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## Meet Me at the Threshold - Asymmetric Preferences in a Threshold Public Goods Game

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# Meet Me at the Threshold

## Asymmetric Preferences in a Threshold Public Goods Game

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### Abstract

In this experiment, we analyse a threshold public goods game in which players have varying benefits from public goods provision, motivated by the existence of large heterogeneities between countries in international environmental cooperation. We find that provision is most frequent when players are symmetric. While increasing the degree of asymmetry does not significantly hamper provision success, contributions become more volatile the more heterogeneous players are. Analysing how players share contribution costs, we see that the extent of asymmetry is not salient, leading to relatively constant burden-sharing across treatments despite varied levels of inequity, often leading to allocations that diverge from both our benchmarks of efficiency or fairness.

## 1 Introduction

There exist many decision situations in which groups of people come together with the aim of realising a joint project, which only materialises if enough effort or contributions towards the common goal accrue. Crowdfunding is an example in which an organiser finances a project by setting a funding goal, and then implements it if enough funds accumulate. Often times in charity fundraising, the charity endeavour is only put into effect if there are sufficient donations. Both of these examples have in common that they can be captured by the structure of a *threshold public goods game* (TPGG). Players in this game contribute towards reaching a threshold, and the public good is only provided if this threshold is met. However, the public good can then be enjoyed by all players independently of their contribution level. Essentially it is thus a game of group effort, in which the members of the group might have varying preferences for the public good or different contribution costs, but can only ensure provision if they work together. Particularly when heterogeneities exist across players, it is not always trivial how the contribution burden should be split among group members.

Another prominent example of a high stakes group effort game is the mitigation of anthropogenic climate change, which is a collective action problem that requires international coordination and cooperation, a task impeded by the fact that no supranational entity can enforce a fair and efficient outcome. Unsurprisingly, achieving a consensus that is impactful has proven to be extremely difficult over the past decades. While it is scientifically undisputed that decisive and immediate action is needed to achieve the the widely pronounced policy goal of net-zero emissions by mid-century, current mitigation efforts, as pledged in the Paris Agreement, are not ambitious enough to achieve such a trajectory (UNEP 2022; IPCC 2022). Due to the fact that mitigation of climate change is impeded by the public goods property of greenhouse gas emission reductions and therefore plagued by freeriding incentives, the challenging nature of international cooperation on environmental policy is not surprising and we observe a constant underprovision of emission reductions. TPGGs resemble the real-world collective action problem of climate change mitigation, in which reaching a common target requires individual sacrifice whereas benefits only emerge if others contribute as well (Milinski et al. 2008), and might therefore provide valuable insights into how the global community could succeed in limiting the increase of surface temperatures to below  $1.5^{\circ}\text{C}$  above pre-industrial levels in due time.

Many scholars have, by means of experimental analyses of public goods games, attempted to shed light on the relative importance of a variety of factors influencing the success of cooperation. One important aspect is the existence of large differences in the world community, for example with regards to wealth or exposure and vulnerability to climate change. Thus,

equity considerations are playing an important role in achieving an impactful consensus in international environmental policy (Lange et al. 2010; Klinsky et al. 2017). One potential way of addressing such concerns is by analysing the behaviour of heterogeneous players in TPGGs. This paper thus discusses an experimental analysis of public goods provision, motivated by the difficulties of the international community in coordinating actions to mitigate climate change stemming from asymmetry between involved agents. In this specific setup, I analyse the effect of different preferences for the public good on whether the public good is provided and how contributions toward the threshold are split between players depending on the degree of asymmetry between them. In the one-shot two-player game, a continuum of Nash equilibria emerge from a theoretical point of view. The experiment thus offers insights into whether and on which equilibrium allocations players implicitly coordinate and how this is affected by asymmetric preferences and varying social value of the public good. Specifically I test how public goods preferences affect (i) the frequency of provision, (ii) the equilibrium selection, and (iii) the resulting allocation once the potentially focal equal split equilibrium is removed from the equilibrium set. I find that asymmetric players provide the public good less frequently than symmetric players, where the degree of asymmetry plays a less important role than hypothesised. Burden-sharing occurs in a way that can be considered unjust, following both efficiency and fairness considerations, observing too high contributions by “poorer” players and too low contributions by “richer” players. This implies that there might be a biased perception of heterogeneities between agents in collective action problems, leading to far from optimal burden-sharing in public goods provision.

TPGGs have been studied for a long time, both theoretically and experimentally. In the standard setting of the game, players simultaneously choose their individual contribution level. Public goods provision occurs, if a certain contribution threshold is reached. From a theoretical point of view, Bagnoli and Lipman (1989) discuss the “one-streetlight-problem”, in which a group of neighbours wants to set up a streetlight and collect funds to do so. They essentially show that a “provision point mechanism” such as a TPGG achieves to alleviate the free-rider problem of public goods provision to some extent. In another early contribution, Palfrey and Rosenthal (1984) give the example of collecting money for a new office coffee pot, discussing the effect of differing refunding rules if not sufficient funds accrue.

In experimental setups, the specific rules of the game are very diverse and therefore only allow for limited comparison. To what extent contributions are multiplied in case of provision and whether contributions are wasted or (partially) refunded in case of non-provision, therefore varies depending on the specific research question and context (for an overview of early experiments see Croson and Marks 2000). Also, group sizes and whether games are repeated or one-shot heavily vary and influence findings. Here I will focus on contributions related to heterogeneity among players both in a general context as well as related to cli-

mate change. Within-group heterogeneity has been found to influence player’s willingness to contribute to collective goods (Rapoport and Suleiman 1993; McGinty and Milam 2013; Fischbacher et al. 2014; Gavrillets 2015), where players can be unequal with respect to their wealth (endowments), their contribution costs, as well as to how non-provision affects their welfare. The degree to which heterogeneity affects successful provision strongly interacts with the specific rules of the game and experiment design, where both positive and negative effects are possible.

A very active and recent literature on TPGGs is specifically set in an environmental context, mirroring the fact that costly mitigation pledges in international environmental agreements are public goods and that there are uncertainties concerning the amount of contributions necessary to make a treaty sufficiently stringent. While even with a known threshold coordination among players proves to be difficult, threshold uncertainty has received a lot of attention and is found to be detrimental to cooperation, since players tend to inaction when contributions are more risky (McBride 2010; Barrett and Dannenberg 2012; Dannenberg et al. 2015). Another complicating factor for coordination is players having differentiated stakes in the game, which is where we put our main focus.

Evidence on how heterogeneity across agents affects the likelihood of public goods provision is also mixed in the environmental literature. Tavoni et al. (2011) show that inequality in individual endowments hampers successful provision. While in their experiment the threshold level is certain, damages from not reaching it materialise only with a probability of 50%. Additionally, they allow for communication in the form of pledges, which is shown to promote coordination. However, they find that the “poor” subjects are not willing to compensate for inaction of the “rich” and thus the paper underlines the importance for early leadership by the wealthy. Waichman et al. (2021), to some extent contrasting the findings from Tavoni et al. (2011), show that heterogeneity does not necessarily lead to lower success rates in public goods provision. In their study, they differentiate between two types of heterogeneity: wealth (endowment) and expected loss heterogeneity and find that in the latter specification, the success rate in meeting the threshold is higher than under symmetry, concluding that heterogeneity might not only be an obstacle. Burton-Chellew et al. (2013) also investigate a double heterogeneity setting, however, suggest that if there exists heterogeneity in wealth, groups are less likely to reach the threshold if the poorer participant are more heavily affected from climate damages. The experiment of Feige et al. (2018) analyses the effect of a non-binding voting procedure, where players are heterogeneous with respect to marginal contribution costs and play a repeated TPGG with an uncertain threshold in groups of four. Similarly to my setup, multiple equilibria exist which differ in the way contributions are split between players. They find that the predominant burden-share is that of equal contribution costs, which in their experiment also coincides with equal payoffs.

This paper adds a number of novel insights to the literature. To our knowledge we are the first to analyse a TPGG with heterogeneous public good preferences in combination with quadratic contribution costs. Also, analysing the effect of player heterogeneity in one-shot games without communication allows for a detailed discussion of the isolated role of asymmetric preferences as well as of varying social value of the public good. The convex cost specification allows for the investigation of the trade-off experimental subjects face between efficiency and equity. Even though convex contribution costs pose a conceptual challenge to participants, this degree of complexity is within reason due to the provision of a payoff calculator, which supports subjects in their understanding of the payoff structure. Finally, from a methodological point of view, the application of a sequential matching procedure is novel and renders it possible to generate a high number of observations compared to if players were playing in groups.

## 2 Theoretical Background

I consider a threshold public goods game with a threshold level  $T$  that is known with certainty. The game is played one-shot among two players called 1 and 2, in the following indexed by  $i, j$ , where  $i \in \{1, 2\}$  and  $j \neq i$ . Players may have different benefits from public goods provision, captured by the preference parameter  $\theta_i$ , but they have identical quadratic contribution costs. In case contributions are not sufficient to reach the threshold, players lose a fraction  $q \in [0, 1]$  of their investment. The specific payoff functions are given as follows:

$$U_i(\theta_i, x_i) = \begin{cases} bT\theta_i - \frac{1}{2}cx_i^2 & \text{if } x_i + x_j \geq T \\ q(-\frac{1}{2}cx_i^2) & \text{otherwise} \end{cases} \quad i, j = 1, 2, j \neq i, c > 0. \quad (1)$$

If the contribution of the other player is above the threshold  $T$ , it is optimal for player  $i$  to contribute zero. In case of  $x_j < T$ , there exists a cut-off value  $\underline{x}_j$  which determines the minimum contribution of the opponent player such that it's a best response of agent  $i$  to contribute a positive amount. Above the cut-off value, the best response is to contribute such as to just reach the threshold. Below this cut-off value, the best response is not to contribute. In summary:

$$x_i = \begin{cases} 0 & \text{if } x_j \geq T \\ T - x_j & \text{if } \underline{x}_j \leq x_j < T \\ 0 & \text{if } x_j < \underline{x}_j \end{cases} \quad i, j = 1, 2 j \neq i, \quad (2)$$

where the cut-off value is type-dependent and is implicitly defined as the contribution level at which a player has a payoff of zero:

$$\begin{aligned} U_i(T - x_j | \text{'provision'}) &= U_i(0 | \text{'no provision'}) \\ bT\theta_i - \frac{1}{2}c(T - x_j)^2 &= 0, \end{aligned} \quad i, j = 1, 2 \ j \neq i. \quad (3)$$

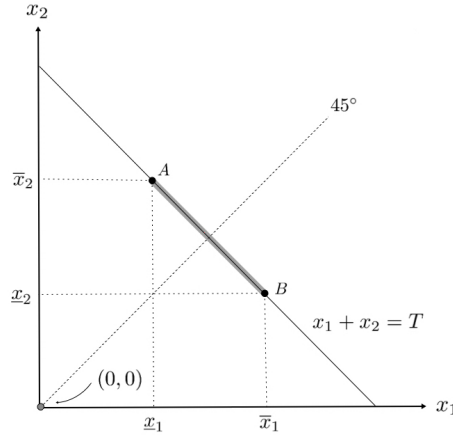
This leads to the following cutoff-values and maximum contribution levels of both players:

$$\underline{x}_i(\theta_j) = T - \sqrt{\frac{2b}{c}T\theta_j}, \quad \bar{x}_i(\theta_i) = \sqrt{\frac{2b}{c}T\theta_i} \quad i, j = 1, 2 \ j \neq i. \quad (4)$$

Hence, there exists a continuum of equilibria, all of which just reach the threshold and, in addition, the no contribution equilibrium  $(x_i, x_j) = (0, 0)$ . The continuum is characterised as follows:

$$\mathcal{C} = \left\{ (x_i, x_j) \mid x_i \in \{\underline{x}_i, \bar{x}_i\}, x_j \in \{\underline{x}_j, \bar{x}_j\}, x_i + x_j = T \right\}. \quad (5)$$

Figure 1 shows the equilibria of the game with symmetric players, that is  $\theta_i = \theta_j$ , indicated by the fact that cut-off values are symmetric as well. The grey line illustrates the continuum (5).



