payoffs.

$$\pi_i = \begin{cases} OF_{i,T+1} + (1-p)e & \text{if } C_T < S \\ OF_{i,T+1} + e & \text{if } C_T \geq S \end{cases} \tag{1}$$

Participants' action sets are treatment-dependent and allow either only non-negative (give) contributions $A_i^G = \{0, 1, 2, 3, 4, 5, 6, 7, 8\}$, or giving and taking, $A_i^{GT} = \{-3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8\}$. Within each treatment, action sets are identical for all participants. In the Give-Take-treatments (GT-treatments), participants can take money out of the group account, possibly reducing the likelihood that the threshold will be reached. This option should reflect the real world climate-damaging possibility of exploiting natural resources. By allowing participants to take money out of the group account, they can increase their operating fund. This is not possible in the Give-treatments (G-treatments). Note that in all treatments, at the end of the game, participants receive the value of the operating fund $OF_{i,T+1}$ regardless of whether the threshold is reached or not.

Heterogeneity: Our experiment includes treatments with homogeneous operating funds (HOM-treatments) and treatments with heterogeneous operating funds (HET-treatments). Similar to Tavoni et al. (2011), we implement homogeneity and heterogeneity by simulating participants' decisions in rounds 1 to 10, that is, contributions in rounds 1 to 10 are determined by the computer.

In the HOM-treatments, each participant contributes a total of 40 over rounds 1 to 10 (passive rounds). Hence, each participant starts round 11 with an operating fund of $OF_{i,11} = 120$.

In the HET-treatments, within each group, three participants each contribute a total of 20 over rounds 1 to 10, and the three remaining participants each contribute a total of 60 over rounds 1

[2] In most variants of the CRSD p is a probability. The parameter p is a fixed loss rate in treatments T3 and T6 in Brown and Kroll (2017) and in treatment Certainty in Dannenberg et al. (2015).

to 10. Hence, at the beginning of round 11 there are three rich participants with $OF_{i,11} = 140$ and three poor participants with $OF_{i,11} = 100$.

For all treatments it holds true that the group account contains $C_{10} = 240$ at the end of round 10. In order to reach the threshold, the sum of contributions in the 10 active rounds (rounds 11 to 20) has to equal 240. For example, if each participant contributes 4 in each active round, the threshold is reached exactly.

The chosen method of implementing heterogeneity reflects the idea of past wealth inheritance (Tavoni et al., 2011). Besides, there are two further reasons for our decision to start the game with 10 passive rounds. First, due to the contributions in the passive rounds, the group account contains 240 at the beginning of round 11. This ensures that there is no way that the group account can become negative. Even if all participants within a group decide to choose $c_{i,t} = -3$ in all active rounds, the group account will total 60. Second, in the treatments with take options, the simulated contributions in rounds 1 to 10 contain negative contributions. Since all participants are informed about all individual contributions in all rounds, the occurrence of negative contributions might raise participants' awareness to the possibility of negative contributions. We think that both design choices - the impossibility of negative values in the group account and the occurrence of negative contributions - increase the chances of participants choosing negative contributions in the active rounds.

Treatments: In total we conduct six treatments (Table 1) which differ according to the distribution of the operating fund at the beginning of round 11 (HOM vs. HET), the actions available to participants within each round (GIVE vs. GIVE-TAKE), and the loss rate *p*. For each treatment, the number at the end corresponds to the loss rate *p*. The potential increase in the operating fund due to the existence of the take options is counteracted by *p*, which is higher in the GT-treatments. We discuss the resulting effects on different equilibria below in section 3.3.

	HOM		HET	
	GIVE	GIVE-TAKE	GIVE	GIVE-TAKE
p low	G-HOM55	GT-HOM80	G-HET55	GT-HET80
p high	-	-	G-HET70	GT-HET95

Table 1: Treatment characteristics.

Procedures: We conducted 15 experimental sessions at the WISO Experimental Lab in Hamburg in July, October, and December 2020. We had three treatments with 60 participants in 10 groups, two treatments with 66 participants in 11 groups, and one treatment with 48 participants in 8 groups. Hence, we had a total of 360 participants. Participants were recruited using hroot (Bock et al., 2014) and the experiment was programmed in z-Tree (Fischbacher, 2007). Once all participants of a session had taken their seats in the laboratory, the instructions were read aloud by the experimenter. In the instructions, detailed screenshots of the experiment were shown as well as various examples of possible courses of the experiment and the resulting payoffs. Test questions at the beginning of the experiment ensured that the participants had understood everything correctly. The experiment was followed by questionnaires on environmental attitudes, risk preferences, and demographic characteristics of the participants. To measure participants' environmental attitudes and concerns, we used the revised New Environmental Paradigm (NEP) scale by Dunlap et al. (2000) in the German translation of Schleyer-Lindemann et al. (2018). To measure participants' risk preference, we relied on the well validated question from Dohmen et al. (2011). The exchange rate was 1 = € 0.05 and participants, on average, earned € 14.13 (including a € 5.00 show-up fee). The duration of each session was approximately 60 minutes.

3.2 Equilibria

Our variant of the CRSD has multiple equilibria. In the following, we focus on equilibria of the subgame starting at the beginning of round 11. There is a *bad equilibrium*, in which all participants choose the lowest possible contribution in each round, i.e., $c_{i,t} = 0$ in the G-treatments and $c_{i,t} = -3$ in the GT-treatments (and for $t \geq 11$). In these cases, the threshold will not be reached. In addition, all strategy profiles in which the threshold is reached exactly (i.e. $S = 480$) and no participant's payoff is below the payoff of the corresponding bad equilibrium are equilibria. Call these the *good equilibria*. Table 2 shows the expected payoffs for bad equilibria and two different types of good equilibria.

Treatment	Participant type	I. Bad eq.	II. Equal contributions eq. (good eq.)	III. Equal payoffs eq. (good eq.)	Diff.: II. – I.	Diff.: III. – I.
G-HET55	Poor	154	180	200	26	46
	Rich	194	220	200	26	6
GT-HET80	Poor	154	180	200	26	46
	Rich	194	220	200	26	6
G-HET70	Poor	136	180	200	44	64
	Rich	176	220	200	44	24
GT-HET95	Poor	136	180	200	44	64
	Rich	176	220	200	44	24
G-HOM55	-	174	200	200	26	26
GT-HOM80	-	174	200	200	26	26

Table 2: Expected payoffs from bad and good equilibria, and differences between bad and good equilibria over treatments and participant types.

Out of all *good equilibria*, two stand out because in these equilibria, certain fairness norms are salient. First, there is an equilibrium in which each participant contributes 40. Call this the *equal contributions equilibrium*. Second, there is an equilibrium in which the threshold is reached and the corresponding contributions result in perfect equality payoffs. Call this the *equal payoffs equilibrium*. In the HOM-treatments, these two equilibria coincide.

The *equal contributions equilibrium* is characterized by $\sum_{t=11}^{20} c_{i,t} = 40$ (on average $c_{i,t} = 4$ in rounds 11 to 20) for all participants with payoffs of $\pi_{i,P} = 180$ for poor and $\pi_{i,R} = 220$ for rich participants. Over all 20 rounds, each poor participant in this equilibrium contributes a total of 100 to the group account while rich participants contribute 60. Consequently, when reaching the set threshold, 300/480=62.5% of the group contributions are provided by poor participants and 180/480=37.5% by rich participants.

The *equal payoffs equilibrium* is characterized by $\sum_{t=11}^{20} c_{i,t} = 20$ (on average $c_{i,t} = 2$ in rounds 11 to 20) for poor participants and $\sum_{t=11}^{20} c_{i,t} = 60$ (on average $c_{i,t} = 6$ in rounds 11 to 20) for rich participants. The corresponding payoffs are $\pi_i = 200$ for all participants. In this equilibrium (and considering all rounds 1 to 20), 50% of the group contributions are provided by poor participants and 50% by rich participants.

In the *bad equilibrium*, the expected payoff is $OF_{i,11} + (1-p)e_i$ for the G-treatments and $OF_{i,11} + 30 + (1-p)e_i$ for the GT-treatments. That is, with the take option being available, participants with the same endowment and operating fund will receive a higher payoff if p would be identical across treatments. Also, note that the expected payoffs in all good equilibria are independent of p. Hence, if p would be identical across treatments, the difference between the bad and a specific good equilibrium would be higher for the G-treatments, compared to the corresponding GT-treatments. Consequently, coordination on the good equilibrium might be easier in the GT-treatments. In order to have a constant bad equilibrium payoff across treatments, we chose higher values for the loss rate p in the GT-treatments.

Table 2 shows that the differences between good and bad equilibria for the G-treatments and GT-treatments within a corresponding treatment pair are always identical if we consider the good equilibrium to be the *equal contributions equilibrium*. When considering the *equal payoffs equilibrium*, the differences are only identical for poor and rich participants within a corresponding treatment pair.

3.3 Hypotheses

Our first set of hypotheses focuses on the effect of the take option. As described above, Krupka and Weber (2013) showed that behavior depends on norms, which define the "social appropriateness" of different actions. Between G- and GT-treatments, behavior might differ because the different action sets might lead to different norms. The lowest possible contribution is 0 in the G-treatments and -3 in the GT-treatments. Consequently, contributing 0 might be considered more acceptable in the GT-treatments, compared to the G-treatments. One would generally expect that small contributions are more acceptable when the take option is present. These differences in "social appropriateness" might increase the frequency of small contributions. This increase might in turn affect participants' beliefs, so that they expect other group members to make smaller contributions in subsequent rounds.

In addition, in the GT-treatments it is possible that even if the threshold was already reached before the last round, withdrawals from the group account in the last round are so large that the threshold cannot be reached in the final round. This is not possible in treatments where the action sets only include give options. Once the threshold is reached in these treatments, it cannot be reduced in a subsequent round.

