Voting and Equilibrium Selection in Threshold Public Goods Games

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Chapter 1

Introduction

This work is concerned with threshold public goods games[1] in which a group of players contributes jointly to a project of collective value. This "public good" is provided only if a predefined minimum joint contribution is reached. In the real world, such projects can entail anything from a few friends pooling their money to host a party, which none of them could afford on their own, to international efforts to reduce greenhouse-gas emissions in order to keep global warming below a critical level.

If said minimum contribution, referred to as the threshold value in the following, is not reached, nothing of collective value is created, and each contributing player may even lose his or her invested contribution, which therefore involves a certain amount of risk. On the other hand, many more people may benefit from the public good than those actually having to pay the cost. The friends will likely invite additional guests to their party, who will also be allowed to eat, drink, and be merry. Likewise, certain island nations with no significant greenhouse-gas emissions to reduce will nevertheless be happy if the sea level does not rise and flood their homes. Accordingly, the basic idea of this game is very similar to a social dilemma: Each player in the group would be better off individually, if somebody else provided the contribution (i.e., paid for the party or took efforts to reduce emissions), because everyone in the group can enjoy the benefits whether or not they have paid for them.

However, aside from being a type of social dilemma, threshold public goods games – or "ThrPGs", as I will call them throughout the rest of this work – also have a few other interesting theoretical properties that have caused this type of game to become the focus of my studies over the past three years:

1. On a more technical level, ThrPGs are different from other social dilemmas[2] in that they permit the players to "rationally" contribute a socially

[1]This type of game is also discussed in the literature under the names "step-level public good" or "provision point public good", the latter being more applicable to games with some form of rebate of contributions in case of overcontribution.

[2]Like, for example, the better known "linear" public goods games, which have been discussed extensively in the literature. See Ledyard (1995) for an overview.

efficient amount to the project, depending on how much the other players are willing to contribute. In fact, ThrPGs are more correctly classified as coordination problems in which the players must decide between a safe, but inefficient strategy of contributing nothing and a risky, but possibly rewarding strategy of making a contribution to the public good while hoping that enough other players do the same.

2. ThrPGs are similar to divide-the-pie bargaining games, like the famous ultimatum game (Güth et al., 1982), in the sense that the group members must allocate the threshold value somehow among themselves, i.e., decide who carries which share of the cost burden (another coordination problem), if they want to reach an efficient outcome. As such, ThrPGs lend themselves to the discussion of research questions that involve distributive fairness.

3. Finally, if a player's contribution decision is interpreted as his preference for a collective outcome, like a particular way in which the threshold value is allocated among the group members, the game corresponds to a (tacit) collective decision. For this reason, ThrPGs can be very easily adapted to study committee voting behavior. In fact, many voting procedures themselves are ThrPGs of some kind, e.g., if a particular number of votes is required for approval and therefore constitutes a threshold for the political implementation of projects of (possible) public interest (cf. Goeree and Holt, 2005).

All of these topics will be addressed to some extent in the following chapters, but a brief overview is given for each of them in the remainder of this introduction. First, however, a basic theoretical model of a ThrPG is presented in the next section.

1.1 Theoretical model of a threshold public goods game (ThrPG)

Although the general idea of ThrPGs has been around for a while, with the first wave of studies in the late 1970s and early 1980s (e.g., Marwell and Ames, 1979, 1980; van de Kragt et al., 1983; Palfrey and Rosenthal, 1984),[3] a standard notation for describing the elements of this game has yet to develop. The notation I employ for this rather general model most closely resembles the one used by Cadsby et al. (2008), taking the first letter of the parameter as its designating variable (for example, e for "endowment"), with the exception

[3]For a literature review see Section 2.7 in Chapter 2, as well as Croson and Marks (2000) and again Ledyard (1995). A review of "step-level public goods" from a psychological perspective is provided by Abele et al. (2010).

of q (for "quantity") instead of c for contributions, which refers to marginal contribution costs in my model.

1.1.1 Basic game

A ThrPG[4] consists in a group defined by a set $\mathcal{N}$ that contains n individual players. These players each simultaneously choose their individual contributions to a public account with a threshold value of T. Each player $i = 1, \dots, n$ starts with an endowment $e_i > 0$ which can then be used to pay for his contribution $q_i \in [0, \bar{q}_i]$ to the public good. The marginal cost of contribution, meaning the conversion rate from endowment to contribution, is given by $c_i > 0$.

If for any vector of individual contributions $\mathbf{q} = (q_1, \dots, q_n)$ the resulting total contribution $Q = \sum_{i=1}^{n} q_i$ is equal to or exceeds the threshold value $T > 0$, i.e., if $Q \geqslant T$, each player i receives a payoff equal to his individual valuation $v_i > 0$ of the public good. Otherwise, the contributions are wasted and the contribution costs are returned to each contributing player at a refund rate of $0 \leqslant r \leqslant 1$. This means that, if $r = 1$, a full refund of contribution costs is granted, similar to a money-back guarantee. Let $\bar{q}_i < T$ for all i, as well as $T \leqslant \sum_{j=1}^{n} \bar{q}_j$, so that one player alone cannot reach the threshold, but the entire group can.

A contribution vector is individually rational if $\forall i : c_i q_i \leqslant v_i$, meaning that no player has contribution costs in excess of his valuation. Moreover, a contribution vector is technologically possible if $\forall i : q_i \leqslant \bar{q}_i$, i.e. all players contribute less than their maximum contribution. I will call a contribution vector feasible if it is both individually rational and technologically possible.