**Figure 1:** Illustration of the equilibrium interval and the no-contribution equilibrium.

The equilibrium interval narrows as the valuation of the public good decreases (lower values

of  $\theta$ ), as stated by (6) and (7).

$$\text{Point A: } \quad \frac{d\underline{x}_j(\theta_i)}{d\theta_i} < 0, \quad \frac{d\bar{x}_i(\theta_i)}{d\theta_i} > 0. \quad (6)$$

$$\text{Point B: } \quad \frac{d\underline{x}_i(\theta_j)}{d\theta_j} < 0, \quad \frac{d\bar{x}_j(\theta_j)}{d\theta_j} > 0. \quad (7)$$

## 2.1 Focal points

While all the points on the interval are equilibria, some of them can be interpreted as focal. In this section, I will highlight two such points, which are the efficient allocation that maximises joint payoff as well as an allocation which can be considered as *fair*, since it equally splits the gains from cooperation.

### Efficiency

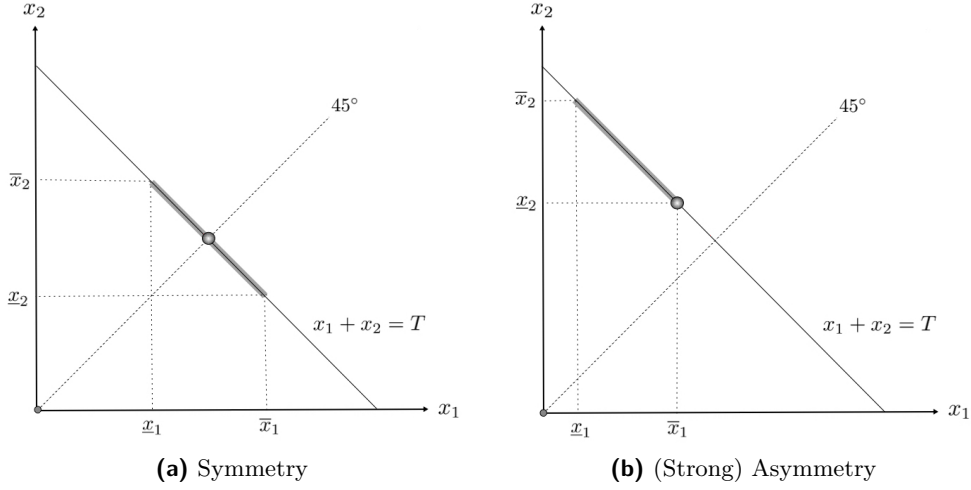
I define efficiency as the allocation that maximises joint payoff of players 1 and 2. Due to the fact that both players have the same quadratic contribution costs, the efficient allocation is given by the *equal split allocation*, that is  $x_i = x_j = \frac{T}{2}$ , as long as the benefits of provision outweigh the costs, that is when  $bT(\theta_i + \theta_j) > 2c(\frac{T}{2})^2$ . This can be seen by maximising joint payoffs given as follows:

$$\max_{x_i, x_j} \sum_{i=1}^2 U_i(\theta_i, x_i) = (\theta_i + \theta_j)bT - \frac{1}{2}c(x_1^2 + x_2^2) \quad \text{s.t. } x_1 + x_2 \geq T, (x_1, x_2) \in \mathcal{C} \quad (8)$$

Maximising joint payoff is a standard cost minimisation problem subject to the constraint that the threshold is reached. First, it is efficient to reach the threshold with precision, since any contribution beyond is wasteful. Second, the cost function  $C = \frac{1}{2}c(x_1^2 + x_2^2)$  reaches a minimum at  $x_1 = x_2$  and thus it is efficient for both to contribute half of the threshold. However, throughout this paper, we will refer to the efficient Nash equilibrium as the efficient allocation. Consequently, the equal split allocation is efficient, as long as it is in the continuum  $\mathcal{C}$  of Nash equilibrium.

Figure 2 illustrates that this corresponds to the intersection of the 45° line with the threshold line. This allocation can be reached in equilibrium, as long as the equilibrium interval covers this point. In case of sufficiently heterogeneous preferences for the public good, this allocation, however, is not a Nash equilibrium. In this case, the most cost-efficient Nash equilibrium is that at the boundary of the equilibrium closest to the 45° line. Lastly, if public goods preferences are sufficiently small, the only and thus efficient equilibrium is the





**Figure 2:** Efficient allocation illustrated by  $\circ$

no-contribution allocation. The efficient allocation, depending on the degree of preference asymmetry can thus be summarised by:

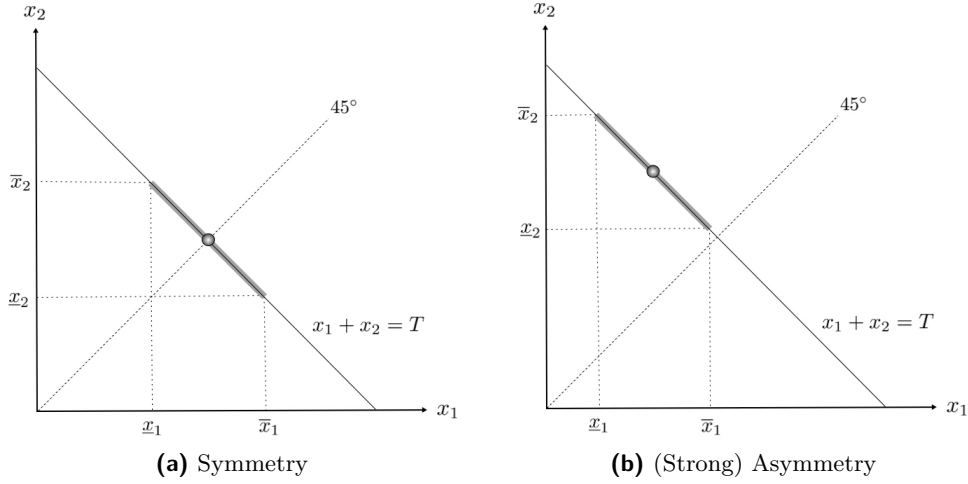
$$(x_1^{eff}, x_2^{eff}) = \begin{cases} \left(\frac{T}{2}, \frac{T}{2}\right) & \text{if } \frac{T}{2} \in (\underline{x}_i, \bar{x}_i), i = 1, 2 \\ (\bar{x}_1, T - \bar{x}_1) & \text{if } \frac{T}{2} \notin (\underline{x}_i, \bar{x}_i), C \neq \emptyset, i = 1, 2 \text{ and } \theta_2 > \theta_1 \\ (T - \bar{x}_2, \bar{x}_2) & \text{if } \frac{T}{2} \notin (\underline{x}_i, \bar{x}_i), C \neq \emptyset, i = 1, 2 \text{ and } \theta_1 > \theta_2 \\ (0, 0) & \text{otherwise.} \end{cases} \quad (9)$$

### Fairness

A possible conception of fairness is that players equally share the surplus generated from reaching the threshold, which can be a second focal point. This is given by the center of the equilibrium interval, given that it exists, as illustrated in Figure 3 and given by (10). Otherwise, the fair allocation equals the no-contribution allocation.

$$(x_1^{fair}, x_2^{fair}) = \begin{cases} \left(\frac{\bar{x}_1 + \underline{x}_1}{2}, \frac{\bar{x}_2 + \underline{x}_2}{2}\right) & \text{if } \underline{x}_i \geq 0 \quad i = 1, 2 \\ (0, 0) & \text{otherwise} \end{cases} \quad (10)$$

Considering Figures 2 and 3 we can see that while in the symmetric case the two points overlap, as soon as there is preference asymmetry between the two players the values diverge. Both focal points will be used as benchmarks in the analysis of the experimental data in Section 4.



**Figure 3:** Fair allocation illustrated by  $\circ$

Finally, note that there potentially exist different conceptions of fairness among players, which would imply that this focal point is not the same for different players. One additional example could be that of equal cost sharing, which in this specification would correspond to equal contributions, coinciding with our definition of efficiency, as long as equal contribution is a Nash equilibrium.

### 3 Experimental Design

In the experiment, two subjects interact as players 1 and 2, choosing contribution levels  $x_1$  and  $x_2$  with the goal of reaching a threshold level  $T$ . Each pair plays 25 rounds, where each round differs with respect to assigned preference parameters for the public good  $\theta_1$  and  $\theta_2$ . The experiment can be interpreted as 25 rounds of one-shot games: players do not receive any feedback on their co-player's contribution and hence whether provision was successful until after all 25 rounds have been played. By randomising the order of rounds, learning and sequence effects are controlled for (see Section 4.1.2).

In the experimental setup, both  $T$  and  $b$  are normalised to 1 without loss of generality, while the cost parameter  $c$  is set to 10. Further, we set  $q = 0.1$ , meaning that players lose 10% of their contributions if the threshold is not reached. Contributions can be interpreted as percentage share of the investment. This simplifies the maximum contribution level according to (4) as follows:

$$\bar{x}_i = \sqrt{0.2\theta_i}, \quad i = 1, 2. \quad (11)$$

Consequently:

$$\underline{x}_i = 1 - \sqrt{0.2\theta_j}, \quad i, j = 1, 2, j \neq i. \quad (12)$$

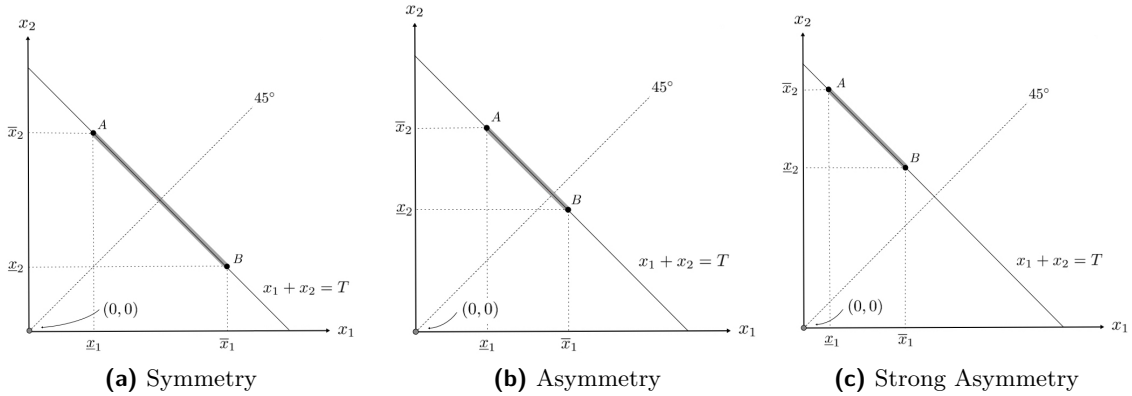
The equilibrium interval (5) thus becomes:

$$\mathcal{C} = \left\{ (x_i, x_j) \mid x_i \in \left\{ 1 - \sqrt{0.2\theta_j}, \sqrt{0.2\theta_i} \right\}, x_j \in \left\{ 1 - \sqrt{0.2\theta_i}, \sqrt{0.2\theta_j} \right\}, x_i + x_j = T \right\}. \quad (13)$$

This interval reduces to a single point if  $\bar{x}_1 = \bar{x}_2 = 0.5$ , which holds for  $\theta_1 = \theta_2 = 1.25$ . Hence, if  $\theta_i < 1.25$ , the equal split allocation is outside of the equilibrium interval. Conversely, the full diagonal would be part of the equilibrium interval if  $\bar{x}_1 = \bar{x}_2 = 1$ , which is the case for  $\theta_1 = \theta_2 = 5$ .