Taken together, these arguments imply that participants are less likely to reach the threshold in the GT-treatments, as compared to the G-treatments. Let the success rate be the share of groups whose aggregate contributions reach or exceed the threshold. We then test our prediction by comparing the success rates between pairs of treatments which differ only in the availability of the take option and the loss rate p. As mentioned above, the difference in loss rates ensures that the payoffs from the three equilibria are identical across both treatments (see also Table 2).

Then, our first three hypotheses are:

Hypothesis 1a: The success rate is higher in G-HET70, compared to GT-HET95.

Hypothesis 1b: The success rate is higher in G-HET55, compared to GT-HET80.

Hypothesis 1c: The success rate is higher in G-HOM55, compared to GT-HOM80.

Our next set of hypotheses is based on the results of previous studies, which show that a higher loss rate leads to a higher success rate. As explained above, the higher the loss rate, the larger the difference between the expected payoffs in the bad equilibrium and the good equilibrium. Put bluntly, if p is higher, participants can gain more if the groups' contributions reach or exceed the threshold. We test this prediction by comparing the success rates between pairs of treatments which differ only in the loss rate p. Thus, our next hypotheses are:

Hypothesis 2a: The success rate is higher in GT-HET95 compared to GT-HET80.

Hypothesis 2b: The success rate is higher in G-HET70 compared to G-HET55.

Our last hypotheses focus on the effect of heterogeneity, or, more precisely, the distribution of operating funds within a group after round 10.

As shown in Table 2, in the HOM-treatments, the *equal payoff equilibrium* and the *equal contributions equilibrium* are identical. This is not the case in the HET-treatments. Both good equilibria correspond to different fairness principles. Hence, if participants hold different fairness principles, this will make coordination more difficult in the HET-treatments. We therefore expect that coordination to a good equilibrium (and reaching the threshold) is more likely in the HOM-treatments, compared to the HET-treatments. We test this prediction by comparing the success rates between pairs of treatments which differ only in the distribution of the operating fund at the beginning of round 11. Thus, our hypotheses are:

Hypothesis 3a: The success rate is higher in GT-HOM80 compared to GT-HET80.

Hypothesis 3b: The success rate is higher in G-HOM55 compared to G-HET55.

4. Results

This section presents the results. In section 4.1, we start by describing the general results and successively examine the hypotheses derived above. We then take a closer look at individual contributions and the take option (section 4.2), before we examine how burden sharing affects group success in the HET-treatments (section 4.3). We conclude the results section by analyzing how a group member's behavior in early active rounds can predict the group's success (section 4.4). Since we find no effect of demographic variables or personal attitudes, we delegate the corresponding analysis to Appendix A.3.

4.1 Main Results

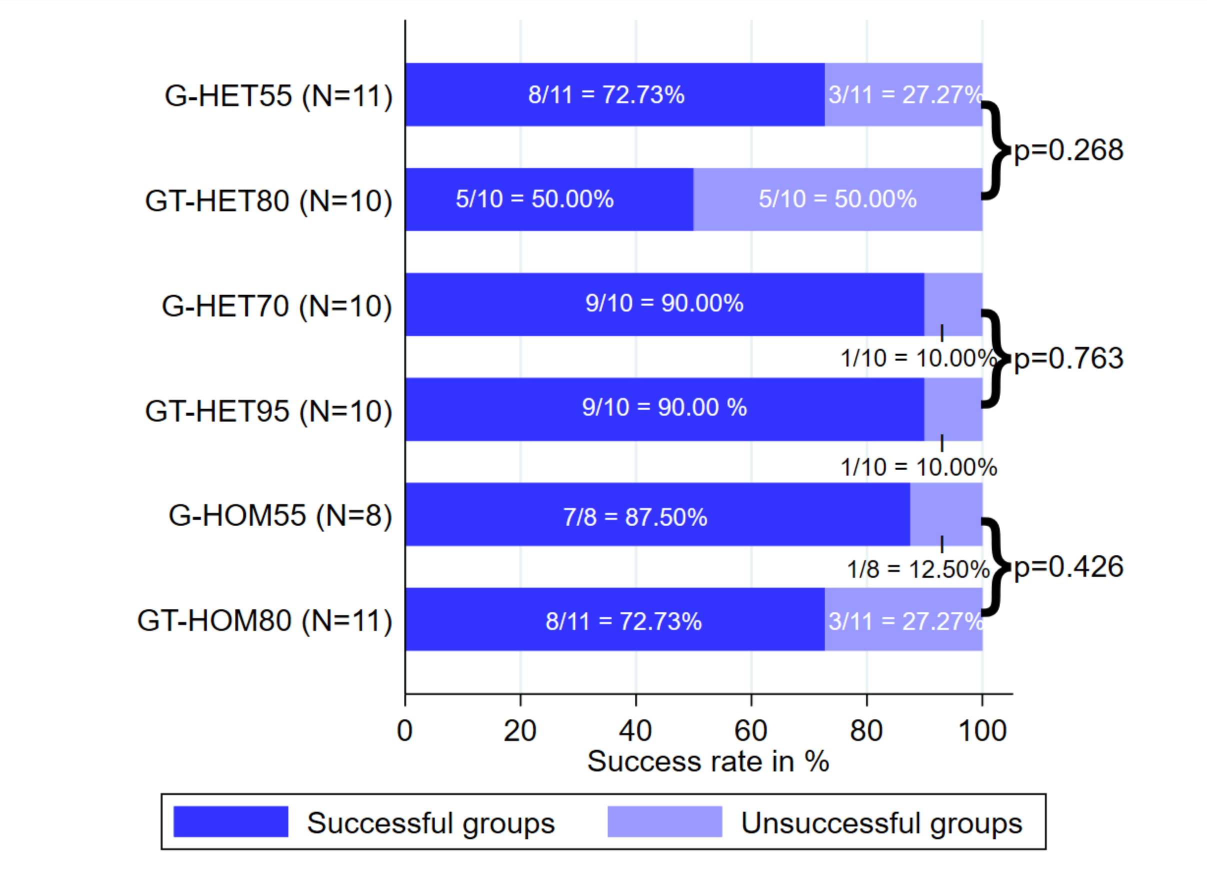

Figure 2: Success rates for each treatment.

Notes. *p*-values from one-sided Fisher's exact tests for all pairwise comparisons (see Hypothesis 1).

Figure 2 shows the success rates for each treatment.[3] In order to analyze the effect of the take option, we compare success rates between pairs of treatments which differ only in the availability of the take option and the loss rate *p*. That is, we compare success rates between treatments G-HET55 and GT-HET80, G-HET70 and GT-HET95, and between G-HOM55 and GT-HOM80. In those treatments with low loss rates, success rates are lower when the take option is available (72.8% in G-HET55 vs. 50% in GT-HET80 and 87.5% in G-HOM55 vs. 72.8% in GT-HOM80). In both treatments with high loss rates (G-HET70 and GT-HET95) success rates are identical at 90%.

[3] Mean values and standard deviations for successful and unsuccessful groups for each treatment can be found in Table 5 (Appendix A.2).

To test whether the results described above are statistically significant, we compare success rates using one-sided Fisher's exact tests. For all pairwise comparisons, the negative effect of the take option is not statistically significant. The resulting *p*-values are 0.268 for G-HET55 vs. GT-HET80, 0.763 for G-HET70 vs. GT-HET95, and 0.426 for G-HOM55 vs. GT-HOM80. Hence, we have to reject Hypotheses 1a, 1b, and 1c.

Result 1: The existence of a take option does not adversely affect success rates.

The success rates are highest (90%) in G-HET70 and GT-HET95, i.e. those treatments in which the loss rates are high and participants have heterogeneous operating funds after round 10. Success rates are lower in the HET-treatments with lower loss rates (72.7% in G-HET55 and 50% in GT-HET80). Apparently, a higher loss rate makes success more likely, which is in line with Milinski et al. (2008). The difference in success rates between the GT-treatments is statistically significant (GT-HET80 vs. GT-HET95, p=0.070), while the difference between the G-treatments is not (G-HET55 vs. G-HET70, p=0.331). Hence, we find support for Hypothesis 2a, but have to reject Hypothesis 2b.

Result 2: A higher loss rate leads to a higher success rate, but only when the take option is available.

Comparing the treatments which differ only with respect to the distribution of the operating fund at the beginning of round 11, we see that success rates are higher in the HOM-treatments (87.5% in G-HOM55 and 72.7% in GT-HOM80), compared to the corresponding HET-treatments (72.7% in G-HET55 and 50% in GT-HET80). This indicates a negative effect of heterogeneity and is in line with the results in Tavoni et al. (2011) and Burton-Chellew et al. (2013). However, the negative effect of heterogeneity is statistically not significant (p=0.268 for GT-HOM80 vs. GT-HET80 and p=0.426 for G-HOM55 vs. G-HET55), forcing us to reject Hypotheses 3a and 3b.

Result 3: Heterogeneity in the operating funds (after round 10) does not negatively affect the success rates.

4.2 Individual Contributions and the Take Option

In the previous section, we looked at the results aggregated at the group level. In this section, we look at individual contributions for all active rounds (11-20), for the first active round (11), and additionally take a closer look at the take option.