Player i's payoff $\pi_i(\mathbf{q})$ is given by:

$$\pi_i(\mathbf{q}) = \begin{cases} e_i - c_i q_i + v_i & \text{if} \quad Q \geqslant T \\ e_i - (1-r) c_i q_i & \text{if} \quad Q < T \end{cases} \tag{1.1}$$

Two design elements deserve particular attention, because they have not yet been discussed in the literature (at least as far as I know). The first is the distinction between a player's endowment e_i and his maximum contribution $\bar{q}_i$. Typically it is assumed that $e_i = \bar{q}_i$ for all i, so that each player can invest his entire endowment in the public good. What is usually a reasonable simplification, becomes important if the model includes marginal contribution costs c_i, which is the second uncommon design element.[5] Now it becomes more apparent that the (monetary) endowment and the contributions to the public good are actually different quantities measured in different units. In a later chapter (Ch. 4), I will argue that this distinction becomes the most relevant

[4] Parts of this section also appear in Feige, Ehrhart, and Krämer (Unpublished).

[5] The idea of marginal contribution costs that are different for different players, has actually been modeled before by Palfrey and Rosenthal (1991a) for binary ThrPGs, yet their approach is more closely related to assuming heterogeneous endowments, because the authors specify that each player "is endowed with one indivisible unit of input" (ibid., p.186) which has a value of c_i if the player does not contribute.

if players are heterogeneous, because then it may matter if this heterogeneity arises from a difference in wealth levels (endowments) or a difference in the ability to contribute (maximum contributions).

Furthermore, although most of the literature on ThrPGs is concerned with positive valuations or rewards earned from providing the public good, a major part of this thesis assumes a different perspective, according to which providing the public good instead prevents a damage payment $d_i > 0$ for player i. This damage payment has the same absolute value as v_i (meaning $d_i = v_i$), but is deducted from the player's endowment if T is not reached. By defining $\hat{e}_i := e_i + v_i$ and substituting d_i for v_i, an equivalent representation of $\pi_i(q_i)$ results:

$$\pi_i(\mathbf{q}) = \begin{cases} \hat{e}_i - c_i q_i & \text{if} \quad Q \geqslant T \\ \hat{e}_i - (1-r)c_i q_i - d_i & \text{if} \quad Q < T \end{cases} \tag{1.2}$$

1.1.2 Theoretical solutions

Any vector of individual contributions $\mathbf{q} = (q_1, \ldots, q_n)$ that is a feasible threshold allocation, so that $Q = \sum_{i=1}^{n} q_i = T$, is a Nash equilibrium of this game. If any player i decreases his own contribution below this amount, the threshold is missed and the player loses v_i, which is more than the contribution costs $c_i q_i$ that he could save in the process. And by increasing this contribution beyond q_i, the same player only manages to further reduce his endowment to no additional benefit.

Another equilibrium is constituted by the zero-contribution vector $\mathbf{q^0} = (0, \ldots, 0)$, which arises from the assumption that no player alone can reach the threshold and accordingly should not contribute, if he believes to be the only contributor. Zero contributions is a strict equilibrium in the case of no or only partial refund if the threshold is missed ($r < 1$), but only a "weak" equilibrium, in which all players play dominated strategies, if contribution costs are fully refunded ($r = 1$). In addition, a full refund establishes an entire set of such "weak" Pareto inferior equilibria with a total contribution of $Q < T$. Because of the refund of contribution costs, a player is indifferent to changes of his individual contribution at any of these points, since whatever he contributes, the threshold will not be reached and his payoff will be the same.

So, in contrast with linear public goods games, contributing nothing is not actually a *strictly* dominant strategy in ThrPGs, to be preferred independently of what the other players are doing. Instead, ThrPGs usually also have a large number of Pareto-optimal Nash equilibria[6] in which the threshold value is met exactly, meaning that they more properly belong to the class of coordination games. And even completely rational and selfish players can be expected to

[6] All feasible threshold allocations are Pareto optimal, but there may be Pareto-optimal threshold allocations that are not individually rational for some players and accordingly not Nash equilibria. Although these players are better off reducing their contributions, the other players are worse off because the good is no longer provided.

reach an efficient outcome, in the sense of not only providing the project successfully (i.e., by reaching the threshold), but also doing so at a minimal cost to society. In theory, once the group decides on a particular way to share the threshold contribution among its members, no overcontribution should occur; no contributions should be wasted.

1.1.3 Sequential contributions

A variant of the ThrPG with sequential contributions is also frequently investigated in the experimental literature (e.g., Erev and Rapoport, 1990; Chen et al., 1996; Coats and Neilson, 2005; Coats et al., 2009; Milinski et al., 2008). However, this strand of the literature is only of tangential interest to the topics discussed in this thesis and will therefore not be covered extensively. From the perspective of equilibrium analysis, sequential contributions lead to a theoretical first-mover advantage and very asymmetric threshold allocations in equilibrium, because the last player(s) can rationally be expected to contribute a large share of their endowment if this ensures that the threshold is reached. On the other hand, zero contributions is *not* a subgame-perfect Nash equilibrium in a ThrPG with sequential contributions. Experimentally, though, the efficient outcome is rarely observed, possibly because the players have other-regarding preferences which deter them from an asymmetric allocation of the threshold (cf. Coats and Neilson, 2005). In any case, with a unique Pareto-optimal subgame-perfect Nash equilibrium, there is no problem of equilibrium selection in this variant, which is why I focus only on simultaneous contributions in this thesis.