The set of assigned preference parameters is given by  $\theta_i \in \{0.75, 1.25, 2.5, 3.75, 4.25\}$ , where all possible combinations among two subjects are played across the 25 rounds. This implies three different types of treatments in terms of preference asymmetry (illustrated in Figure 4), defined as follows:

- Symmetry (5 rounds):  $\theta_1 = \theta_2$ ,
- Asymmetry (12 rounds):  $\theta_1 \neq \theta_2$  and  $\theta_i \neq 0.75$  for  $i = 1, 2$ ,
- *Strong* asymmetry (8 rounds):  $\theta_1 \neq \theta_2$  and  $\theta_i = 0.75$  for either  $i = 1, 2$ .



**Figure 4:** Treatment types

Furthermore, this specification allows to disentangle the effects of preference heterogeneity and varying aggregate value of the public good. The latter relates to the fact that successful provision is expected to be easier if players value the public good more on aggregate. In

order to isolate the effect of preference heterogeneity, five treatments keep the aggregate value of the public good constant at  $\theta_1 + \theta_2 = 5$ , and therefore constitute a special set of games:

- Constant social value:  $\theta_1 + \theta_2 = 5$   
 $(\theta_1, \theta_2) = (2.5, 2.5), (0.75, 4.25), (1.25, 3.75), (3.75, 1.25), (4.25, 0.75)$

Within this set, all three treatment types are represented. Note that for half of the remaining 20 treatments, the aggregate value of the public good is either higher or lower than 5. In Table 5 in the Appendix, a full overview over the 25 games is provided.

### 3.1 Hypotheses

The general aim of the experiment is to determine:

- (i) How often the threshold is reached (success rate) and with which precision (deviation from threshold),
- (ii) how contributions  $x_1$  and  $x_2$  compare (burden-sharing),
- (iii) and how contributions compare to focal equilibrium points (deviation from fair/efficient).

I analyse how these insights are affected by the width and location of the equilibrium interval (5). Successful public good provision implies some implicit coordination on how to split contributions towards the threshold. This implicit coordination may be facilitated by focal points, where both efficiency and fairness, as defined in Section 2.1, may serve as such. As stated, under symmetry the two focal points coincide, while under asymmetry they diverge, conceivably hindering coordination. On top of that, in strongly asymmetric games, the equal split allocation is not available and thus no longer coincides with either of the two focal points, making coordination even more difficult. This leads to the following hypothesis:

#### **Hypothesis 1 (Coordination and Preference Asymmetry)**

*Coordination is easier in symmetric games than in asymmetric games, making successful public good provision more frequent in symmetric games. Coordination is hardest and thus provision least frequent in strongly asymmetric games.*

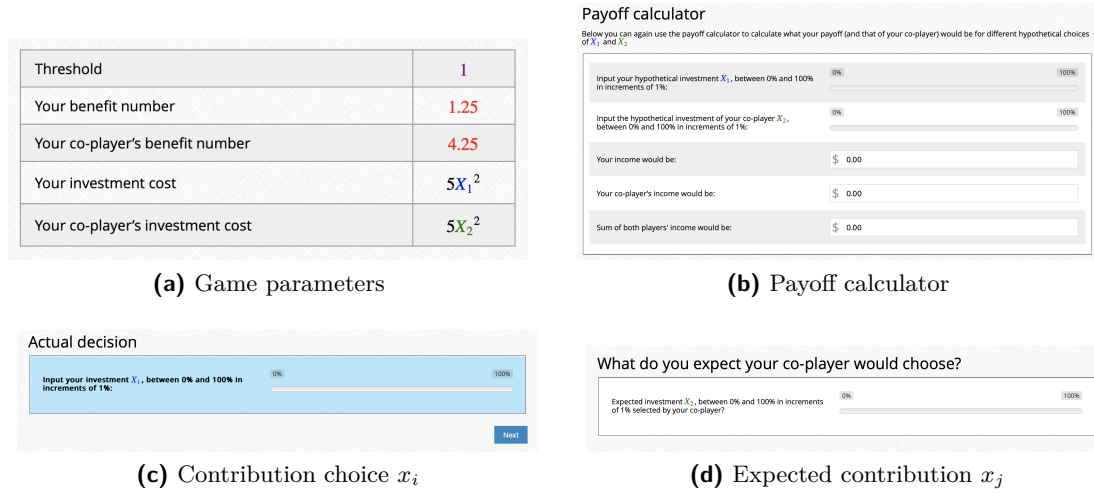
In addition, implicit coordination may be more difficult the larger the continuum  $\mathcal{C}$  of Nash equilibria, as there are more options to profitably deviate from one of the focal points. However, at the same time a larger equilibrium interval also implies higher benefits (social value) of successful public goods provision, which should facilitate reaching the threshold. Therefore, we have two counteracting forces, which might harm or improve success rates, leading to the second hypothesis:

## Hypothesis 2 (Coordination and Social Value)

*The relation between increasing social value of the public good and the success rate of public good provision is non-monotonic.*

### 3.2 Implementation

The experiment was programmed by Expilab Research and consisted of four main phases. In the first phase, participants expressed consent and commitment to participate in the study and were then shown detailed instructions for the experiment and informed about compensation (fixed fee of 5£, bonus payment depending on average payoff across 25 rounds). In the next phase, participants had to complete three rounds of a tutorial aimed at testing their grasp of the provided payoff calculator. The third and main phase of the study consisted of the 25 rounds of the game. In each round, participants were given the parameters of the game (which changed across rounds) as well as a payoff calculator, as depicted in Figure 5. The payoff calculator provided two sliders for contribution levels  $x_1$  and  $x_2$  ranging from 0% to 100% in 1% increments. At the beginning of each round, the sliders were not set to any value in order to avoid framing effects (as pictured in Figure 5b). This payoff calculator allowed them to easily determine their own, their co-player's and joint payoff depending on contribution levels. For each round, players then had to choose an actual contribution level  $x_i$  and also indicate, what contribution  $x_j$  they expect their co-player to make<sup>1</sup>.



**Figure 5:** Screenshots from main phase of experiment.

After the subjects completed 25 rounds of the game, the final phase followed in the form of a

<sup>1</sup> Due to technical issues, the expectation of  $x_j$  was not recorded throughout the experiment and can thus not be used in the data analysis.

questionnaire. Here, participants indicated demographic information and were asked about various aspects of the game. An overview of questionnaire replies is given in Section 4.1.1. Finally, participants received a completion code, which allowed them to retrieve compensation for participating in the study. After rounds 8 and 16 attention checks were included to ensure continuous attention of experimental subjects. The questions were completely unrelated to the experiment and concerned favourite fruits and cities. If a subject failed an attention check, the experiment was discontinued, which occurred one time.

As players played 25 rounds of a one-shot game without feedback after each round, it was not necessary for players to play the game simultaneously (as of calendar time) in pairs. In order to determine each player’s payoff at the end of the 25 rounds, all players were matched with the player who at their respective start time had most recently completed the experiment. The contribution choices of this matched co-player thus served as  $j$  values for player  $i$ . This, however, meant that some participants were chosen as the co-player of multiple other subjects, giving their contribution choices a higher weight in the total dataset, while some players’ contribution choices never appear as player  $j$ . While this was the matching procedure relevant for the computation of the bonus payments, the data analysis will be based on a randomised matching in which each player is randomly determined to be one other participant’s co-player.

## 4 Results

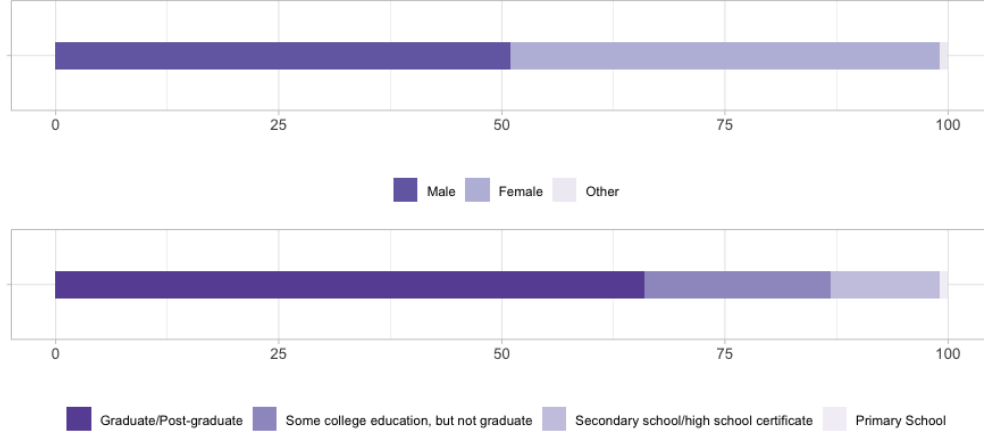
The results of the experiment will be reported in three parts. First, an overview of the subject pool will be provided with respect to demographics as well as detailing participants’ responses in the post-experiment questionnaire. Also, a potential learning effect over the course of the experiment will be discussed. Second, a focus is put on symmetric treatments in order to address the interaction of interval width and the success rate and thus Hypothesis 1. Third, I will discuss constant social value games, asymmetric games as well as strongly asymmetric games separately in order to focus on the isolated effect of preference asymmetry from different angles, addressing Hypothesis 2.

### 4.1 Overview

The experiment was conducted on 20 January 2023 on the platform Prolific with a subject pool of 106 participants based in the United Kingdom.

#### 4.1.1 Subject Pool

The subject panel is balanced in terms of gender and highly educated, with more than 60% of participants having completed higher education. Figure 6 details the exact distribution of gender and education. The mean age is 42 years, with the youngest participant being 20 and the oldest 71 years old. 89% of participants indicated English to be their first language.