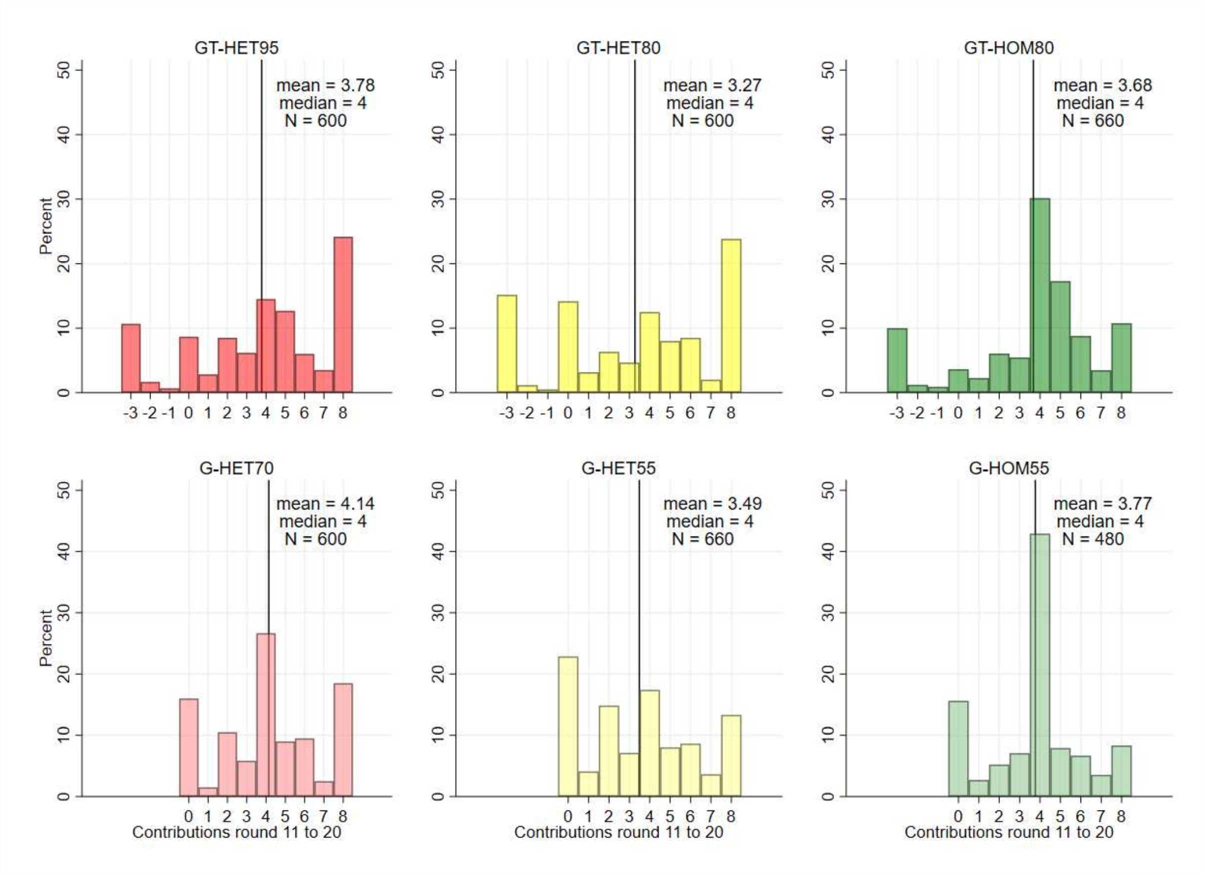

Figure 3: Distribution of contributions in rounds 11 to 20 by treatment.

Notes. Vertical lines indicate mean values.

Figure 3 shows the distribution of contributions by treatment for all active rounds, as well as the mean and median values. For all treatments, the mean is between 3.27 and 4.14 and the median is 4. In the GT-treatments, we see that a take option ($c_{i,t} < 0$) was chosen in at least ten percent of all cases.

Focusing on mean contributions, it can be seen that means are smaller when the take option is available. In Figure 3, each GT-treatment in the top row has a smaller mean than the corresponding G-treatment in the bottom row. A pairwise comparison of means between treatments which differ only with respect to the loss rate (i.e., the red and yellow treatments in Figure 3) suggests that a higher loss rate is associated with higher mean contributions. A pairwise comparison of means between treatments which differ only with respect to the distribution of the operating fund at the beginning of round 11 (i.e., the yellow and green treatments in Figure 3) shows that heterogeneity is associated with smaller mean contributions.[4]

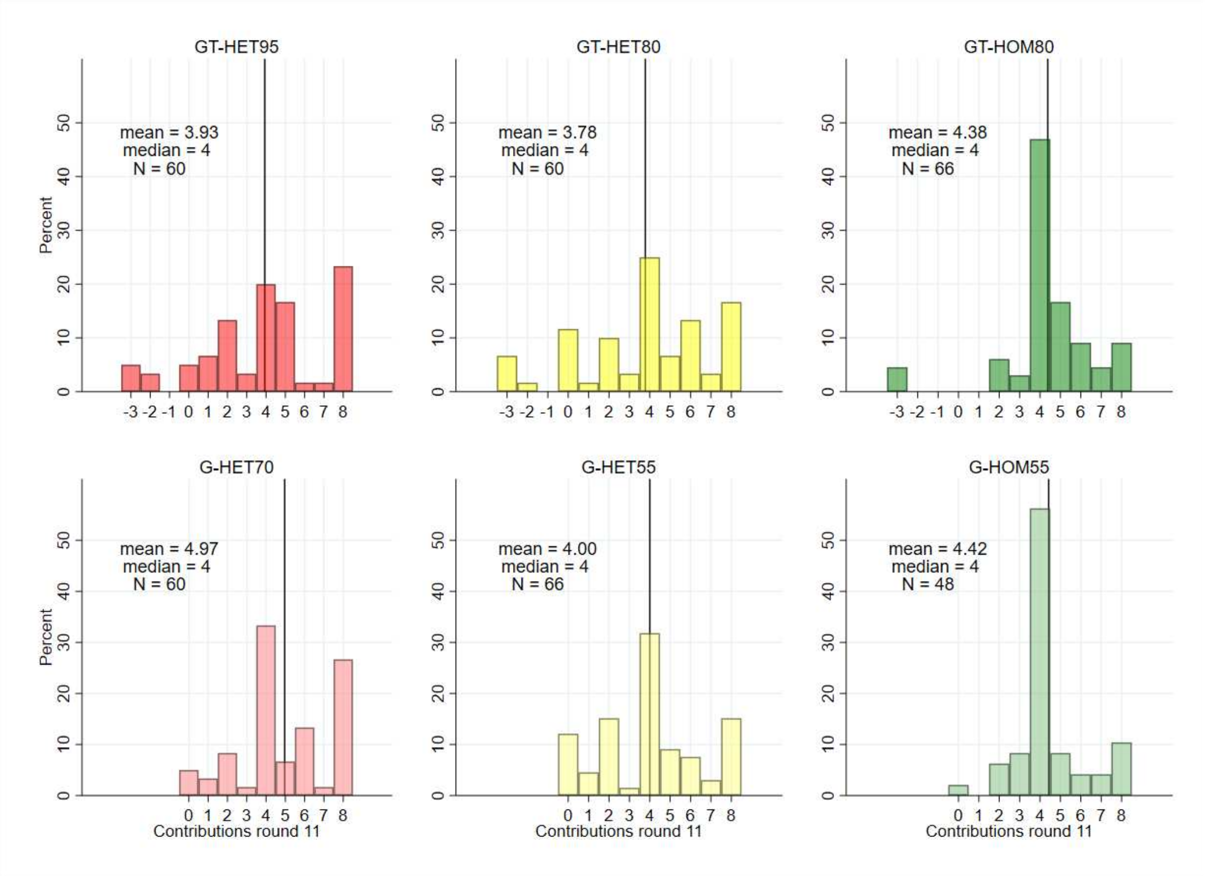

Figure 4. Distribution of contributions in round 11 by treatment.

Notes. Vertical lines indicate mean values.

Figure 4 shows the distribution of contributions in round 11 by treatment, as well as the mean and median values. Again, mean values are in a narrow range between 3.78 and 4.97, and the median contribution is 4 in all treatments. Since round 11 contributions are independent observations, we can conduct statistical tests using individual contributions in round 11 as observations. Due to the non-normal distribution of contributions, we use non-parametric two-sided Mann-Whitney-tests. In all three G-treatments the mean is higher, compared to the corresponding GT-treatments. However, there are no significant differences between the corresponding treatments (all p-values>0.05). In the HET-treatments, a higher loss rate is associated with higher mean contributions in round 11. Yet, the difference is only significant between G-HET70 and G-HET55 (N=126, p-value=0.031). Although mean contributions in

[4] We do not conduct any statistical tests comparing means or medians (of all contributions between rounds 11 and 20) because within each group, contributions are dependent.

both HOM-treatments are higher than in the corresponding HET-treatments, these differences are not significant (both p-values>0.05).

Treatment	Type	Successful groups	Unsuccessful groups	All groups
GT-HET95	rich	4 (1.48%)	19 (63.33%)	23 (7.67%)
	poor	22 (8.15%)	19 (63.33%)	41 (13.67%)
GT-HET80	rich	1 (0.67%)	42 (28.00%)	43 (14.33%)
	poor	7 (4.67%)	41 (27.33%)	48 (16.00%)
GT-HOM80		21 (4.38%)	45 (25.00%)	66 (10.00%)
All three		55 (4.17%)	166 (30.74%)	221 (11.88%)

Table 3: Frequencies and shares of take3-decisions in GT-treatments.

The existence of the take option is the central characteristic that distinguishes our version of the CRSD from existing experimental investigations of the CRSD. In the remainder of this section, we take a closer look at those treatments in which the take option is available. To do so, we focus on the most extreme take option, namely the decision to take 3 out of the group account ($c_{i,t} = -3$, henceforth take3-decisions). Figure 3 shows that the vast majority of all chosen take options were take3-decisions (82.05% in GT-HET95, 90.10% in GT-HET80, 82.50% in GT-HOM80).

Table 3 shows the frequency and the relative share of take3-decisions among all contribution decisions. Three points are worth highlighting. First, participants are willing to use the take3-decision. Over all GT-treatments, 11.88 % of all contributions (i.e. both take and give) are take3- decisions (see also Figure 3). Second, in the HET-treatments, the majority of take3-decisions are made by poor participants, although this effect is driven by poor participants in successful groups. In unsuccessful groups, both rich and poor participants chose the take3-decision equally often. And third, across all GT-treatments, there were four groups which already reached the threshold at the end of round 19. In these groups, no single participant chose a take option in round 20 (see Table 6 in Appendix A.2).