1.1.4 Finitely repeated ThrPGs

A common assumption in the experimental literature is that ThrPGs are played repeatedly for a finite number of times. It is usually taken for granted that the Nash equilibria of the one-shot basic game (or stage game) can be implemented as subgame-perfect Nash equilibria of the repeated game, as well. While this is indeed the case, many additional allocations can also be implemented as subgame-perfect Nash equilibria in the repeated game, namely as part of a trigger strategy with $\mathbf{q^0}$ as a threat point.[7] Accordingly, any allocation that constitutes a Pareto improvement over $\mathbf{q^0}$ can be implemented as an equilibrium. Furthermore, even outcomes that are Pareto inferior to $\mathbf{q^0}$ can be played in this way in some rounds, as long as every player's cumulative payoff over all rounds is still at least as high as he would earn by playing $\mathbf{q^0}$ throughout all rounds.

[7] See Benoit and Krishna (1985) as well as Section 5.2.2 in Chapter 5 for more details.

1.2 Equilibrium selection and threshold public goods games

Given that there are usually many feasible allocations of the threshold and even more inefficient equilibria if the game is played repeatedly, the group may have difficulties picking exactly one from all of the possible outcomes. At this point, one can turn to theories of equilibrium selection, whose concepts do not actually reduce the number of equilibria, but put a spotlight on only a few of them, making them the prime candidates for the final outcome. Most notable here are the works by Harsanyi and Selten (1988) on a selection algorithm based in part on a risk-dominance ranking of multiple equilibria, Samuelson (1997) on equilibrium selection via dynamic learning processes, and Schelling (1980) on focal points. These concepts – some of which are normative and state which equilibrium the players *should* select, while others are descriptive and state which equilibrium the players *will* (likely) select – will be discussed in more detail in Chapters 2 and 4. To begin with, Chapter 2 will provide a theoretical model describing under which parameter settings a group is more likely to attempt to reach the threshold, even at the risk of coordination failure and the associated reduction of total earnings.

1.3 Distributive fairness and threshold public goods games

The idea of achieving equilibrium selection by means of principles of distributive fairness that might apply in the context of a ThrPG is discussed mainly in Chapter 4, but surfaces again in later chapters. Many of these fairness principles single out a unique threshold allocation as a focal point in the sense of Schelling (1980). For example, many people would probably agree that sharing a cake equally, so that everybody receives a piece of equal size, is a fair outcome, because everybody is treated the same.

If the group members are heterogeneous in some respect, however, fairness considerations may lead to a variety of distinct outcomes. In the international negotiations to prevent global warming, industrialized countries like Germany or the U.S. can reduce their emissions only at relatively high marginal costs compared to fast-growing developing countries like China and India (see, e.g., Duscha and Ehrhart, 2016). From a global perspective, convincing China and India to contribute more, in exchange for Germany and the U.S. contributing less, would reduce global costs of emissions reduction and thus increase global welfare. In that sense, this asymmetric contribution outcome could be considered fairer than equal shares.

Obviously, though, the redistribution makes China and India worse off due to their now higher cost burden. If these countries object to sacrificing their personal wealth for the greater good, as it turns out to be the case both in real life[8] and in my experimental investigation (see Chapters 4 and 6), an equal-payoff allocation may be a very attractive compromise if a redistribution of contributions can indeed reduce the global costs of emissions reduction, as with the global warming example. However, this outcome is far from an efficient, "welfare-maximizing" allocation in terms of reduction costs, which assigns a contribution burden to players with low marginal costs that is as large as possible. Chapter 5 therefore introduces the option of transfer payments, making it possible to compensate players with low marginal contribution costs for carrying the higher cost burden, so that overall the trade-off between welfare maximization and payoff equalization can be overcome. Consequently, two formerly distinct fairness principles can both be satisfied at the same time.

1.4 Voting and threshold public goods games

A major part of this thesis is concerned with cooperative approaches to ThrPGs in the form of voting on the contributions to the public good. Although most of the literature on ThrPGs focuses on individual voluntary contributions, i.e., a non-cooperative approach, projects of public interest obviously also fall into the scope of political decision-making processes, like, for example, a committee of community members discussing and then voting on different proposals for funding such a project. In most situations, the political authority invested in the community by a democratic election is sufficient to implement their choice in a binding manner.

Following a theoretical discussion of voting in ThrPGs in Chapter 3, Chapters 4 and 5 also describe experimental treatments which employ a unanimous vote on contribution vectors, thereby extending the research questions investigated in these chapters to a different, although still non-cooperative, decision rule.

Chapter 4 furthermore discusses how various principles of distributive fairness relate to the outcomes collectively chosen by a group of players in an experimental setting. A complementary analysis comparing self-reported individual fairness attitudes (based on individual responses to a series of questionnaire items) gives indication that this collective choice may not be related at all to the questionnaire responses. Instead, the decision rule has a much larger impact on the outcome, possibly because of strategic considerations in the actual game. So, despite its explanatory power with respect to focal outcomes, distributive fairness in ThrPGs may be nothing more than an epiphenomenon, a side-effect, likely brought about by the (still unidentified) true cause of this procedure effect. Another interpretation of this result, in line with the distinction between normative and descriptive concepts of equilibrium selection, is to

[8] Neither China nor India, which are both Non-Annex I countries, have so far agreed to legally binding targets for emissions reductions, although China has at least made a tentative pledge to "peak CO_2 emissions by 2030 at the latest" (see www.climateactiontracker.org/countries.html, last accessed October 10, 2015).