**Figure 6:** Gender and education distribution

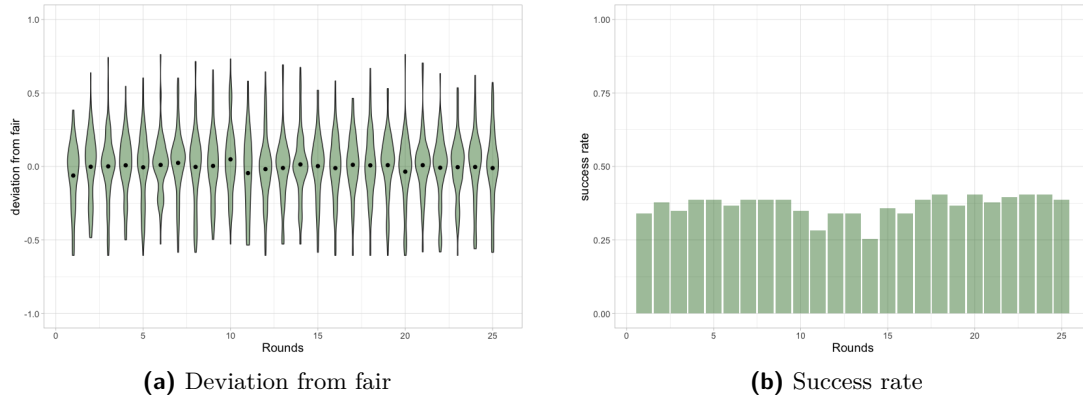
In the post-experiment questionnaire, participants on average indicated the level of difficulty to be slightly above average with a mean of 3.69 on a scale of 0 (extremely easy) to 6 (extremely difficult). When asked about risk attitudes, more than half of participants stated to be between risk neutral to risk prone, with the average being at 2.9 on a scale from 0 (extremely risk prone) to 6 (extremely risk averse). This might seem surprisingly high, however, it has to be kept in mind that these are self-reported values rather than deducted from a lottery. The subject pool quite evenly distributed on a scale from “very rarely” to “very often” when asked about whether they tend to trust people. Almost all participants indicated to have donated to charity before, with a frequency evenly ranging from “monthly” to “at most 5 times in my life”. Finally, when asked about their skills at working with fractions, subjects averaged a score of 3.63 on a scale from 0 (not good at all) to 6 (extremely good).

Participants were also asked about their strategies and their perception of several aspects of the game. A majority of subjects (53%) indicate that the allocation they perceive as fair is the one in which players choose contributions such as to maximise joint payoff. Interestingly, this corresponds to what we define as the efficient focal point. However, as pointed out in Section 2.1, this could also be interpreted as “cost fairness”. Roughly a quarter of subjects (23%) consider the allocation which ensures similar payoffs to both players as fair, which

is also our definition of the fair focal point. Furthermore, 57% think that contributions should be such that both players have a positive payoff, if possible. When asked about picking the most difficult aspect of the game, the most frequent answers were “grasping the differences between rounds” (37%) and “guessing contribution  $X_2$ ” (32%). The most important rationale for contribution decisions for most players (49%) was “group efficiency”, which was defined as maximising the joint income of players, followed by “monetary self-interest” (17%) and “avoiding risk” (14%), the latter being defined as avoiding being alone with a high contribution, potentially risking not reaching the threshold. A more detailed picture of the post-experiment survey can be found in the appendix.

#### 4.1.2 Sequence Effect

The different variants of the game were played in a randomised order for each subject, which allows us to interpret each game as a one-shot game. However, it could theoretically be possible that subjects (i) experience a learning effect from playing the game and therefore their performance might systematically improve over the rounds, or that (ii) player’s attention or motivation decreases, leading to deteriorating performances. This is not what we see in the data, illustrated by Figure 7.



**Figure 7:** No sequence effect over rounds.

Figure 7a shows the distribution of deviations from the fair contribution in each round of the game, a measure comparable across different treatments, with the black dots indicating means per round. Due to the fact that the order of games was randomised, in each round a random mix of games was played. If there was a sequence effect from playing the game for 25 rounds, we could expect to see a trend, which is not what is depicted. This visual impression is confirmed by one-way ANOVA tests, with the null hypotheses being that there is no difference between means across rounds. The null hypothesis is clearly not rejected ( $p =$



0.890). The same exercise can be done with the deviation from the efficient contribution, where a one-way ANOVA test also clearly indicates that means are not significantly different ( $p = 0.594$ ), see Figure 30 in Appendix C. A second variable of interest is the success rate, which is computed as the percentage share of games in which the threshold was successfully reached. If subjects experienced a sequence effect, they might have reached the threshold more or less frequently as rounds progressed. Figure 7b depicts average success rates per round, the difference between which is not statistically significant (one-way ANOVA,  $p = 0.304$ ). We therefore conclude that there is no significant sequence effect during the course of the study.

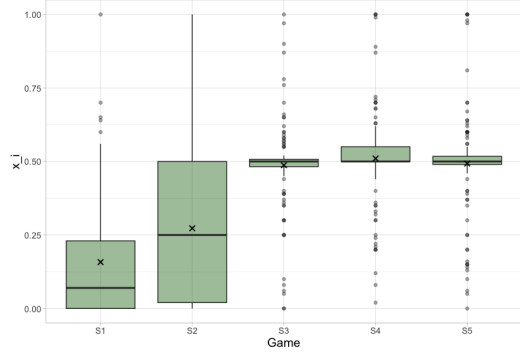
## 4.2 Symmetry

In this section, I will focus on the five symmetric games, which will be referred to as games S1–S5. Note that the preference parameters in S1 are so low that an efficient provision of the public good is not possible. In S2, only the equal split and the no contribution allocations ensure non-negative payoffs. For the remaining three games, it is efficient and fair to choose the equal split allocation. Table 1 provides summary statistics. We can see that for games S3–S5, the mean and medium contribution levels of player  $i$  are practically indistinguishable, which is confirmed by pairwise two-sided Wilcoxon rank-sum (WRS) tests (S3 & S4  $p = 0.176$ , S3 & S5  $p = 0.842$ , S4 & S5  $p = 0.241$ ). Furthermore, the spread of contributions in games S1 and S2 is visibly higher, as seen in Figure 8. Note that the mean is indicated with a cross, where the bar corresponds to the median.

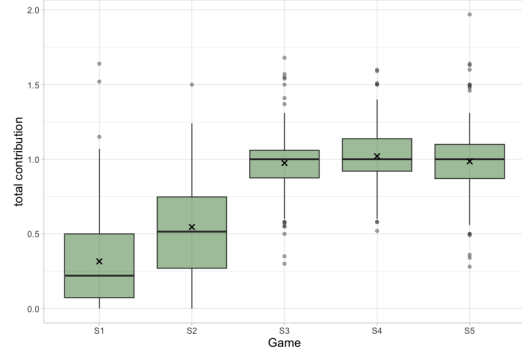
**Table 1:** Summary statistics for symmetric treatments

| Game | Type | $(\theta_i, \theta_j)$ | mean $x_i$ | median $x_i$ | sd $x_i$ |
|------|------|------------------------|------------|--------------|----------|
| S1   | S    | (0.75, 0.75)           | 0.1578     | 0.0700       | 0.2107   |
| S2   | S    | (1.25, 1.25)           | 0.2728     | 0.2500       | 0.2301   |
| S3   | S    | (2.5, 2.5)             | 0.4873     | 0.5000       | 0.1623   |
| S4   | S    | (3.75, 3.75)           | 0.5102     | 0.5000       | 0.1701   |
| S5   | S    | (4.25, 4.25)           | 0.4929     | 0.5000       | 0.1904   |

The equal split allocation in symmetric games corresponds to the fair and efficient focal point when available part of the equilibrium interval. In Game 1, only a contribution of zero ensures a non-negative payoff, which is chosen most frequently ( $x_i = 0$  with 38.7%). For the other four games, a contribution of 0.5 is on the equilibrium interval and as illustrated in Figure 9 is focal. Note that in S2, contributions of zero and the equal split are equivalent in terms of payoffs, that is, both equal to zero. Indeed, participants chose those two levels with similar frequency ( $x_i = 0$  with 22.6%).

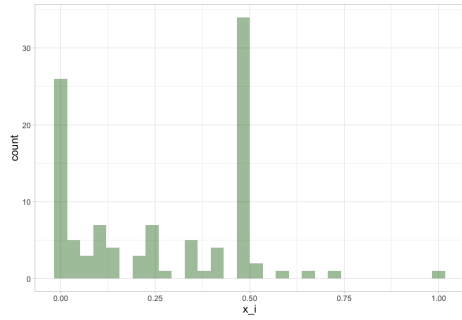


(a) Contributions  $x_i$

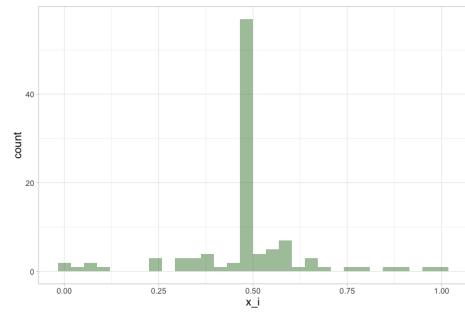


(b) Total contributions  $x_i + x_j$

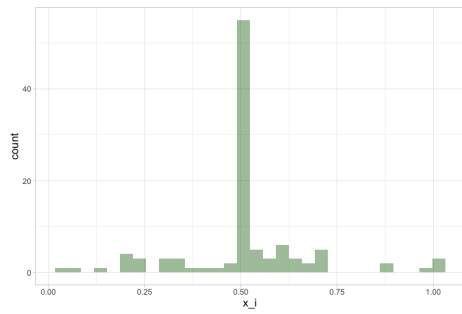
**Figure 8:** Distribution of contributions in symmetric games.



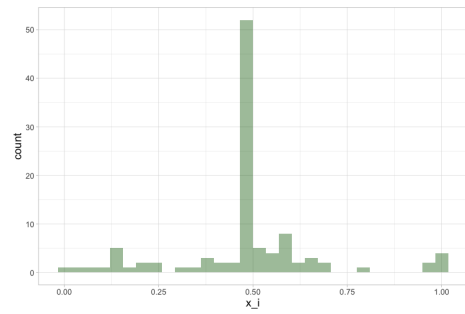
(a) S2:  $x_i = 0.5$  with 30.2%



(b) S3:  $x_i = 0.5$  with 47.2%



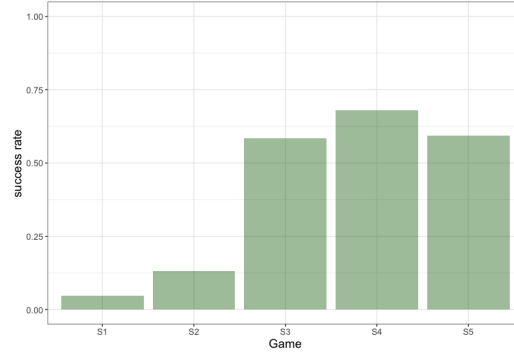
(c) S4:  $x_i = 0.5$  with 48.1%



(d) S5:  $x_i = 0.5$  with 40.6%

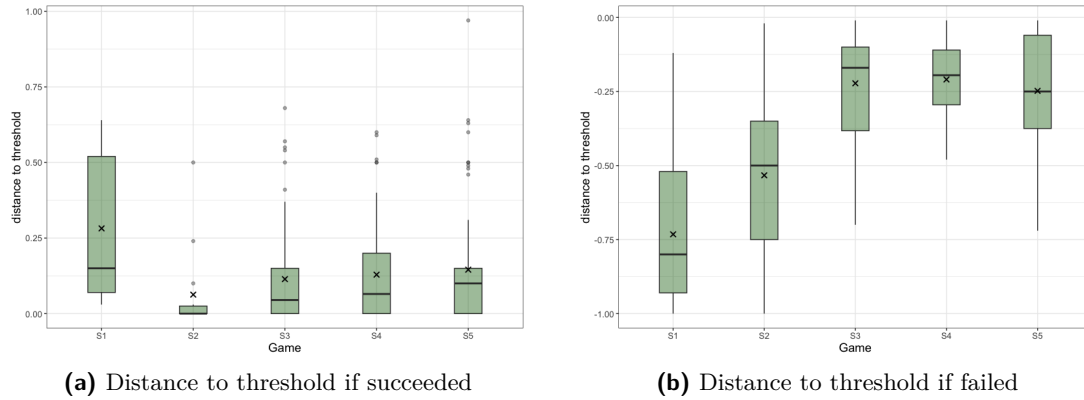
**Figure 9:** Contribution frequencies in the 5 symmetric games.