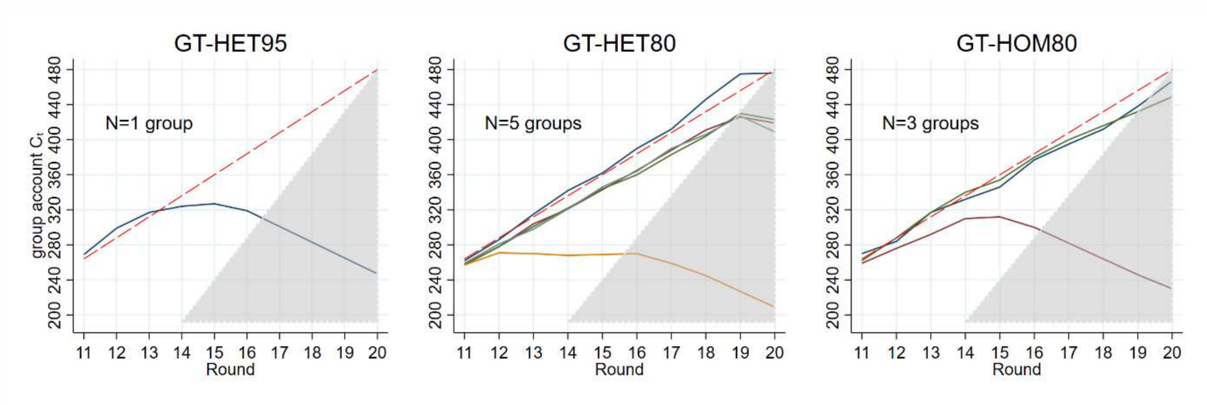

Figure 5: Evolution of group accounts in unsuccessful groups over GT-treatments.

Notes. The individual curves show the evolution of group accounts for each unsuccessful group within the respective GT-treatment. The red dashed line shows the evolution of the group account for the case that a total amount of 24 is contributed in each round and the threshold of 480 is thus exactly reached.

Since the take option is rarely used in successful groups, we focus on unsuccessful groups in the rest of this section. Figure 5 depicts the evolution of the group account (C_t) over all active rounds.[5] The gray area in the lower right contains all possible values of C_t, for which it is impossible to reach the threshold.

We see that in each of the three GT-treatments, there is one group for which the group account decreases before the gray area is reached. In treatments GT-HET95 (blue line) and GT-HOM80 (dark red line), the decrease starts at round 15, and in treatment GT-HET80 (yellow line), it starts even earlier. From the point where the blue (GT-HET95), yellow (GT-HET80), and dark red (GT-HOM80) lines cross the gray area, it can be seen that the impossibility to reach the threshold only became apparent in rounds 16 or 17.

For all other unsuccessful groups, the value of the group account increased until rounds 19 or 20. In treatment GT-HET80, there is one group with $C_{19} = 475$. This group failed to reach the threshold because aggregate contributions in round 20 were only 1 (individual contributions: -3,-3,+1,+2,+2,+2). For the other four unsuccessful groups in GT-HET80, the threshold could not be reached any more ($C_{19} < 432$) and the take3-decision was selected by 22 out of 24 participants (91.67%)[6]. In treatment GT-HOM80, the two remaining unsuccessful groups could still reach the threshold in round 20 ($C_{19} = 432$ and $C_{19} = 438$), but failed because round 20 contributions were 17 and 29 respectively.

Result 4: The majority of chosen take options is the most extreme take3-decision. In some groups, the group account was decreasing even though the threshold could still be reached.

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[5] In Appendix A.2, Figure 8 shows the respective graphs for all unsuccessful groups in G-treatments and Figure 9 for all successful groups in GT- and G-treatments.
[6] The other two participants in these groups chose contributions of 8.

Once it was obvious that reaching the threshold was no longer possible, almost all participants selected the take3-decision.

4.3 Burden Sharing in HET-treatments

In this section, we focus on HET-treatments and explore how burden sharing between rich and poor participants differs between successful and unsuccessful groups. After the 10 passive rounds (1-10), each group had a group account totaling 240. Thus, at the end of the passive rounds, the three poor participants had contributed a total of 180 (a relative share of 75%) and the three rich participants a total of 60 (a relative share of 25%).

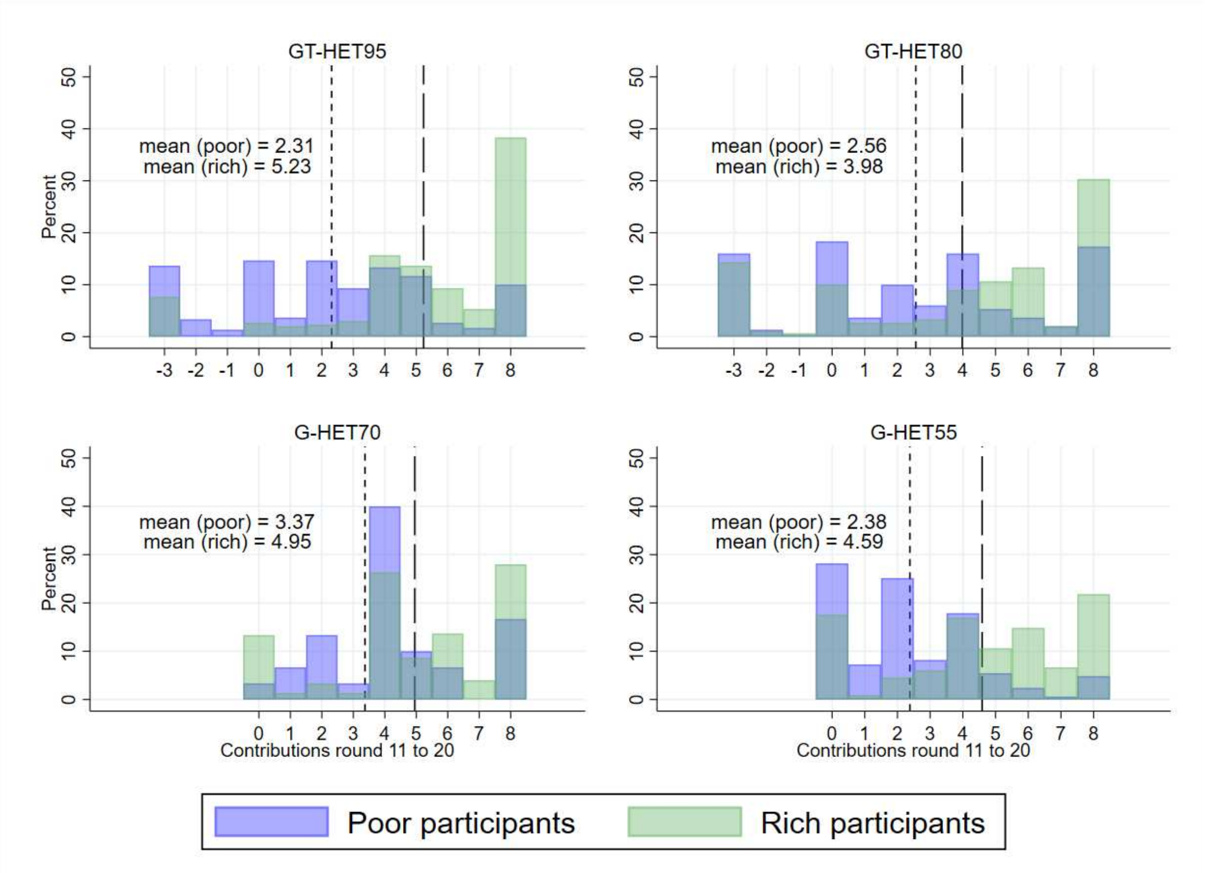

Figure 6: Distribution of contributions in rounds 11-20 by participant type and HET-treatment.

Notes. Vertical short (long) dashed lines indicate mean values for poor (rich) players.

Figure 6 shows the distribution of contributions and mean values for rich and poor participants for all active rounds. On average, poor participants contributed between 2.31 and 3.37 while rich participants contributed between 3.98 and 5.23. Besides the finding that the highest contribution of 8 is chosen more often by rich participants, no clear pattern can be observed.[7]

[7] Higher contributions of rich participants and a higher frequency of contributions of 8 can also be seen in the first active round. Figure 10 in Appendix A.2 shows the distributions and means for round 11.