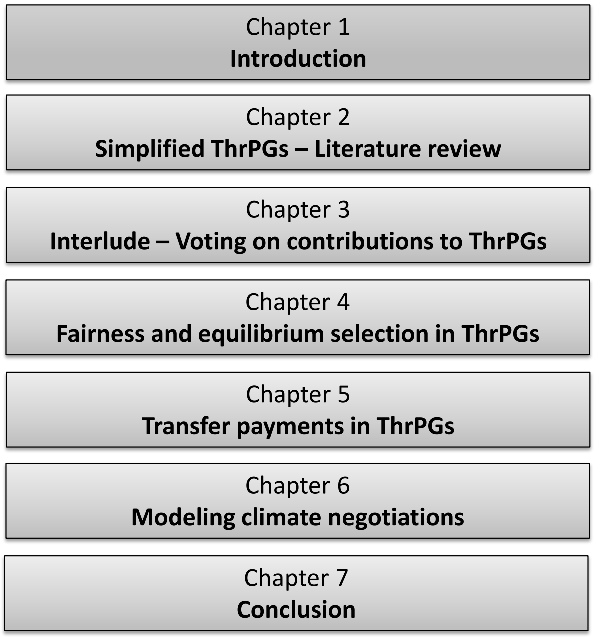

Figure 1.1: Outline of the thesis

say that what *should* be implemented according to a more generally applicable social norm is not necessarily what *can* be implemented under the specific circumstances of a strategic interaction.

The final study of my thesis, presented in Chapter 6, discusses a variant voting procedure, called "top-down" voting, which, with the additional assumption of a randomly distributed threshold value, is then employed to model the climate negotiations in particular and to derive political implications based on these results.

1.5 Outline of the thesis

Building on the rough sketch presented above, the following chapters are structured as follows (see also Figure 1.1).

Chapter 2 gives a guided tour through the literature on experimental research involving non-cooperative ThrPGs. Guidance is provided by a theoretical model predicting how particular design elements affect experimentally observed success rates, i.e., the frequency with which the threshold is reached. In a nutshell, the original ThrPG is simplified by assuming that the group has already agreed on a particular allocation of the threshold, but must still decide (each group member individually) to honor this agreement or to deviate from the agreement and contribute nothing, thus avoiding the risk of wasting their contributions if any of the other players does not honor the agreement. The model is tested in both a qualitative meta-analysis, comprising said literature review, and a quantitative meta-analysis involving a comparison to a meta-regression on experimental data from earlier studies conducted by Croson and Marks (2000).

Chapter 3 expands the view to also include a cooperative-choice approach to ThrPGs. This chapter contains a game-theoretical analysis of a ThrPG in which contributions are decided by means of a unanimous vote. As the procedure to replicate this voting rule in the experimental investigation presented in the subsequent chapters is non-cooperative, this voting game must also be solved theoretically for Nash equilibria. The theoretical analysis is complemented by an additional literature survey of voting in public goods experiments, providing an idea of what to expect from these theoretical predictions in the laboratory.

Chapter 4 experimentally investigates equilibrium selection in ThrPGs under both individual voluntary contributions and unanimous voting on contribution vectors, following the premise that the subjects will use fairness principles as selection criteria. Chapter 5 builds on part of these findings by reconciling the conflict between welfare maximization and payoff equalization for heterogeneous marginal contribution costs via optional transfer payments. In addition to motivating the effectiveness of transfer payments theoretically, another experimental investigation extending the parameterization used in Chapter 4 also establishes the empirical validity of this chapter's findings.

Chapter 6, employing a different parameter setting than the experiments described in the two preceding chapters, introduces threshold uncertainty and top-down voting as two additional design elements. The result is a model intended to simulate climate negotiations in a laboratory environment and to investigate their efficiency in terms of contribution costs under different decision rules as well as heterogeneity of marginal costs. Whereas Chapters 4 and 5 provide a full refund of contribution costs if the threshold is missed, no such money-back guarantee exists in this scenario. In concordance with the theoretical model for success rates in ThrPGs presented in Chapter 2, the absence of a refund policy induces many subjects to rather contribute nothing and incur a damage payment than risk losing their contribution costs as well, because the threshold value is not reached.

Chapter 2

Success rates in simplified threshold public goods games: a theoretical model

2.1 Introduction

As mentioned before, the general idea of a threshold public goods game (ThrPG) is that a group of people needs to jointly provide a specified amount of money to successfully fund a project of public interest. The problem is that the group has to not only come to an agreement (whether tacit or overt) on whether or not to provide this public good, but also on which player will provide which share of the specified amount.

Roughly fifteen years ago, Croson and Marks (2000) published a meta-study on success rates in ThrPGs, i.e., the probability of whether or not the group's total contribution exceeds a predefined threshold value, postulating the "step return," which refers to the ratio of total valuation from reaching the threshold to the necessary threshold contribution, as one of the main explanatory variables in this game. Nevertheless, this parameter alone, although found to be significantly positively correlated with success rates by the same authors, does not yet make a model that can predict, let alone explain, experimental outcomes. What is worse, even at the same value of the step return, group decisions vary widely. Several experimental studies (including Isaac et al., 1989; Alberti et al., Unpublished) do not vary the valuations, the group size, the threshold value, or in fact any part of the experimental design, but still observe that some subject groups reach the threshold consistently, while other groups appear to have no hope of ever reaching this goal, leading them to converge on an outcome where nobody contributes anything.