Figure 10 illustrates the success rates for the symmetric games. Remember that in S1 it is not possible to reach the threshold without incurring a negative joint payoff, where in S2 only the equal split allocation ensures a non-negative joint payoff, justifying the low success rates. We can see that the success rate increases up until S4, but then decreases for S5. The difference in the success rate, however, is not statistically significant between games S4 and S5 (one-sided WRS test,  $p = 0.100$ ). Increasing stakes, that is higher social value, tend to increase provision success more than a narrower interval seems to facilitate coordination. Still, it is notable that the success rate does not further increase after S4, despite the fact that all focal points coincide, suggesting a potential non-linear relationship between the interval width and the success rate, as suggested in Hypothesis 2.



**Figure 10:** Success rate in symmetric games.

Figure 11b depicts the groups which failed to meet the threshold and indicates the distance distribution from total contributions to the threshold. The substantial distance in S1 and S2 is not surprising, but interestingly in S5 the threshold was missed by more on average than in the two other games (means S3–S5:  $-0.2223$ ,  $-0.2094$ ,  $-0.2479$ ), even though in this game the social value of the public good was the highest.



**Figure 11:** Success and failure in symmetric games.

Figure 11a analogously show the distribution of distances to the threshold for successful groups. Note that the surprisingly high value for S1 can be attributed to the fact that success in this game only occurred five times and thus is based on outlier values. The spread of S2 contributions is very low and most values close to zero, mirroring the fact that only the equal split yields non-negative payoffs. For S3–S5, the mean overshoot ranges from 0.114 to 0.145.

### 4.3 Effect of Asymmetry

This section highlights the effect of asymmetry from three different angles. First, keeping the social value of the public good constant, I investigate how different degrees of asymmetry affected success rates and burden-sharing among players. Second, focussing on the asymmetric treatment type, I discuss how increasing one player’s stake in the game affects success and contributions. Finally, the same exercise will be conducted for strongly asymmetric games.

#### 4.3.1 Constant Social Value Games

We define the *constant social value* (CSV) treatments as the five games in which the sum of  $\theta$  values is equal to 5, and therefore the games in which the effect of asymmetry is isolated. Note that CSV3 is identical to game S3 discussed in the previous section. The summary statistics of the five games are given in Table 2 and contribution levels are illustrated in Figure 12. In all five games it is possible to reach the threshold with a positive joint payoff.<sup>2</sup>

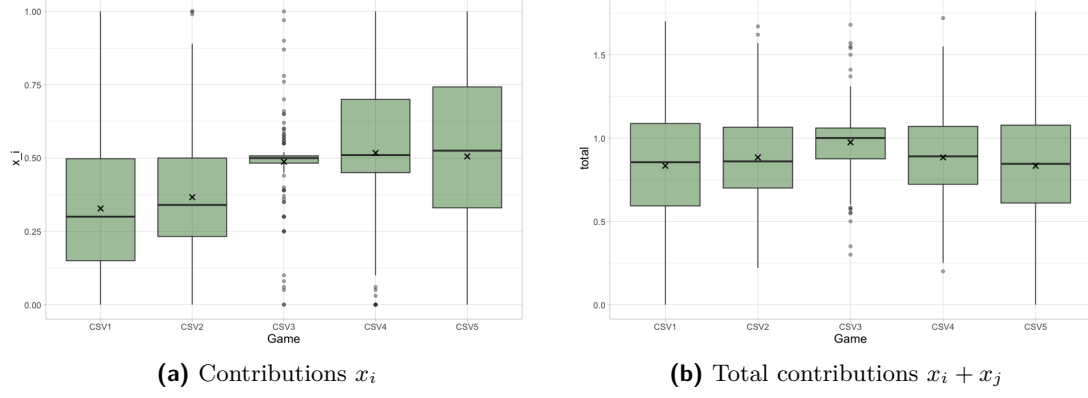
**Table 2:** Summary statistics for CSV treatments

| Game | Type | $(\theta_i, \theta_j)$ | mean $x_i$ | median $x_i$ | sd $x_i$ |
|------|------|------------------------|------------|--------------|----------|
| CSV1 | SAS  | (0.75, 4.25)           | 0.3279     | 0.3000       | 0.2597   |
| CSV2 | AS   | (1.25, 3.75)           | 0.3663     | 0.3400       | 0.2277   |
| CSV3 | S    | (2.5, 2.5)             | 0.4873     | 0.5000       | 0.1623   |
| CSV4 | AS   | (3.75, 1.25)           | 0.5173     | 0.5100       | 0.2308   |
| CSV5 | SAS  | (4.25, 0.75)           | 0.5055     | 0.5250       | 0.2833   |

Figure 12a essentially pictures two groups of games between which contribution levels clearly differ, that is games CSV1 and CSV2 in which asymmetry is against player  $i$  and the remaining games CSV3–CSV5. The mean contribution level also significantly varies within

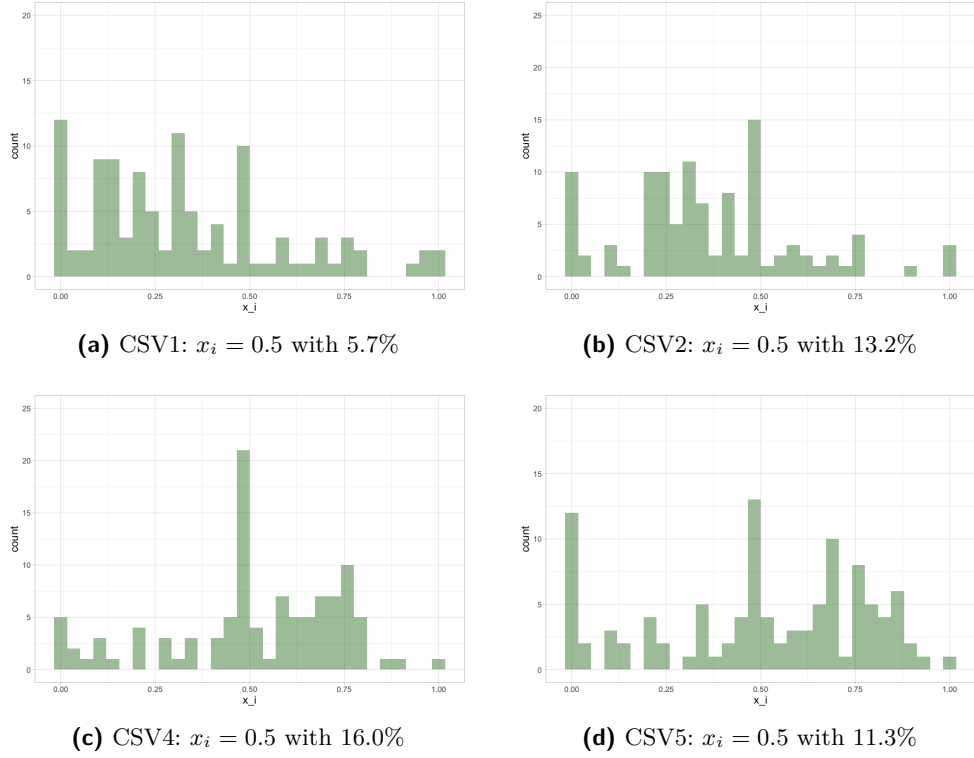
<sup>2</sup> Note that theoretically speaking, games CSV1/CSV5 and CSV2/CSV4 are *mirror* games. However, because subjects did not play in fixed pairs, results based on  $x_i$  and  $x_j$  are not exactly identical for mirror games. Example: Player  $a$  played CSV1 with their co-player  $b$ , but player  $b$  played CSV5 with *their* co-player  $c$ .

the first group (one-sided WRS test,  $p = 0.043$ ) as well as between CSV4 and the two others (pairwise one-sided WRS test, CSV3 & CSV4  $p = 0.015$ , CSV3 & CSV5  $p = 0.041$ ). The spread of contributions is lowest in the symmetric game.



**Figure 12:** Distribution of contributions in CSV games.

As seen in Figure 12b, on average, total contributions are highest in the symmetric game CSV3, with the difference being significantly different to all four games (pairwise one-sided WRS test, highest  $p = 0.014$ ).

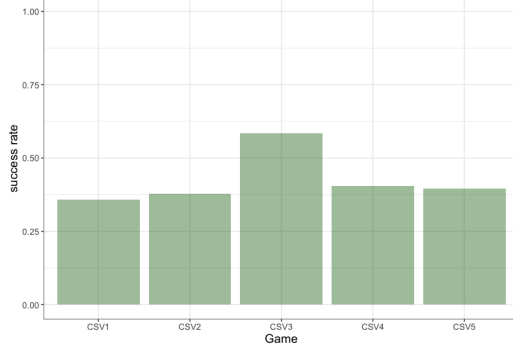


**Figure 13:** Contribution frequencies in the asymmetric constant social value games.

The equal split contribution is less frequent than in AS and SAS games than in CSV3, as seen by comparing the frequency of  $x_i = 0.5$  contributions between Figure 9b and 13. While, with the exception of CSV1, the equal split is still the contribution level with the highest count in asymmetric games, however, only with a maximum share of 16% compared to 47.2% in Game CSV3.

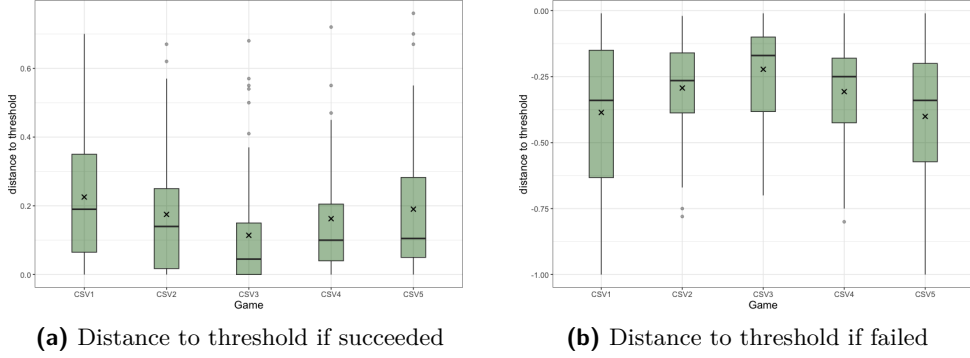
The difference in success rates between symmetric and asymmetric/strongly asymmetric games is statistically significant (two-sided WRS test, pair-wise between all games, max.  $p = 0.0093$ ). The difference between AS and SAS games is, however, not statistically significant (two-sided WRS test, CSV1 & CSV2  $p = 0.7773$ , CSV4 & CSV5  $p = 0.8899$ ). This implies that while the first part of Hypothesis 1 can be confirmed, the second is rejected.