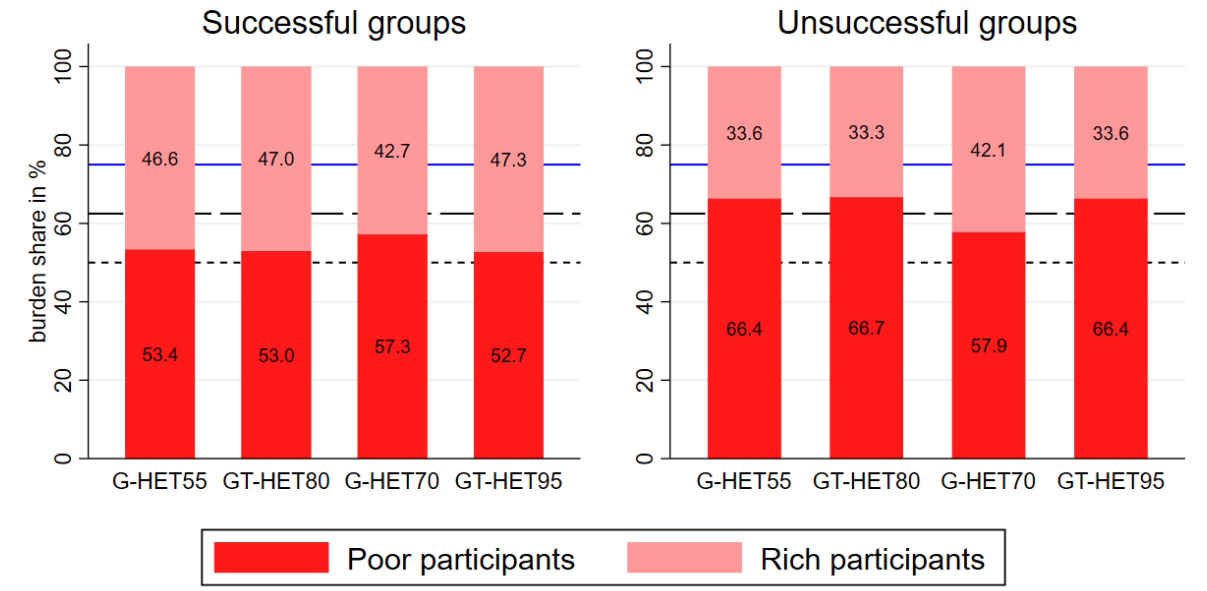

Figure 7: Burden sharing between poor and rich participants in successful and unsuccessful groups.

Notes. The values within the bars indicate the average percentage of the group account contributed by poor and rich participants over all 20 rounds. The solid blue line marks the distribution of contributions after round 10. The long dashed lines correspond to the relative shares which would result from the equal-contributions equilibrium. The short dashed lines correspond to the relative shares which would result from the equal-payoffs equilibrium.

Figure 7 shows the relative shares of total contributions over all 20 rounds. The relative share at the beginning of the active rounds is indicated by the solid blue line. Although rich participants contributed more than poor participants in the 10 active rounds, the difference in contributions over rounds 11 to 20 was not sufficient to establish an equal burden sharing between poor and rich participants. Over all 20 rounds, rich participants contributed, on average, less than poor participants. This holds true regardless of treatment type and whether the threshold was reached or not. Within each treatment, however, the rich participants' burden share is higher for successful groups, compared to unsuccessful groups.

Result 5: In all groups in the HET-treatments, the rich compensated the poor over rounds 11 to 20, but successful groups are characterized by higher compensations.

4.4 Predicting a Group's Success

We saw that in most groups, the take option is primarily used once it is apparent that the threshold cannot be reached any more. In rounds 11 to 13, however, it is always possible to reach the threshold[8], and yet, we observe that some participants use the take option in these

[8] At the beginning of round 11, the group account contains 240. If every participant contributes -3, the group account decreases by 18 per round, so that at the end of round 14, the group account contains 240-4*18=168. In the remaining six rounds, the maximum contribution by all six group members is 6*6*8=288. Since 168+288=456, the threshold (480) would not be reached. If all group members contribute -3 only in rounds 11, 12 and 13 and contribute 8 thereafter, the group account would contain 522 at the end of round 20 and the threshold would be reached.

rounds. The early use of the take option might negatively affect participants' beliefs, such that they expect lower contributions in subsequent rounds (see section 3.3). If participants condition their own contribution on their belief about others' contributions, this could result in a vicious circle.

Similarly, the burden share could affect participants' beliefs. A low burden share of rich participants could signal rich participants' unwillingness to take a large burden and, hence, might negatively affect beliefs of poor participants.

Although we do not have data on beliefs, we can test these conjectures by running a probit regression in which we include the number of take3-decisions and the burden share of rich participants at the end of round 13 as independent variables. The binary outcome variable indicates whether the threshold was reached (=1) or not (=0). Table 4 shows three specifications.

	(1)	(2)	(3)
Group contribution		0.07^{***}	0.05^{***}
(rounds 11-13)		(0.02)	(0.02)
HET	-0.31	-0.13	-8.25^{**}
	(0.49)	(0.51)	(3.53)
p high	0.99^{**}	0.46	0.49
	(0.49)	(0.54)	(0.59)
Take	-0.39	-0.46	-0.03
	(0.46)	(0.57)	(0.66)
Take*take3-decisions			-0.27
(rounds 11-13)			(0.28)
HET*burden share rich			24.85^{**}
(rounds 11-13)			(11.09)
Constant	0.80^{**}	-3.89^{***}	-3.16^{**}
	(0.33)	(1.25)	(1.40)
N	60	60	60
Wald Chi^2	4.56	15.28	32.07
Pseudo R^2	0.08	0.32	0.42

Table 4: Probit regressions of group success on group contribution behavior in rounds 11-13.

Notes. Standard errors clustered by group in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Model (1) includes only indicator variables for the heterogeneity of the operating fund (HET), the loss rate (*p* high), and the existence of the take option (Take). As hypothesized, both the existence of the take option and heterogeneity have a negative effect, although these effects are insignificant. Only the loss rate has a significant positive effect. In model (2), we add the sum of contributions over rounds 11-13 (Group contribution) as independent variable. While the loss rate effect is no longer significant, group contributions have a positive significant effect, which can be linked to the correlation between loss rates and contributions over rounds 11-13.

In model (3), we add the frequency of take3-decisions (only for GT-treatments) and the burden share of rich participants after round 13 (only for the HET-treatments). The frequency of take3-decisions has no significant effect, although this might be due to the multicollinearity between take3-decisions and group contributions. Despite heterogeneity now showing a significant negative effect, the interaction with rich participants' burden share is positive and significant. That is, in the HET-treatments, groups in which the rich signal their willingness to contribute (comparatively more) in rounds 11 to 13 are more likely to reach the threshold.

Result 6: In the HET-treatments, groups are more likely to reach the threshold when rich participants signal their willingness to contribute early on.

5. Discussion and Conclusion

The possibility of exploiting public goods or the threat of exploitation characterizes numerous conflicts in the world outside the laboratory. By analyzing the effects of a take option, our experiment considers an important aspect of climate change-related coordination problems that has not been covered by previous experimental literature on the so-called collective-risk social dilemma (CRSD). Ignoring the existence of a take option restricts not only the external validity of the existing studies on the CRSD, but might also bias the resulting policy implications. By conducting a laboratory experiment which extends the previous literature on the CRSD, we aim to fill this research gap.

The CRSD used in our experiment is a threshold PGG in which groups of six participants interact over ten active rounds. Within each round, participants simultaneously contribute to a group account and the public good is then only provided if the sum of contributions at the end of the game exceeds a commonly known threshold. In the G-treatments, participants can only choose non-negative contributions, while in the GT-treatments participants can choose their contributions from a larger action set which also includes negative contributions.

Our main research question was to investigate whether achieving a threshold in such a CRSD is more difficult in GT-treatments than in G-treatments. Our results show that, with a low loss rate, success rates are lower when the take option is available. However, these effects are statistically not significant. For treatments with high loss rates, we find no difference in success rates. This is in line with the results of Khadjavi and Lange (2015) who also do not find significant differences between contributions in G- and GT-treatments in repeated linear PGGs.

Besides the effect of the take option, we investigated how changes in the loss rate and heterogeneity in the distribution of the operating fund (the pot of money out of which contributions are paid) affect cooperation. Regarding the effect of the loss rate, we find that a higher loss rate leads to more groups reaching the threshold. This effect is statistically significant but only for the GT-treatments. For heterogeneity, we find that success rates are lower for groups with heterogeneous operating funds, but again, the effect is not statistically significant.

Although the participants in our experiment have wider action sets than in similar studies, we observe that in five of the six treatments, about half of the participants already choose contributions that correspond to one of the described good equilibrium paths in the first active round. We further find that a group's total contributions in the first three active rounds have a high predictive power for group success. In contrast, when controlling for the value of the group account at the end of the first three active rounds, the number of take3-decisions in the first three active round has no predictive power for the group's success.

For HET-treatments, we find that the burden share of rich participants (i.e., the share of total contributions made by rich participants) is a key driver of group success, which confirms one key finding of Tavoni et al. (2011).

As shown in Figure 5, in each GT-treatment, there is one group whose group account is already decreasing, although the threshold could still be reached. In addition, Figure 8 (Appendix A.2) shows that in all HET-treatments, both poor and rich participants already choose the smallest possible contribution (0 or -3) in the first round. Figure 4 in section 4.2 shows that similar decisions can also be observed in the HOM-treatments. This could indicate that in all six treatments, several participants were pessimistic about reaching the threshold already at the beginning of the active rounds. Alternatively, it could suggest that these participants chose the smallest possible contributions in order to force other group members to make higher contributions.

Although the direction of the effects is mostly as expected, results are predominantly not statistically significant. This implies that we cannot make a conclusive statement regarding the take option effect. Most of our results are based on one-sided Fisher's exact tests which we use for the pairwise comparisons of treatments which differ only with respect to one characteristic. This is a very conservative approach which will detect significant effects only if they are large enough. In order to get more conclusive results, further experiments could use a larger number of groups per treatment.

Our results contribute to a better understanding of the cooperation dynamics in climate change experiments. We hope that they may motivate future research to investigate which institutions (see e.g., Dannerberg and Gallier, 2019; Chaudhuri, 2011; Gürerk et al., 2006) are appropriate to effectively promote cooperation and prevent the exploitation of (global) public goods. Furthermore, future studies could use similar experimental settings to investigate whether cooperation is hampered when a take option is available only for some group members or when the range of a take option varies between group members. The effect of a take option could also be examined in CRSD versions with uncertain or ambiguous thresholds (Brown and Kroll, 2017; Dannenberg et al., 2015) in intergenerational PGGs on climate change (e.g., Böhm et al., 2020; Lohse and Waichman, 2020).

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Appendix

A.1 Instructions (translated from German)

Welcome to the experiment and thank you for participating

General Information

Please read these instructions carefully. Do not talk to the other participants during the whole experiment. If you have any questions, please contact the experimenter silently by raising your hand. We will then come to you and answer your questions. Compliance with this rule is very important. Otherwise, the results of this experiment lose their scientific value.