2.1.1 Descriptive vs. normative equilibrium selection theories

In the present chapter,[1] I will develop a descriptive model aiming to encompass this variability of results, which however has its foundations in previous, exclusively normative, work on equilibrium selection (Harsanyi and Selten, 1988; Harsanyi, 1995). The idea is that the players in a ThrPG concentrate on the most salient or "focal" (in the sense of Schelling, 1980) allocation of the threshold value in their group and then decide whether or not this risky Nash equilibrium, in which the deviation of only a single player severely reduces all players' payoffs, is to be preferred to the safe choice of contributing nothing. Sometimes the decision is in favor of the risky, but efficient, outcome; sometimes the group achieves a tacit agreement to "play it safe." Normative equilibrium selection theories[2] convey the message that

Normative Statement A player that is a utility-maximizer *should* play equilibrium strategy X under the specified game parameters (and nothing else).

A descriptive (or empirical) approach[3] instead would stipulate that

Descriptive Statement 1 If a player is a utility-maximizer, the player *will* play equilibrium strategy X under the specified game parameters (and nothing else).

Theories that rely on social norms or fairness principles for equilibrium selection can be classified as either normative or descriptive, depending on how their statements are phrased. This can be seen by substituting the phrase "is a utility-maximizer" (which is nothing but the norm of maximizing one's individual utility) in the two statements given above by "prefers outcomes with equal payoffs for all players" for example. So even a descriptive statement can have a normative component. Nevertheless, Schelling (1980) follows a descriptive approach to equilibrium selection, because he starts with the empirical observation that people are drawn to focal points, like symmetric outcomes, when they face coordination problems in real life (see ibid, p. 56f., for several examples). The decision is in fact not about what a player individually prefers

[1]Some of the following sections also appear in a paper titled "Success rates in simplified threshold public goods games" (Feige, Unpublished).

[2]Besides Harsanyi and Selten (1988) and Harsanyi (1995), whose methods will be discussed in the following, another notable normative approach by Carlsson and van Damme (1993) involves a "global game" that includes an entire set of games similar to the one to be analyzed, whose elements are attained by random payoff perturbations.

[3]Quantal response equilibrium (McKelvey and Palfrey, 1995), impulse balance equilibrium (Ockenfels and Selten, 2005; Selten and Chmura, 2008), and stochastic stability (Kandori et al., 1993; Samuelson, 1997; Peski, 2010) are all based on descriptive theories and therefore can generate descriptive statements.

according to his own notions of fairness, i.e., what he thinks he *should* choose. It is about what the player believes *is* the prevalent social norm that *everyone else* adheres to, i.e., an empirical observation. As Schelling states (ibid., p. 91), "...tradition points to the particular set that everyone can expect everyone else to be conscious of as a conspicuous candidate for adoption; it wins by default over those that cannot readily be identified by tacit consent."[4]

The difference between a normative and a descriptive approach becomes even more apparent if a player happens to *not* play strategy X, with the consequence that the group also does not "select" the specified equilibrium. Followers of the normative approach will argue that this individual player just did not listen to them or did not follow their suggestion for some other reason. The validity of their approach, the claim that here an equilibrium where everybody plays X should be played by the group, is untouched.[5] Followers of the descriptive approach, on the other hand, would admit (albeit grudgingly) that their stipulation might be false and then improve their theory to better fit their empirical observations. For instance, they might adjust their statement as follows:

Descriptive Statement 2 If a player maximizes his individual utility function, the player *is likely to* play equilibrium strategy X under the specified game parameters.

As a consequence, the accordingly modified descriptive approach no longer selects a unique equilibrium with certainty, but only assigns a positive probability to each of the equilibria. Of course, this more general theory still permits the testing of deterministic hypotheses like the claim that an equilibrium in which everybody plays X is indeed the only equilibrium that is observed, if each individual player has a high probability p of playing X.[6] Notwithstanding that such hypotheses are obviously rejected if some groups tacitly coordinate on a different equilibrium.

Although a probabilistic model already has a higher explanatory power than a deterministic one, because the former incorporates the latter as a special case, I submit the claim that the increased flexibility resulting from this generalization in fact improves its predictive accuracy. I therefore argue that a probabilistic measure, namely the relative attractiveness of the most focal threshold allocation compared to zero contributions, is the main determinant

[4] I will address this issue in more detail in Chapter 4.

[5] For example, Sugden (1995) argues that empirical evidence against his normatively motivated "collective rationality" criterion "may cast doubt on the general validity of collective rationality as a component of a descriptive theory, but it need not undermine the normative status of such a criterion" (ibid, p. 543).

[6] This corresponds to the concept of p-dominance (Morris et al., 1995) which Peski (2010) uses to generalize risk dominance (or $\frac{1}{2}$-dominance). The "solution" to the problem of equilibrium selection presented by Harsanyi (1995) also selects the equilibrium with the highest theoretical probability of being played. Haruvy and Stahl (2007) furthermore discuss an empirically motivated "selection probability."

in a class of ThrPGs that give no or only a partial refund of contributions if the threshold is not reached. It is only indirectly, via this relation, that the step return and other game parameters affect average success rates.