Yet, the success rate only gives an average over the whole sample, without detailing by how much the threshold was missed or overshoot. Figure 15 illustrates these average distances to the threshold for the five CSV games. We can see that values for CSV2 and CSV4 (AS) are less noisy than for CSV1 and CSV5 (SAS). Interestingly, the mean overshoot for the strongly asymmetric games is 0.226 and 0.190 and the mean “miss” is by 0.386 and 0.401 respectively, all higher in absolute terms than for the asymmetric games. This indicates that



**Figure 14:** Success rates in CSV games.

even though there is no discernible difference in success rates, play in SAS games was more erratic than in AS games. This U-shape (reverse U-shape) is completed by the values for CSV3, where both overshoot and miss are closest to zero.



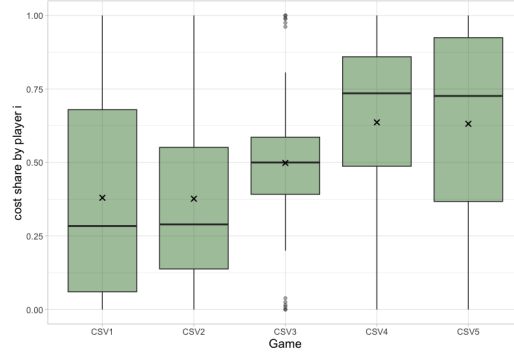
**Figure 15:** Success and failure in CSV games.

Burden-sharing is usually defined by the the relative size of one player's contribution level to total contributions (see e.g. Waichman et al. 2021). However, in our quadratic cost setup, the actual burden a player faces is the contribution cost, the share of which does not correspond to the contribution share as in a linear setting. We therefore define the burden-share of player  $i$  as the relative share of their costs to total costs as given by:

$$\text{share}_i = \frac{c(x_i)}{c(x_i) + c(x_j)} = \frac{5x_i^2}{5x_i^2 + 5x_j^2} \quad (14)$$

Figure 16 illustrates the distribution of cost shares across the five games. The mean contribution share in the symmetric game is significantly different to the asymmetric and strongly asymmetric games (pairwise one-sided WRS tests, highest  $p = 0.0004$ ) whereas the means between CSV1 and CSV2 as well as CSV3 and CSV4 do not differ significantly. However, the

cost shares differ with respect to their spread: in strongly asymmetric games, contribution shares have a higher variance, also indicated visually by the wider box.

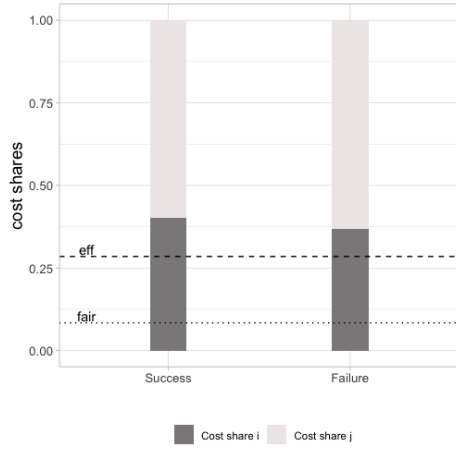


**Figure 16:** Distribution of cost shares in CSV games.

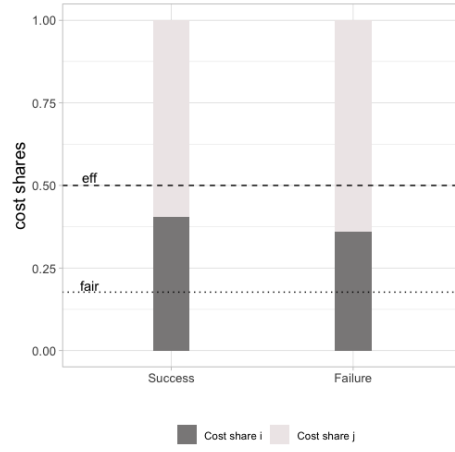
We can also compare the cost shares between successful and unsuccessful games, plotting them against the cost shares corresponding to the fair and efficient focal points, as defined in Section 2.1. Figure 17 illustrates this for all five CSV games. For the symmetric game CSV3 (see Figure 17c) we can see that the burden share between the successful and unsuccessful groups was practically identical (means 0.4977 and 0.4992), both at the focal points of efficiency and fairness. The main difference between the success and failure groups, however, lies in the spread of the contribution shares, with the standard deviation being much higher for failed groups (see  $sd_s$  for successful and  $sd_f$  for failed groups). This implies that while on average the contribution share was fair and efficient, individual contribution levels were more erratic, leading to threshold misses.

A similar picture follows for asymmetric and strongly asymmetric games, that is, the mean contribution share does not differ largely between successful and failed groups, whereas the variance does. The most striking difference between asymmetric games CSV2 and CS4 and strongly asymmetric games CSV1 and CSV5 lies in the fact that in the former group, cost sharing is too equal compared to what would be both fair or efficient, whereas in the latter group, cost shares lie in between the two focal points. This implies that players seem to play both types of games very similarly, which leads to especially unequal burden-sharing in the case of strongly asymmetric games. Note that the efficient focal point for SAS games implies that the “richer” player receives the full surplus from cooperation, and we see that on average, poor players contribute even beyond this point.

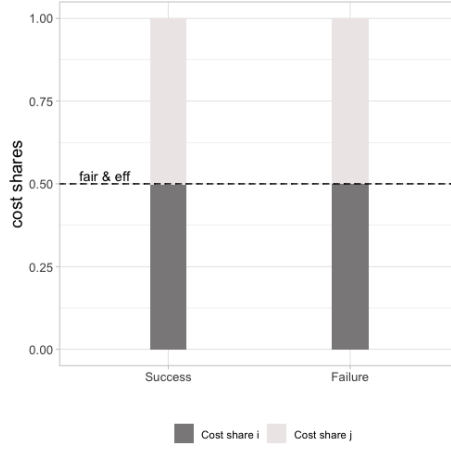




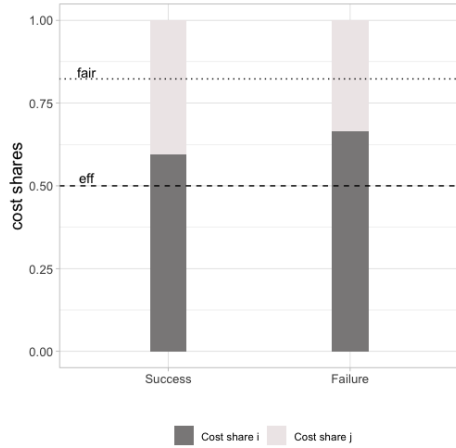
(a) CSV1:  $sd_s = 0.2605$ ,  $sd_f = 0.3907$



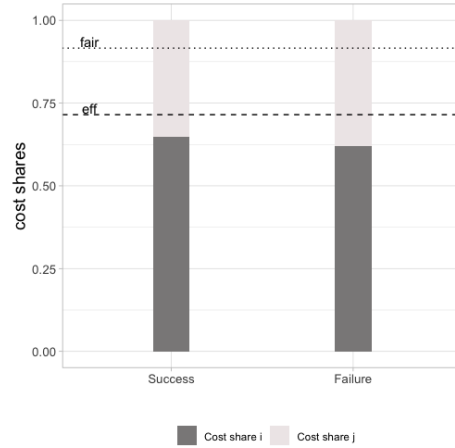
(b) CSV2:  $sd_s = 0.2347$ ,  $sd_f = 0.3488$



(c) CSV3:  $sd_s = 0.1195$ ,  $sd_f = 0.3004$



(d) CSV4:  $sd_s = 0.2309$ ,  $sd_f = 0.3483$



(e) CSV5:  $sd_s = 0.2523$ ,  $sd_f = 0.3857$

**Figure 17:** Burden sharing in success vs. failure games

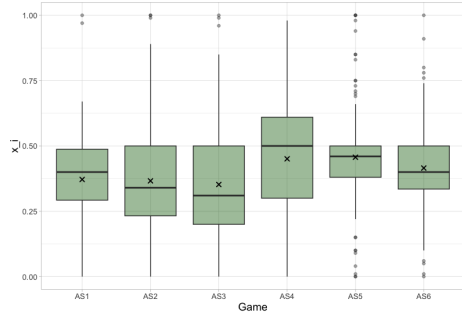
### 4.3.2 Asymmetric Games

The treatment type of asymmetric games is characterised by the existence of an equilibrium interval in which the equal split allocation is contained. Henceforth we will divide them into four subgroups, keeping the preference parameter of player  $i$  fixed and analyse contribution levels and success rates accordingly. Table 3 provides summary statistics.

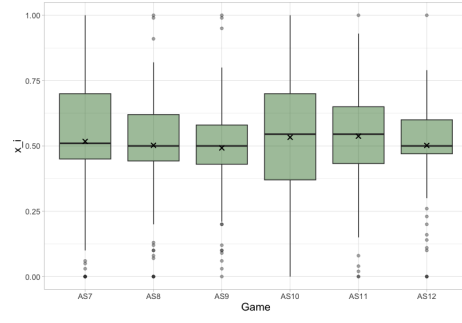
**Table 3:** Summary statistics asymmetric treatments.

| Game | Type | $(\theta_i, \theta_j)$ | mean $x_i$ | median $x_i$ | sd $x_i$ |
|------|------|------------------------|------------|--------------|----------|
| AS1  | AS   | (1.25, 2.5)            | 0.3717     | 0.4000       | 0.1960   |
| AS2  | AS   | (1.25, 3.75)           | 0.3663     | 0.3400       | 0.2277   |
| AS3  | AS   | (1.25, 4.25)           | 0.3524     | 0.3100       | 0.2190   |
| AS4  | AS   | (2.5, 1.25)            | 0.4507     | 0.5000       | 0.2340   |
| AS5  | AS   | (2.5, 3.75)            | 0.4567     | 0.4600       | 0.2054   |
| AS6  | AS   | (2.5, 4.25)            | 0.4154     | 0.4000       | 0.1756   |
| AS7  | AS   | (3.75, 1.25)           | 0.5173     | 0.5100       | 0.2308   |
| AS8  | AS   | (3.75, 2.5)            | 0.5025     | 0.5000       | 0.2014   |
| AS9  | AS   | (3.75, 4.25)           | 0.4924     | 0.5000       | 0.1820   |
| AS10 | AS   | (4.25, 1.25)           | 0.5331     | 0.5450       | 0.2323   |
| AS11 | AS   | (4.25, 2.5)            | 0.5374     | 0.5450       | 0.1984   |
| AS12 | AS   | (4.25, 3.75)           | 0.5020     | 0.5000       | 0.1686   |

Figure 18a illustrates contribution levels, which we would expect to decrease from both AS1–AS3 and from AS4–AS6. Mean contributions do not significantly decrease from AS1–AS3 (pairwise one-sided WRS, lowest  $p = 0.076$ ), where average contributions in AS6, which is the most asymmetric game in this subgroup, is significantly lower than in AS4 and AS5 (pairwise one-sided WRS, highest  $p = 0.044$ ). Figure 18b analogously depicts the third and fourth subgroup, where we would expect contributions to decrease from AS7–AS9 as well as from AS10–AS12. The only statistically significant mean difference is between AS7 and AS9 (one-sided WRS,  $p = 0.034$ ). Note that the most asymmetric games, that is AS3 and AS10, have among the highest contribution spreads, mirroring the more erratic play as asymmetry is increased.