Please take sufficient time to read the explanations when making your decisions. You cannot influence the duration of the experiment by making a quick decision, as you always have to wait for the other participants. The experiment is completely anonymous. During the experiment or afterwards, you will not be informed with whom you have interacted. The other participants will not, neither during the experiment nor afterwards, receive information on your decisions and final earnings.

For your participation in this experiment you will receive a fixed payment of € 5.00 and an **additional variable payment.** At the end of the experiment, a questionnaire follows. Afterwards, all participants of the experiment are called one after the other and receive their payment. The payout is private, anonymous, and in cash. The duration of the experiment is **approximately 60 minutes.**

The Experiment

Today's experiment involves 30 people who are divided into **five groups of six group members** each. The group allocation is carried out randomly. During the experiment you will only interact with the other members of your group of six. Within a group, each group member is randomly assigned a pseudonym which is displayed at the top right of the screen during the experiment. The pseudonyms correspond to the names of moons and dwarf planets from our solar system. Thus, you can follow the decisions of the group members while anonymity is guaranteed.
All amounts in the experiment are displayed in the currency Taler. For your final compensation, the exchange rate is 20 Taler = € 1 or 1 Taler = € 0.05.

The starting point: Each group member has an active account of 160 Taler and a passive account of 120 Taler. The experiment consists of a total of 20 rounds. Each group has a common **group account** which contains 0 Taler at the beginning of the first round.

The contribution decision within a round: Within a round, all group members decide simultaneously which amounts they want to contribute to or withdraw from the group account. Each group member can either contribute 8, 7, 6, 5, 4, 3, 2, 1 or 0 Taler from their own active account and add this to the joint group account, or withdraw -1, -2 or -3 Taler from the joint group account and add this to their own active account. The amount of the passive account does not change.

Rounds 1-10: In rounds 1 to 10, the contribution decisions of all group members are made by the computer. That is, a random contribution is selected for each group member and the balances of the active account and group account change accordingly. Positive contributions (8, 7, 6, 5, 4, 3, 2, 1) correspond to payments into the group account, and negative contributions (-1, -2, -3) correspond to withdrawals from the group account. Before initiating round 11, the contribution decisions and account balances from rounds 1 to 10 are displayed in a **results table** (see figure on page 4). For each group member, the results table shows the contribution for each round, the sum of the contributions to the group account, and the total sum in the active account. Furthermore, the average contribution per group member and the total contribution to the group account are displayed.

Rounds 11-20: In rounds 11 to 20, all group members make their own contribution decisions. This means that in each round, all group members decide simultaneously what amount they want to contribute to or withdraw from the group account. After each round, the results for all group members are displayed in the results table. The results table is visible after each round for a maximum of 60 seconds before the next screen appears. By clicking on the OK button, you can leave the results table screen before the 60 seconds have ended.

Calculation of payments

The variable payment, which you receive in addition to the fixed payment of €5.00, consists of two parts. The first part is the amount that is in your active account after round 20. The second part of the variable payment is the same for all group members and depends on the total balance of the group account:

- If there are **at least 480 Taler** in the group account after round 20, you will receive the **full 120 Taler** from your passive account.
- If there are **less than 480 Taler** in the group account after round 20, 95% (114 Taler) of the passive account will be lost and you will only receive **the remaining 5% (6 Taler)** from your passive account.

Your payment is therefore composed as follows:

Payment = fixed payment + active account after round 20 + passive account

Results table (will be shown after each round from 10 to 20)

The column **Round** shows the respective round.

The columns to the right of it in the top cell indicate the pseudonym (here **Deimos**) of each group member and, in the cells below, the (positive or negative) contribution of the group member to the group account in each individual round.

Round	Deimos
1	8
2	3

The column **Average per Person** shows the average contribution of the group members to the group account for the respective round.

The column **Sum Round** shows the sum of all group members' contributions to the group account for the respective round.

The column **Sum Group Account** shows the total amount in the group account at the end of the current round.

Average per Person	Sum Round	Sum Group Account
4	24	24
4	24	48

Result after Round 10

You are Player **Surtur**

Round	Deimos	Mimas	Oberon	Neso	Surtur	Amalthea	Average per Person	Sum Round	Sum Group Account
1	8	-1	8	-1	3	7	4	24	24
2	3	8	8	-2	0	2	4	24	48
3	8	5	8	6	2	0	4	24	72
4	6	7	-3	-1	7	8	4	24	96
5	8	6	6	0	0	4	4	24	120
6	8	7	8	5	-2	-2	4	24	144
7	-2	5	6	4	6	5	4	24	168
8	8	8	8	4	-2	-2	4	24	192
9	8	7	6	7	-2	-2	4	24	216
10	5	8	5	-2	8	0	4	24	240
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

	Deimos	Mimas	Oberon	Neso	Surtur	Amalthea	Average per Person
Contribution Group Account	60	60	60	20	20	20	40.00
Sum Active Account	100	100	100	140	140	140	120.00

OK

	Deimos	Mimas
Contribution Group Account	60	60
Sum Active Account	100	100

The row **Contribution Group Account** shows each individual group member's contribution to the group account at the end of the current round.

The row **Sum Active Account** shows each group member's current amount in their Active Account.

Average per Person
40.00
120.00

The column **Average per Person** in the upper cell shows the average contribution to the group account and, in the lower cell, the average amount in the active account by group member at the end of the current round.

Example

There are several possible scenarios over the course of the experiment, two of which are explained as examples. Of course, all other scenarios are also possible over the course of the experiment.

Scenario A:

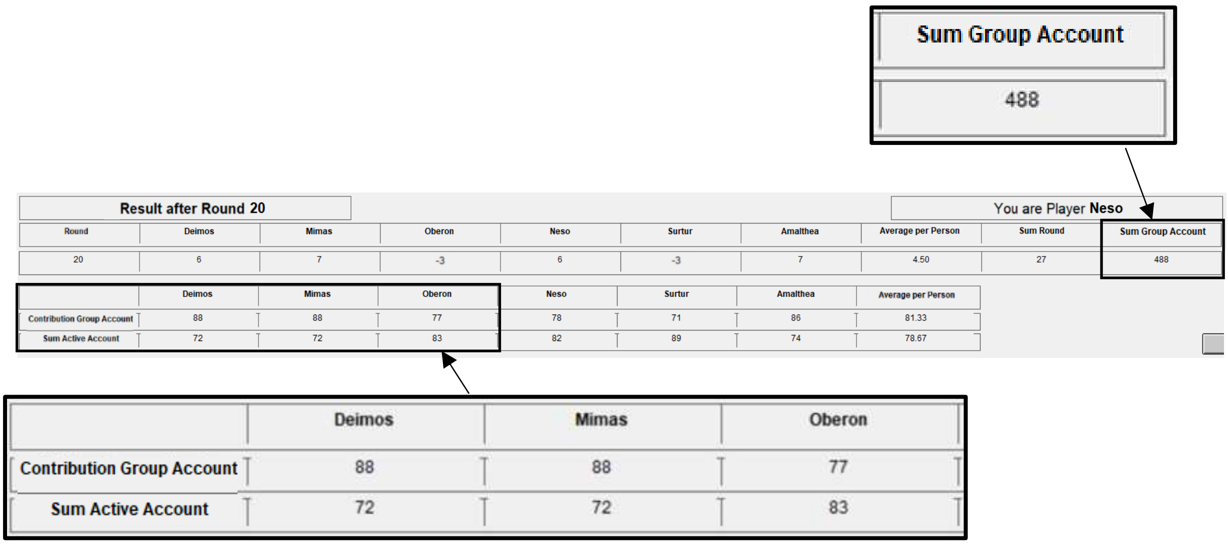
The figure below shows the result after round 20 and, to illustrate the example, we look at the group members Mimas and Oberon.

Mimas has contributed 88 Taler to the group account and still has 72 Taler in the active account. These 72 Taler represent the first part of the variable payment. The group account contains 488 Taler which is more than 480 Taler. Therefore, the 120 Taler of the passive account will be paid out. These 120 Taler represent the second part of the variable payment. The **variable payment** that Mimas receives in addition to the fixed payment of €5.00 is therefore

$$\mathbf{72 + 120 \ = \ 192 \ Taler \ or \ respectively \ 192 \ \times €0.05 \ = €9.60.}$$

Oberon has contributed 77 Taler to the group account and still has 83 Taler in the active account. These 83 Taler represent the first part of the variable payment. The group account contains 488 Taler which is more than 480 Taler. Therefore, the 120 Taler of the passive account will be paid out. These 120 Taler represent the second part of the variable payment. The **variable payment** that Oberon receives in addition to the fixed payment of €5.00 is therefore

$$\mathbf{83 + 120 \ = \ 203 \ Taler \ or \ respectively \ 203 \ \times €0.05 \ = €10.15.}$$



Scenario B:

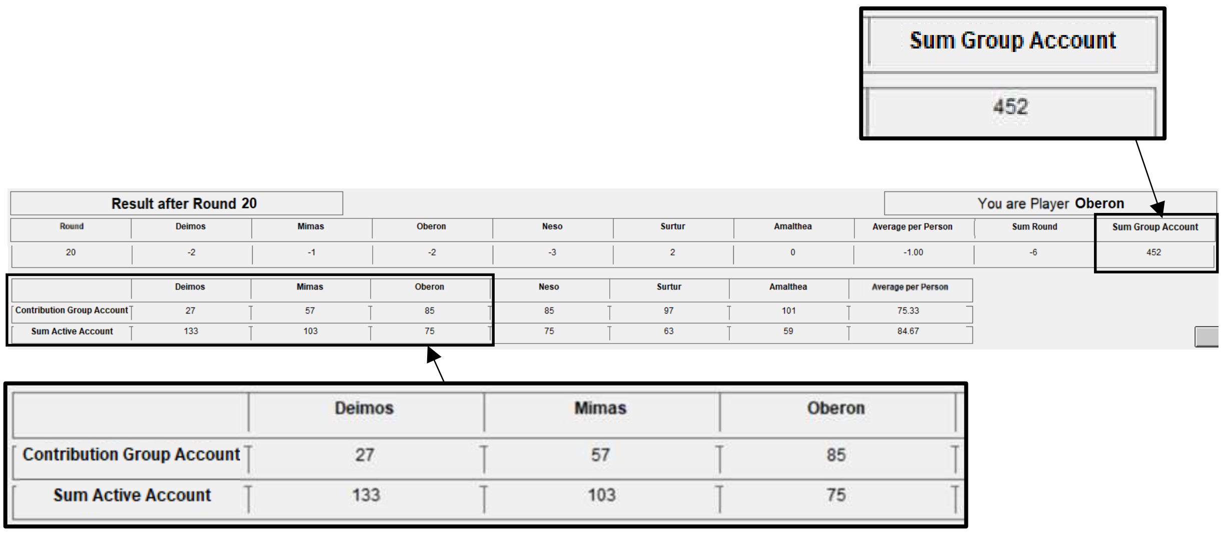
The figure below shows the result after round 20 and, to illustrate the example, we look at the group members Deimos and Mimas.