2.1.2 Previous work on predicting success rates in ThrPGs

Admittedly, there have been a number of other attempts in the past to theoretically predict contribution behavior in ThrPGs, but they all have their limitations, if they make accurate predictions at all. A first attempt has been made by Palfrey and Rosenthal (1984), who calculate the equilibria for binary ThrPGs with and without a refund of contributions if the threshold is missed. In binary ThrPGs, each player has only two pure strategies – contribute his entire endowment or not contribute at all – which means that there is no symmetric pure-strategy equilibrium that exactly reaches the threshold (unless the threshold is equal to the total endowment of all players). Offerman et al. (1998) calculate the quantal response equilibria (McKelvey and Palfrey, 1995), for this type of ThrPG, whereby they assume that the players make random mistakes in the calculation of expected payoffs and consequently do not always play their best response to other strategies. Goeree and Holt (2005) use a similar approach and are even able to perform a comparative statics analysis for success rates dependent on the number of players and the step return. Yet despite the minimal strategy set, both models can provide only implicit characterizations of the success rate, which could be taken to mean that an explicit model for (binary) ThrPGs simply does not exist.

Recently, Alberti et al. (Unpublished) and Cartwright and Stepanova (Unpublished) have applied impulse balance theory to ThrPGs, theorizing that the players learn from outcomes in previous rounds and experience a certain drive (impulse) to adapt their contributions afterwards. Just like the quantal response model, theirs yields only an implicit characterization of success rates, albeit with a more general applicability to larger individual strategy sets.

What all of these models have in common, though, is that they ignore the possibility of convergence to a pure-strategy equilibrium, i.e., of the idea that the players learn to coordinate their behavior and then attain a stable outcome in which everyone always makes the same contribution. Goeree and Holt (2005) instead calculate the probability that the threshold is reached under the assumption that the group plays the efficient symmetric *mixed-strategy* equilibrium. In this (theoretically) stable outcome, the threshold is nevertheless not reached with certainty, because each individual contributes his endowment with a specific probability and makes this choice independently of the other players. On some occasions, the group will accordingly contain too few contributors to reach the threshold. Goeree and Holt (2005) simply calculate the probability that enough players contribute given that their mixed-strategy equilibrium is played and use this value as a predictor of success rates. Yet this approach is of little help if the players coordinate on a pure-strategy equilibrium, because in this case all players can contribute a fixed share of the threshold. No variation in individual contributions accordingly would mean a success rate of 100%, which however is typically not the case. Similarly, the corrections that impulse balance theory and quantal response equilibrium make to mixed-strategy equilibria (see in particular Selten and Chmura, 2008) can improve predictions for such a concept of success rates in binary ThrPGs. Yet this reasoning cannot easily be transferred to the continuous game.

Apart from this problem, these studies have nevertheless also generated a few valuable insights concerning equilibrium convergence in ThrPGs. Palfrey and Rosenthal (1984), for instance, mention that "the inefficient pure strategy equilibria of the [game with refund rule] are *weak*" (ibid., p. 180) and therefore inferior.[7] McKelvey and Palfrey (1995) even give conditions under which the quantal response equilibrium concept "implies a unique selection from the set of Nash equilibria", but the binary ThrPG studied by Offerman et al. (1998) (see also Offerman et al., 1996, 2001) is ill-suited to observe convergence to an efficient outcome, because this means choosing either one of several asymmetric pure-strategy equilibria or a symmetric equilibrium in mixed strategies. In addition to that, the authors use a strangers procedure (i.e., randomly changing group compositions) in their accompanying experimental study, presumably to control for effects of learning through repeated interaction, making it even more difficult for the subjects to coordinate their behavior and thus converge to an equilibrium.

On the other hand, papers discussing convergence in ThrPGs (or its lack thereof) frequently point out that equilibrium convergence is difficult to achieve even in repeated games with a *fixed* group composition (partners procedure). For instance, Cadsby and Maynes (1999) state that "14 periods did not appear to be sufficient in many cases for convergence to an equilibrium. [...] we increase the number of periods to 25." In contrast, other studies observe convergence to zero contributions after only seven rounds (Guillen et al., 2006) or ten rounds (Isaac et al., 1989). My own experimental research (see in particular the repeated-game (RG) treatments discussed in Chapter 6) provides another example for such a quick coordination process. In the literature, the convergence of total contributions to the threshold level is discussed on the basis of experimental data in several studies by Croson and Marks (1998, 1999), as well as by Cadsby and Maynes (1999).

In addition, there are also at least two different theoretical approaches that employ concepts of evolutionary game theory to model equilibrium convergence in ThrPGs, both of which rely on a deterministic selection. The first, by Myatt and Wallace (2008), is again restricted to binary ThrPGs and draws on the above mentioned literature on quantal response equilibrium. The second approach, initially brought fourth by Wang, Fu, Wu, and Wang (2009), assumes a replicator dynamic in which only two strategies compete with each

[7] See also Bagnoli and Lipman (1989, 1992).

other: a "cooperator" strategy that contributes an equal share of threshold and a "defector" strategy that contributes nothing. By developing such a convergence model, much can also be learned about success rates in ThrPGs, because the one is contingent on the other: In order to converge to zero contributions, a group must necessarily fail to reach the threshold.