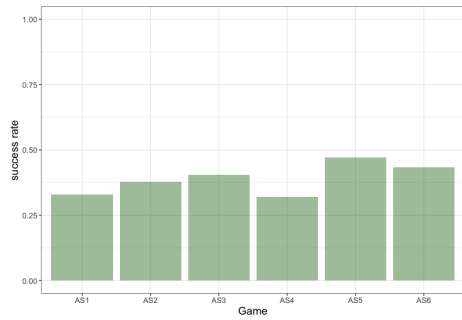
(a) AS1–AS6



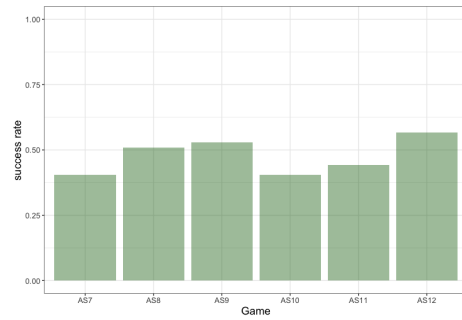
(b) AS7–AS12

**Figure 18:** Contribution distribution in asymmetric games.

When looking at success rates, we have to consider two forces at play: the social value of the public good and the degree of asymmetry. We hypothesise that increasing the first should facilitate provision and increasing the latter is expected to hamper success. In the first subgroup, illustrated in Figure 19a, the two forces counteract each other (higher stakes combined with higher asymmetry) and therefore, it is unclear which effect will prevail, which shows in no statistically significant differences in success rates within games AS1–AS3. In the second subgroup, the success rate of AS4 is significantly lower compared to the other two (pairwise one-sided WRS, highest  $p = 0.045$ ), which is unsurprising due to the low stakes. The difference between AS5 and AS6 is not significant, but the decreasing success rate hints at the existence of a harmful effect of asymmetry. The other two subgroups are depicted in Figure 19b. The success rates are significantly different between AS7 and AS9 (one-sided WRS,  $p = 0.037$ ) and between AS12 and the other two (pairwise one-sided WRS, highest  $p = 0.037$ ), the latter difference confirming that a simultaneous increase in stakes and decrease in asymmetry facilitates provision.



(a) AS1–AS6



(b) AS7–AS12

**Figure 19:** Success rates in asymmetric games.

### 4.3.3 Strongly Asymmetric Games

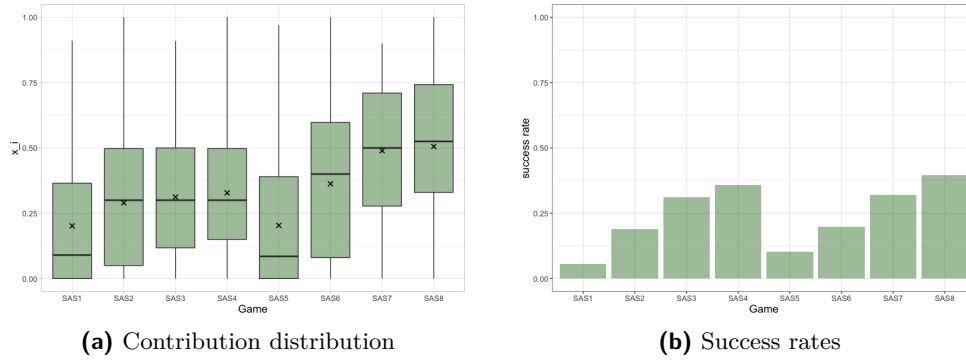
By definition, strongly asymmetric games are those in which one of the two players has a preference parameter of 0.75, meaning that the equal split allocation is not part of the equilibrium interval. Therefore, in these games, in order to reach the threshold, the player with the higher preference parameter would have to step up and contribute significantly more than half of the threshold. Note that in SAS1 and SAS5 provision is never efficient, since the “richer” player does not have sufficiently high benefits in order to contribute enough to reach the threshold in a way that both players have a non-negative payoff. Table 4 provides summary statistics for the two subgroups of this treatment type, where in SAS1–SAS4 asymmetry is against player  $i$  and in SAS5–SAS8 asymmetry is in favour of player  $i$ . Note that the efficient contribution split in strongly asymmetric games would be 0.387/0.613 for the poorer and richer player respectively.

**Table 4:** Summary statistics for strongly asymmetric treatments.

| Game | Type | $(\theta_i, \theta_j)$ | mean $x_i$ | median $x_i$ | sd $x_i$ |
|------|------|------------------------|------------|--------------|----------|
| SAS1 | SAS  | (0.75, 1.25)           | 0.2010     | 0.0900       | 0.2379   |
| SAS2 | SAS  | (0.75, 2.5)            | 0.2899     | 0.3000       | 0.2525   |
| SAS3 | SAS  | (0.75, 3.75)           | 0.3120     | 0.3000       | 0.2295   |
| SAS4 | SAS  | (0.75, 4.25)           | 0.3279     | 0.3000       | 0.2597   |
| SAS5 | SAS  | (1.25, 0.75)           | 0.2034     | 0.0850       | 0.2539   |
| SAS6 | SAS  | (2.5, 0.75)            | 0.3626     | 0.4000       | 0.2799   |
| SAS7 | SAS  | (3.75, 0.75)           | 0.4893     | 0.5000       | 0.2628   |
| SAS8 | SAS  | (4.25, 0.75)           | 0.5250     | 0.5055       | 0.2833   |

We can see that while means are significantly lower in SAS1 and SAS5 compared to the other games, average contributions are clearly positive, while median contributions are significantly lower, implying that this relatively high average is driven by few players who contributed highly above their means. The standard deviation is substantial across all 8 games. We can also see that in the game in which asymmetry is most in favour of player  $i$ , that is SAS8, they on average only contribute slightly above the equal split, which is not enough to ensure a provision combined with a non-negative payoff by their co-player. Figure 20a illustrates these facts.

Figure 20b picture success rates across the 8 games. Finally, note that the two groups SAS1–SAS4 (asymmetry against  $i$ ) and SAS5–SAS8 (asymmetry in favour of  $i$ ) consist of pairwise mirror games and therefore illustrate the same trend: keeping one preference parameter at 0.75, increasing stakes similarly lift the success rate.



**Figure 20:** Contribution and success rates in strongly asymmetric games.

## 5 Conclusion

This paper discusses a one-shot threshold public goods game played in groups of two, in which players have varying preferences for the public good. This gives rise to three treatment types: symmetric, asymmetric and strongly asymmetric games, the last being characterised by the fact that the equal split allocation is not feasible. For sufficiently high preference parameters, an equilibrium interval emerges on the threshold line. Two potential focal equilibrium points are discussed: the efficient equilibrium ensures minimised contribution costs across players, whereas the fair equilibrium equally splits the surplus generated from provision. Furthermore, if on the equilibrium interval, the allocation in which both players contribute half of the threshold level, is expected to be a focal point.

Our specific experimental specification implies that in symmetric treatments, all three focal points of equal split, efficiency and fairness coincide. In asymmetric treatments, the fair focal point diverges and furthermore for strongly asymmetric treatments, the equal split is no longer an equilibrium. We thus hypothesise that provision success decreases in the degree of asymmetry. Indeed we find that groups with symmetric players have a significantly higher success rate in reaching the threshold than other treatment types. Surprisingly, the specific degree of asymmetry has no effect on average provision success, yet when considering the distribution of contributions, we see that volatility increases with stronger asymmetry. This also leads to the fact that successful groups on average overshoot the threshold by most in strongly asymmetric games, and analogously miss the threshold most clearly in failed groups.

Within a subgroup of treatments in which the social value of the public good is constant, burden-sharing between the two players is analysed. Results suggest that while experimental subjects notice and act on asymmetry, the degree of asymmetry is less salient than

anticipated. This shows in relatively stable burden-sharing across a variety of asymmetric specifications, resulting in the fact that “poor” players tend to contribute too much and “rich” players too little compared to both the fair and efficient benchmark. This result hints at a potentially biased perception of asymmetries, both from the perspective of the advantaged and disadvantaged players, leading to both relatively low success rates and unjust cost sharing in asymmetric specifications. Re-contextualising this finding to the motivating example of international cooperation on climate change mitigation, this would imply that wealthier nations might underestimate the degree to which their contributions have to exceed that of poorer countries when aiming for either efficient or fair outcomes.

## Appendix

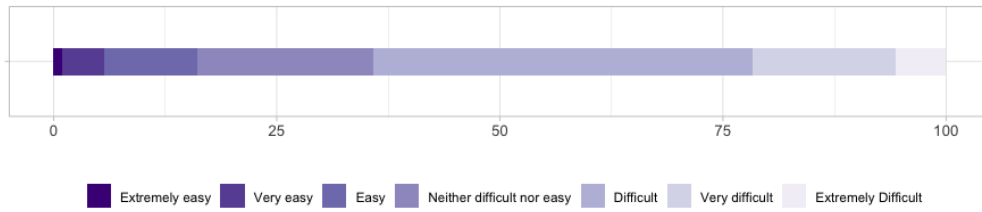
### A Specifications

**Table 5:** Game Specifications

| Game | Type | Name      | $(\theta_i, \theta_j)$ | Social value | Efficient $x_i$ | Fair $x_i$ |
|------|------|-----------|------------------------|--------------|-----------------|------------|
| 1    | S    | S1        | (0.75, 0.75)           | 1.5          | 0               | 0          |
| 2    | SAS  | SAS1      | (0.75, 1.25)           | 2            | 0               | 0          |
| 3    | SAS  | SAS2      | (0.75, 2.5)            | 3.25         | 0.387           | 0.340      |
| 4    | SAS  | SAS3      | (0.75, 3.75)           | 4.5          | 0.387           | 0.261      |
| 5    | SAS  | CSV1/SAS4 | (0.75, 4.25)           | 5            | 0.387           | 0.233      |
| 6    | SAS  | SAS5      | (1.25, 0.75)           | 2            | 0               | 0          |
| 7    | S    | S2        | (1.25, 1.25)           | 2.5          | 0 / 0.5         | 0.5        |
| 8    | AS   | AS1       | (1.25, 2.5)            | 3.75         | 0.5             | 0.396      |
| 9    | AS   | CSV2/AS2  | (1.25, 3.75)           | 5            | 0.5             | 0.317      |
| 10   | AS   | AS3       | (1.25, 4.25)           | 5.5          | 0.5             | 0.289      |
| 11   | SAS  | SAS6      | (2.5, 0.75)            | 3.25         | 0.613           | 0.660      |
| 12   | AS   | AS4       | (2.5, 1.25)            | 3.75         | 0.5             | 0.604      |
| 13   | S    | S3/CSV3   | (2.5, 2.5)             | 5            | 0.5             | 0.5        |
| 14   | AS   | AS7       | (2.5, 3.75)            | 6.25         | 0.5             | 0.421      |
| 15   | AS   | AS8       | (2.5, 4.25)            | 6.75         | 0.5             | 0.393      |
| 16   | SAS  | SAS7      | (3.75, 0.75)           | 4.5          | 0.613           | 0.739      |
| 17   | AS   | CSV4/AS5  | (3.75, 1.25)           | 5            | 0.5             | 0.683      |
| 18   | AS   | AS9       | (3.75, 2.5)            | 6.25         | 0.5             | 0.579      |
| 19   | S    | S4        | (3.75, 3.75)           | 7.5          | 0.5             | 0.500      |
| 20   | AS   | AS11      | (3.75, 4.25)           | 8            | 0.5             | 0.472      |
| 21   | SAS  | CSV5/SAS8 | (4.25, 0.75)           | 5            | 0.613           | 0.767      |
| 22   | AS   | AS6       | (4.25, 1.25)           | 5.5          | 0.5             | 0.711      |
| 23   | AS   | AS10      | (4.25, 2.5)            | 6.75         | 0.5             | 0.607      |
| 24   | AS   | AS12      | (4.25, 3.75)           | 8            | 0.5             | 0.528      |
| 25   | S    | S5        | (4.25, 4.25)           | 8.5          | 0.5             | 0.5        |