Deimos has contributed 27 Taler to the group account and still has 133 Taler in the active account. These 133 Taler represent the first part of the variable payment. The group account contains 452 Taler which is less than 480 Taler. Therefore, 95% (114 Taler) of the passive account will be lost and Deimos will only receive the remaining 5% (6 Taler) from the passive account. These 6 Taler represent the second part of the variable payment. The **variable payment** that Deimos receives in addition to the fixed payment of €5.00 is therefore

$$\mathbf{133 + 6 \;=\; 139\ Taler\ or\ respectively\ 139\ \times €0.05\ = €6.95.}$$

Mimas has contributed 57 Taler to the group account and still has 103 Taler in the active account. These 103 Taler represent the first part of the variable payment. The group account contains 452 Taler which is less than 480 Taler. Therefore, 95% (114 Taler) of the passive account will be lost and Deimos will only receive the remaining 5% (6 Taler) from the passive account. These 6 Taler represent the second part of the variable payment. The **variable payment** that Mimas receives in addition to the fixed payment of €5.00 is therefore

$$\mathbf{103 + 6 \;=\; 109\ Taler\ or\ respectively\ 109\ \times €0.05\ = €5.45.}$$



Summary:

- **Each group consists of six group members.**
- **The experiment runs for 20 rounds.**
- **The contribution decisions in rounds 1-10 are made by the computer and in rounds 11-20 by yourself.**
- **Prior to round 1, each group member has 160 Taler in her/his active account and 120 Taler in her/his passive account. Prior to round 1, there are 0 Taler in the group account.**
- **In each round, each group member can either contribute 8, 7, 6, 5, 4, 3, 2, 1 or 0 Taler from their own active account and add this to the joint group account, or withdraw -1, -2 or -3 Taler from the joint group account and add this to their own active account.**
- **If there are at least 480 Taler in the joint group account after round 20, each group member will receive her/his complete passive account of 120 Taler.**
- **If there are less than 480 Taler in the group account after round 20, 95% (114 Taler) of the passive account will be lost and each group member will only receive the remaining 5% (6 Taler) from her/his passive account.**
- **Your payment = fixed payment + active account after round 20 + passive account**.
- **Exchange rate: 20 Taler = €1 or respectively 1 Taler = €0.05.**

If you have any questions, please raise your hand and wait silently until someone comes to you. Please remain silent and do not communicate with the other participants during the whole experiment.

Thank you very much for your participation

A.2 Additional Statistical Analysis

Treatment	Successful groups	Unsuccessful groups	All groups
GT-HET95	490.89	247.00	466.50
	(7.20)	-	(77.42)
	N=9	*N*=1	*N*=10
G-HET70	489.78	477.00	488.50
	(5.85)	-	(6.84)
	N=9	*N*=1	*N*=10
GT-HET80	485.40	387.20	436.30
	(3.36)	(102.97)	(86.00)
	N=5	*N*=5	*N*=10
G-HET55	488.50	345.00	449.36
	(3.82)	(64.78)	(73.09)
	N=8	*N*=3	*N*=11
GT-HOM80	490.00	382.00	460.55
	(2.33)	(131.94)	(77.66)
	N=8	*N*=3	*N*=11
G-HOM55	488.71	309.00	466.25
	(3.35)	-	(63.61)
	N=7	*N*=1	*N*=8

Table 5: Mean group accounts and standard deviations (in parentheses) after round 20 over experimental treatments, ordered by successful and unsuccessful groups.

	$C_{19} \geq 480$ (threshold reached after round 19)			$C_{19} < 480$ (threshold not reached after round 19)		
Treatment	N	Mean (sd) contribution in round 20	Minimum contribution in round 20	N	Mean contribution in round 20	Minimum contribution in round 20
GT-HET95	2	2.08 (2.68)	0	7	3.24 (2.85)	-3
GT-HET80	2	0.42 (1.44)	0	3	2.94 (2.34)	0
GT-HOM80	0	-	-	8	3.50 (2.43)	-2
G-HET70	3	0.00 (0.00)	0	6	4.67 (2.48)	0
G-HET55	0	-	-	8	3.33 (2.31)	0
G-HOM55	0	-	-	7	4.88 (2.10)	0

Table 6: Contribution behavior of successful groups in round 20 ordered by whether the threshold was reached after round 19.

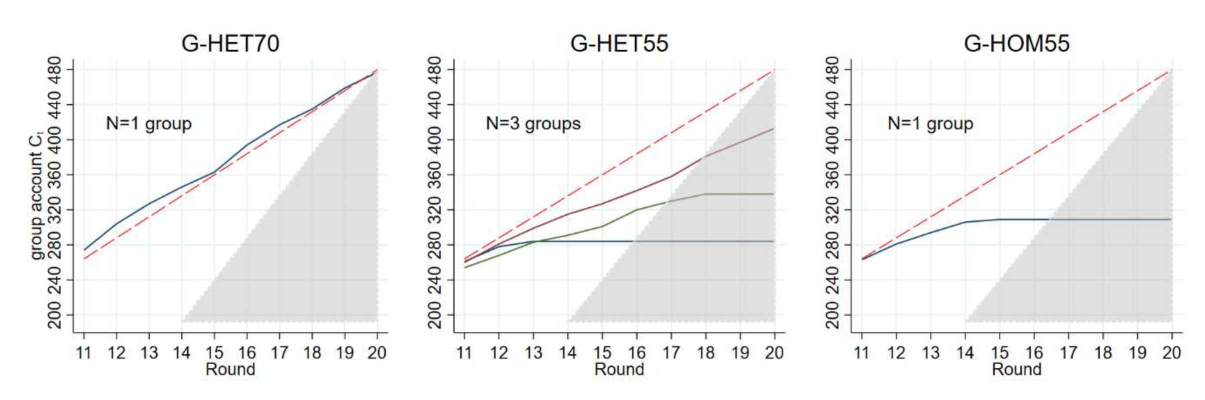


Figure 8: Evolution of group accounts in unsuccessful groups over G-treatments.

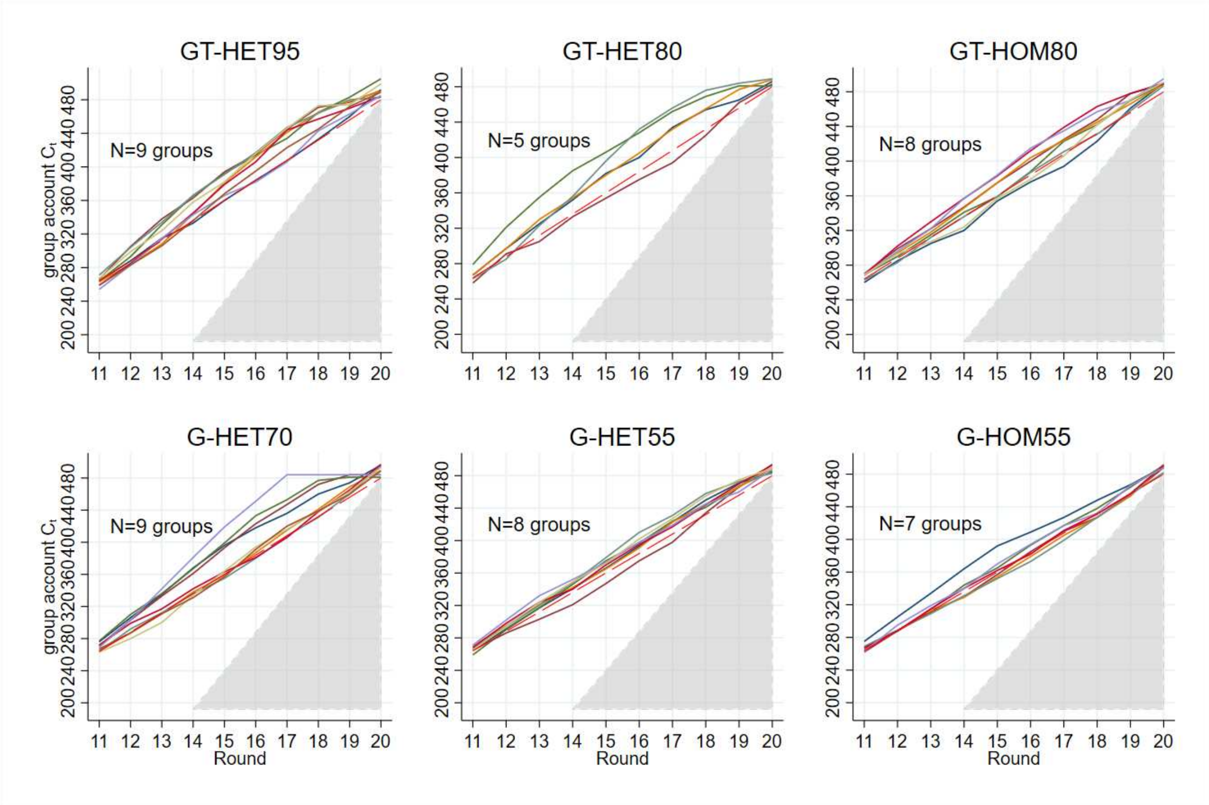


Figure 9: Evolution of group accounts in successful groups over GT- and G-treatments.