A probabilistic model of equilibrium selection, like the one that I present here, is even better suited to predict success rates, because one probability (that of converging to zero contributions) can be related to another (that of reaching the threshold). In other words, the lower the probability of convergence to zero contributions, the higher the success rate. This is the general principle behind the model of a "Simplified ThrPG" as it is presented in this chapter. Just like Wang, Fu, Wu, and Wang (2009), only two contribution strategies are matched against each other in the model, even though a large set of (continuous) contribution strategies is assumed. Yet apart from that, the model is probabilistic, assigning to each pure strategy equilibrium a positive (although possibly negligible) probability of being played. The resulting "Simplified ThrPG" also provides a more general description of contribution behavior, e.g., because it accounts for player heterogeneity.

Whereas the first half of the chapter is concerned with deriving this theoretical model and its implications, the second half contrasts these theoretical findings with empirical observations in a guided tour through the experimental literature on ThrPGs.

2.2 Risk dominance and the probability of playing a particular equilibrium

Before discussing equilibrium convergence – which of necessity requires a dynamic perspective according to which a game is played repeatedly by members of the same population of players, or even by the same (fixed) group of people – it is helpful to start with equilibrium selection in a one-shot interaction. In this situation, the best even a rational player can do is determine a probability with which a particular equilibrium is played from the game's payoff structure (which is assumed to be common knowledge).

The theoretical work on equilibrium selection, like Harsanyi and Selten (1988), rarely goes beyond discussing 2×2 normal-form games, clearly because a generalized analysis of more complicated games is, well, too complicated to be worthwhile. Having two players with two strategies each is sufficient to create the fundamental part of this problem. Assuming $A_i > B_i > C_i$ for each player $i = 1, 2$, the game shown in Figure 2.1 has two Nash equilibria in pure strategies: (X, X), which is payoff dominant because it yields the highest payoff A_i to each player i, and (Y, Y), which gives a lower payoff of B_i. However, this lower payoff is guaranteed to every player who chooses Y, no matter what the other player does. This "safe" option becomes particularly attractive if $2B_i > A_i + C_i$ for all i, i.e., if (Y, Y) is risk dominant, which also means that there is a conflict between these two dominance criteria in this case. The game also has a unique mixed-strategy equilibrium, which figures prominently in the subsequent theoretical analysis.

		Player 2	
		X	Y
Player 1	X	A_1, A_2	C_1, B_2
	Y	B_1, C_2	B_1, B_2

Figure 2.1: A 2 × 2 normal-form game with two pure-strategy Nash equilibria ($A_i > B_i > C_i$ for each player $i = 1, 2$).

Whereas Harsanyi and Selten (1988) still make a normatively motivated claim that the payoff-dominant equilibrium (X, X) should be selected even if (Y, Y) is risk-dominant,[8] Harsanyi (1995) places more importance on risk dominance as selection criterion.[9] He "propose[s] a mathematical model for measuring the strength of the *incentive* that each player has to use any particular strategy, and then for employing these incentive measures to estimate the *theoretical probability* that any given equilibrium will emerge as the actual outcome of the game." (Harsanyi, 1995, p. 92, italics in original). With respect to the model that Harsanyi subsequently develops, the incentive for a player i to choose strategy X in the above defined coordination game depends on the size of this strategy's stability set, which refers to the set of mixed strategies of the *other* player j against which this pure strategy is a best response for player i. More precisely, the incentive of choosing X is the larger, the larger its stability set, because X is then the best response in a larger number of possible game situations.

A stability set is demarcated by points at which the player is indifferent between choosing this pure strategy and a different one. In the case of strategy X and player i, this is a mixed strategy for player j which makes i indifferent between X and Y and is accordingly determined by i's possible payoffs, A_i, B_i, and C_i, from playing either of these strategies. But that a player is made indifferent between all of his pure strategies by his opponent's equilibrium mixed-strategy is also the condition for a mixed-strategy equilibrium. So we can determine the incentive that i has to choose X by determining the equilibrium mixed strategy of the other player j as this gives a measure of the size of X's stability set for player i.

Following the reasoning of Harsanyi (1995), the probability that (X, X), i.e., the payoff-dominant equilibrium, results, then depends on the relative dis-

[8]This is mentioned only very briefly in the final chapter of their book (Harsanyi and Selten, 1988, Section 10.11).

[9]Interestingly, this switch seems to be theoretically motivated (cf. Harsanyi, 1995, Section 1.5) and not caused by the at that point steadily increasing empirical evidence that experimental subjects select risk-dominant over payoff-dominant equilibria (e.g., van Huyck et al., 1990).

tance between this equilibrium and the mixed-strategy equilibrium. Figure 2.2 illustrates this reasoning for the game described above. Subfigure 2.2 a) shows the strategy space of this game, whereby (X, X) and (Y, Y) refer to the two pure-strategy equilibria and **M** denotes the mixed-strategy equilibrium. In symmetric games the mixed-strategy equilibrium **M** is located on the straight line from (X, X) to (Y, Y), but this need not be the case in a game with asymmetric payoffs. The interior of the rectangle demarcated by the four points (X, X), A_1, **M**, and A_2 contains all points of the strategy space, i.e., mixed-strategy profiles, at which the mixed strategy played by one player is in the stability set of strategy X for the respectively other player. Similarly, the interior of the rectangle demarcated by the four points (Y, Y), B_1, **M**, and B_2 contains all points of the strategy space, at which the mixed strategy played by one player is in the stability set of strategy Y for the respectively other player. At any point in either of the two sets, a player would prefer switching to a pure strategy. Moreover, given that at any point in either of these two sets *both* players would consider a switch to the *same* pure strategy, they should expect to end up at the respective pure-strategy equilibrium. For this reason, I will associate these two sets of points directly with the respective equilibrium in the following, and speak of, e.g., "equilibrium (X, X)'s stability set" instead of "the stability sets of players 1 and 2 with respect to pure strategy X."