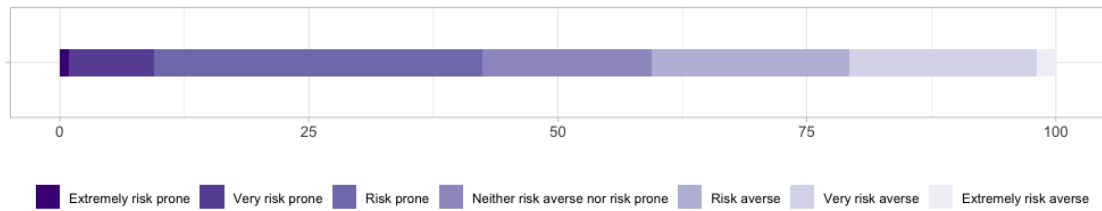
## B Subject Pool Demographics

**Question:** *Was the experiment difficult to understand?*



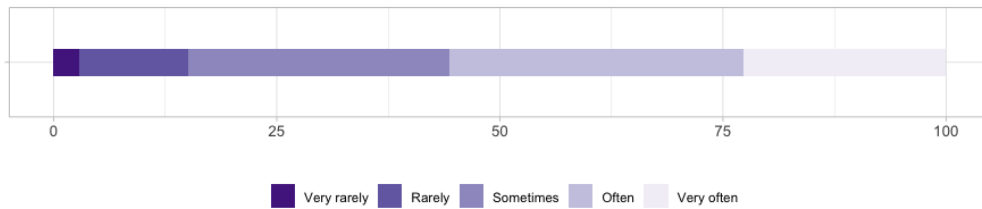
**Figure 21:** Difficulty

**Question:** *Are you generally a person who is fully prepared to take risks (risk prone) or do you try to avoid taking risks (risk averse)?*



**Figure 22:** Risk attitude

**Question:** *Generally speaking, how often do you trust others?*

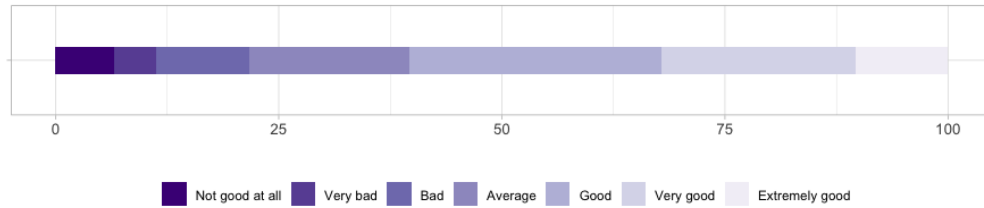


**Figure 23:** Trust

Choices “never” and “always” were never selected.

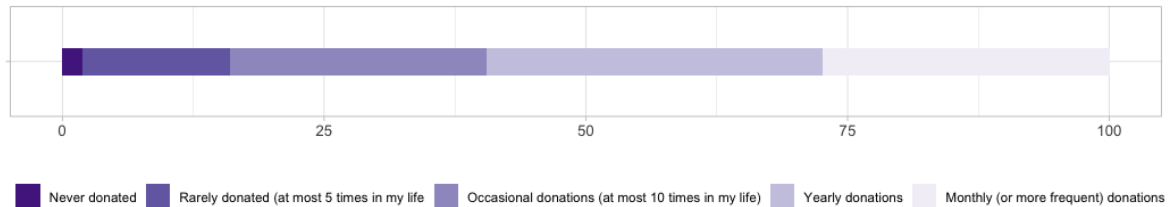


**Question:** *How good are you at working with fractions (e.g. “one fifth of something”) or percentages (e.g. “20% of something”)?*



**Figure 24:** Fraction skills

**Question:** *Have you ever donated money or goods to a charitable organisation? If yes, how frequently?*

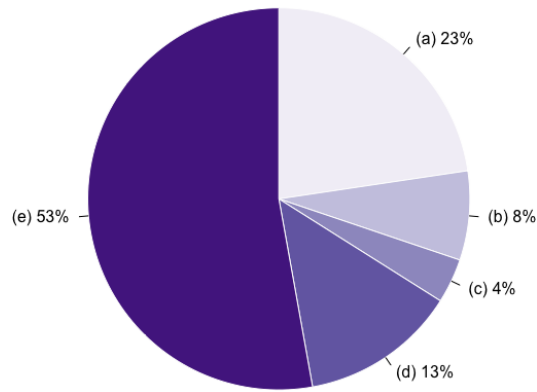


**Figure 25:** Donations

**Question:** *Which of the following guiding principles best describes your understanding of fairness in the context of the experiment you took part in (the 25 rounds you played before)?*

Answers:

- (a) The player with the highest benefit from contributing to the project should invest more in it, such that payoffs are roughly the same for both players.
- (b) Both players should choose 50%, irrespective of relative benefit numbers.
- (c) Both players should choose 0%, irrespective of relative benefit numbers.
- (d) Both players should choose what's in their own best interest, i.e. maximizes own payoffs.
- (e) Players should choose the values of  $X_1$  and  $X_2$  that maximize the joint payoffs (i.e. the sum of the payoff from player 1 and player 2)

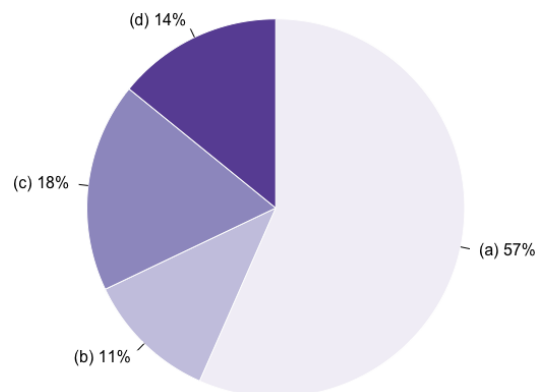


**Figure 26:** Understanding of fairness

**Question:** *Assume that benefit numbers are such that joint payoff can be positive. Which of the following statements do you agree with most?*

Answers:

- (a) Players should choose contributions such that both players have a positive payoff.
- (b) Players should prioritize reaching the threshold, irrespective of whether individual payoffs are positive.
- (c) Both players should contribute their fair share in order to reach the threshold.
- (d) The threshold should be met with precision such as to not waste any investments.

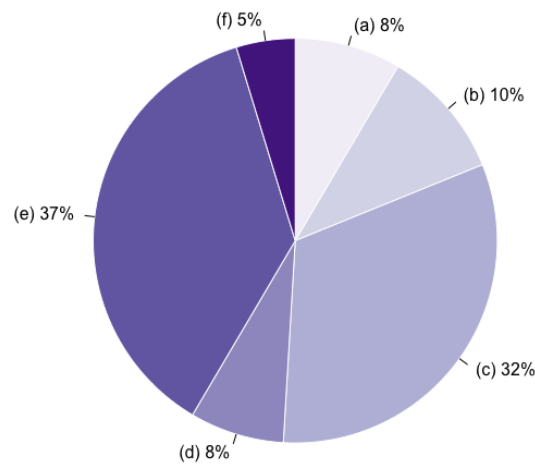


**Figure 27:** Statements

**Question:** *Please pick the MOST difficult aspect of the experiment.*

Answers:

- (a) None
- (b) Using the payoff calculator
- (c) Guessing contribution  $X_2$
- (d) Choosing contribution  $X_1$
- (e) Grasping the differences between rounds.
- (f) Something else



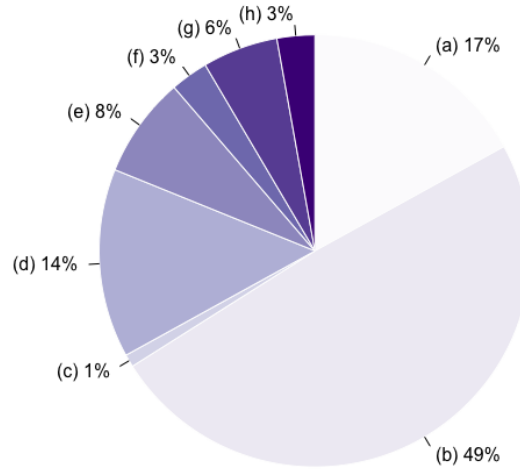
**Figure 28:** Most difficult aspect

**Question:** *What was the MOST important rationale for your decisions during the experiment?*

Answers:

- (a) Monetary self-interest (i.e. maximising own income)
- (b) Group efficiency (i.e. maximising joint income of both players)
- (c) Minimise time spent on the task
- (d) Avoiding risk (i.e. avoiding being the “sucker” who contributes a high fraction when co-player contributes little, potentially risking not reaching the threshold)
- (e) Reciprocity (i.e. contributing a similar fraction to the one that the co-player was expected to contribute)

- (f) Outperforming the co-player (i.e. earning a higher income than s/he)
- (g) Contributing a bit extra as a precaution, such as to increase the likelihood of reaching the threshold
- (h) Other

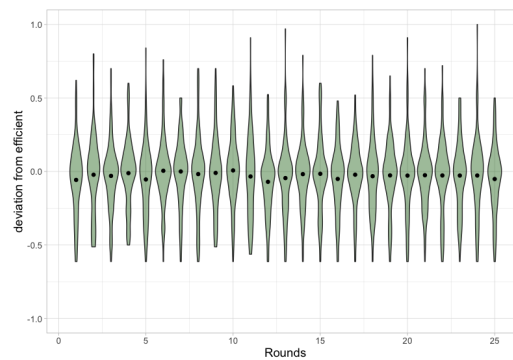


**Figure 29:** Most important rationale

## C Further Results

### Sequence effects

Note that for Figures 7a and 30, the games for which a clear fair or efficient allocation cannot be defined, have been removed from the dataset, which are games 1, 2, 6, 7 for *fair* and game 7 for *efficient*.



**Figure 30:** Deviation from efficient

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