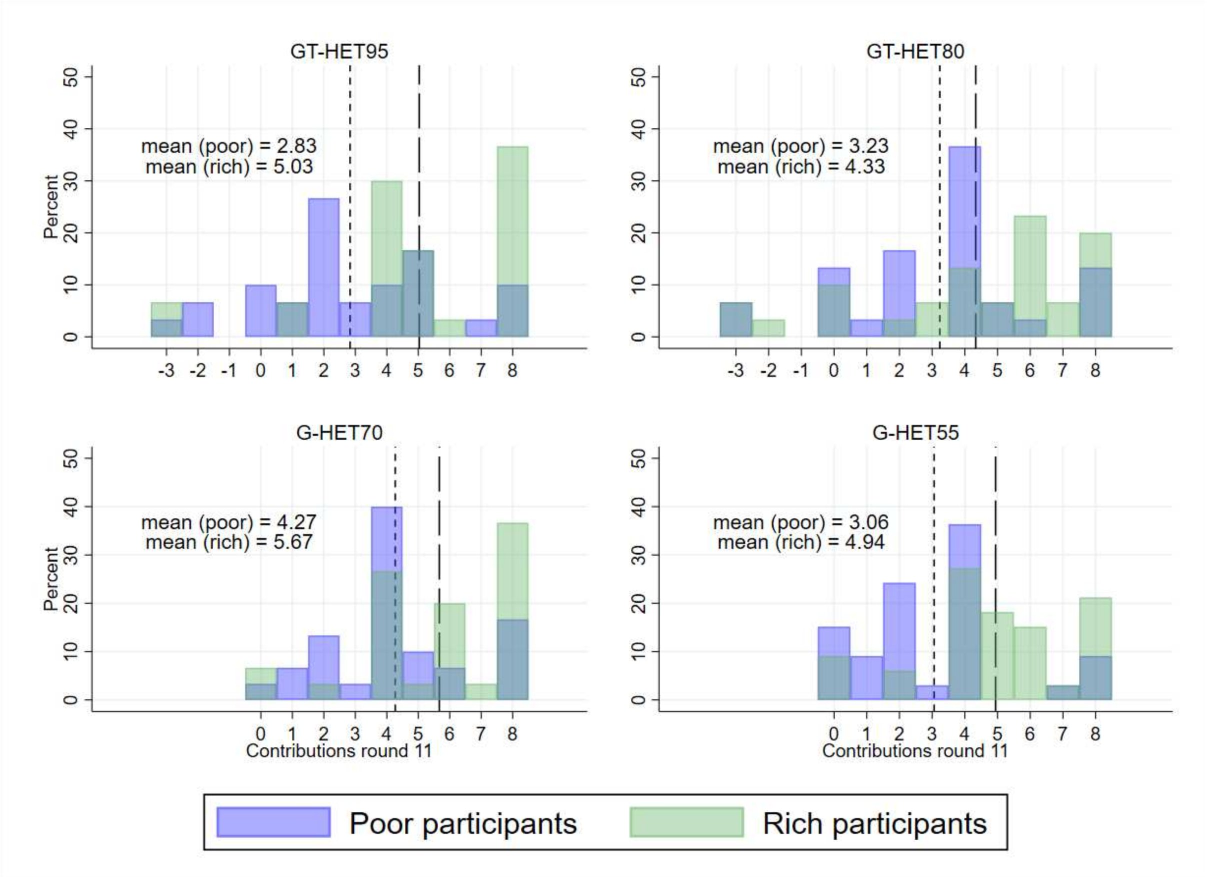


Figure 10: Distribution of contributions in round 11 by participant type and HET-treatment.

Notes. Vertical short (long) dashed lines indicate mean values for poor (rich) players.

A.3 The Impact of Demographics and Personal Attitudes

In this section, we examine the influence of participants' demographic characteristics and personal attitudes on their contributions in round 11 and on group success. In the OLS regression in Table 7, the dependent variable is the individual contribution in round 11 in heterogeneous treatments (model 1) or homogeneous treatments (model 2). Both regression models include independent variables for *Gender* and *Age*, as well as for the previous number of experiments participated in (*Experiments*). *NEP-Index* is the sum of answer values for the NEP scale by Dunlap et al. (2000). *NEP-Index* is calculated from the 11 items[9] that yield the highest Cronbach's alpha value (0.79). *Risk* contains the participants' reported risk propensity. Mean values and standard deviations for each item of the NEP scale and for the risk question can be found in Tables 8 and 9. Model 1 (heterogeneous treatments) includes a dummy variable which takes a value of 1 for rich players.

As Table 7 shows, both demographic characteristics and personal attitudes have no significant effect on contributions in round 11. In the heterogeneous treatments, rich players choose statistically significant higher contributions.

Next, we examine whether demographic characteristics and personal attitudes affect group success. Table 10 shows the results of probit regressions in which the dependent variable indicates whether the respective group reached the threshold or not. The independent variables *Gender_group*, *Age_group*, *NEP-Index_group*, *Risk_group*, and *Experiments_group* each indicate mean values per group. Model 1 refers to HET-treatments and model 2 to HOM-treatments. We find no clear evidence that any of the independent variables has an effect on group success. The variables *Gender_group* (model 2) and *Risk_group* (model 1) each have a significant negative effect on group success, but only in one model. The variable *Age_group* also has a significant positive effect on group success , but only in model 2.

[9] These are the NEP items 2, 3, 4, 5, 7, 8, 10, 12, 13, 14, and 15.

	(1) HET	(2) HOM
Gender (Female=1)	0.45	0.12
	(0.39)	(0.38)
Age	-0.04	-0.01
	(0.03)	(0.06)
Experiments	0.00	-0.01
	(0.01)	(0.01)
NEP-Index	-0.01	0.00
	(0.03)	(0.03)
Risk	-0.08	0.05
	(0.09)	(0.10)
Rich	1.69***	
	(0.40)	
Constant	4.51***	4.43**
	(1.35)	(1.98)
N	246	114
R^2	0.13	0.01
Adjusted R^2	0.10	-0.05

Table 7. OLS regression of contributions in round 11 on demographic characteristics and personal attitudes.

Notes. Both regression models include controls for treatments. Standard errors clustered by group in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Item	Do you agree or disagree that:	Mean (sd)
NEP1	We are approaching the limit of the number of people the earth can support.	4.13 (1.44)
NEP2 (R)	Humans have the right to modify the natural environment to suit their needs.	3.81 (1.13)
NEP3	When humans interfere with nature it often produces disastrous consequences.	4.64 (1.14)
NEP4 (R)	Human ingenuity will insure that we do NOT make the earth unlivable.	3.49 (1.27)
NEP5	Humans are severely abusing the environment.	5.16 (1.02)
NEP6 (R)	The earth has plenty of natural resources if we just learn how to develop them.	2.51 (1.21)
NEP7	Plants and animals have as much right as humans to exist.	4.89 (1.36)
NEP8 (R)	The balance of nature is strong enough to cope with the impacts of modern industrial nations	4.91 (1.11)
NEP9	Despite our special abilities humans are still subject to the laws of nature.	4.96 (1.13)
NEP10 (R)	The so-called "ecological crisis" facing humankind has been greatly exaggerated.	5.30 (1.09)
NEP11	The earth is like a spaceship with very limited room and resources.	3.33 (1.35)
NEP12 (R)	Humans were meant to rule over the rest of nature.	5.06 (1.18)
NEP13	The balance of nature is very delicate and easily upset.	4.54 (1.16)
NEP14 (R)	Humans will eventually learn enough about how nature works to be able to control it.	3.84 (1.28)
NEP15	If things continue on their present course, we will soon experience a major ecological catastrophe.	5.06 (1.03)
All 15		4.38 (0.57)
Answer: (1) Strongly disagree; (2) Somewhat disagree; (3) Rather disagree; (4) Rather agree; (5) Somewhat agree; (6) Strongly agree		

Table 8: NEP scale (Dunlop et al., 2000).

Notes. Means and standard deviations (in parentheses). (R) denotes reverse items.

Question	Mean (sd)
How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please tick a box on the scale, where the value 0 means: 'not at all willing to take risks' and the value 10 means: 'very willing to take risks'.	5.11 (1.98)

Table 9: Question on risk attitude (Dohmen et al., 2011).

Notes. Mean and standard deviation (in parentheses).

	Probit	
	(1)	(2)
	HET	HOM
Gender_group	-2.49	-5.10***
	(1.53)	(1.55)
Age_group	0.00	0.53**
	(0.07)	(0.21)
NEP-Index_group	-0.17	0.35
	(0.10)	(0.25)
Risk_group	-0.58*	0.82
	(0.30)	(0.84)
Experiments_group	-0.05	0.27
	(0.03)	(0.20)
Constant	15.64***	-31.91***
	(5.19)	(10.27)
N	41	19
Wald Chi^2	28.57	17.58
Pseudo R^2	0.29	0.51

Table 10: Probit regressions of group success on demographic characteristics and personal attitudes.

Notes. Both regression models include controls for treatments. Standard errors clustered by group in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$