A closer look at Figure 2.2 shows that relative size of (X, X)'s and (Y, Y)'s stability sets, shown dotted in Subfigure 2.2 a), can be approximated by the relative position of **M** in the one-dimensional representation of the stability sets shown in Subfigure 2.2 b), which is just the shortest distance from (X, X) to (Y, Y) via **M**. On this one-dimensional representation, the mixed-strategy equilibrium cleanly separates the stability set of equilibrium (X, X) from that of equilibrium (Y, Y). At any point closer to (X, X) on the line, a player will be better off switching to the pure strategy X. Similarly, at any point closer to (Y, Y), a player will prefer switching to strategy Y.

Let σ_i denote the probability with which player i plays X in the mixed-strategy equilibrium. The probability p that the associated pure-strategy equilibrium $\mathbf{X}$:= (X, X) is played, is then equal to the distance between $\mathbf{X}$ and $\mathbf{M}$ relative to the total distance between $\mathbf{X}$ and $\mathbf{M}$ as well as $\mathbf{M}$ and $\mathbf{Y}$:= (Y, Y):

$$p = \frac{|\overline{XM}|}{|\overline{XM}| + |\overline{MY}|} = \frac{\sqrt{(1-\sigma_1)^2 + (1-\sigma_2)^2}}{\sqrt{(1-\sigma_1)^2 + (1-\sigma_2)^2} + \sqrt{\sigma_1^2 + \sigma_2^2}} \tag{2.1}$$

In a symmetric game with $A = A_1 = A_2$, $B = B_1 = B_2$, and $C = C_1 = C_2$, the mixed-strategy probabilities in equilibrium play are the same for both players. Accordingly, by letting $\sigma = \sigma_1 = \sigma_2$, Eq. (2.1) can be simplified to

$$p = 1 - \sigma = \frac{A - B}{A - C}. \tag{2.2}$$

If (X, X) is risk dominant in this symmetric game, it must be true that

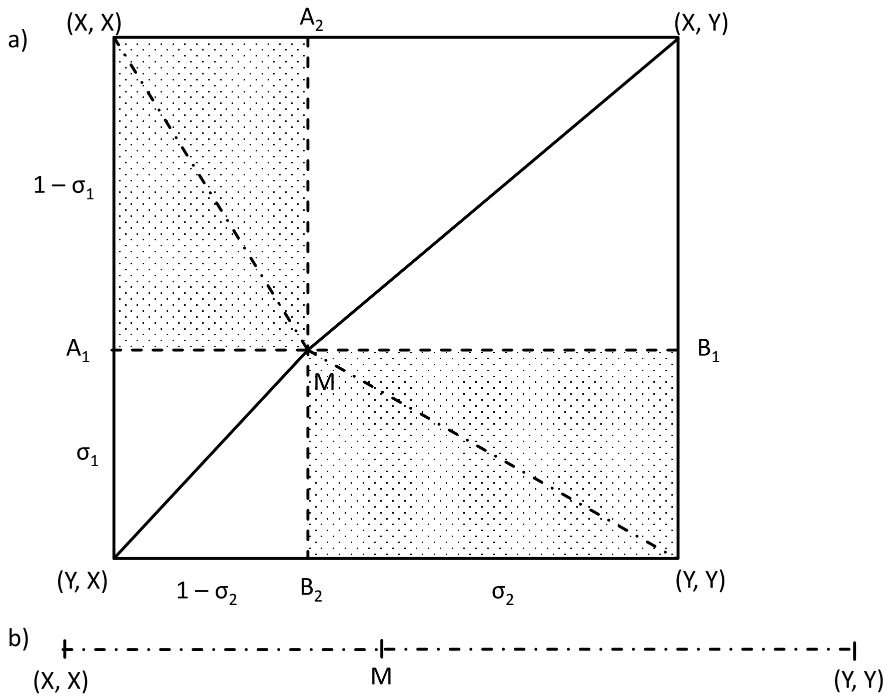

Figure 2.2: Strategy space (a) and one-dimensional representation of stability sets (b) of a 2 × 2 normal-form game with two pure-strategy equilibria (X, X) and (Y, Y) and a single mixed-strategy equilibrium **M**. The probability that equilibrium (X, X) is played, is equal to the relative distance between (X, X) and **M**.

$2B < A + C$. Eq. (2.2) then implies that $p > 0.5$. Consequently, and as Harsanyi (1995) suggests as well, the equilibrium with the highest theoretical probability of being played is the risk-dominant outcome. Furthermore, the model can be used to calculate, for example, how increasing any of the parameters, A, B or C, affects the players' incentive to choose X and therefore the probability that (X, X) results. In contrast, if payoff dominance were the more important selection criterion, the absolute value of the parameters should not matter at all, only that A is greater than both B and C.

Note, from Eq. (2.2), that p is equal to the weight placed on strategy Y (i.e., the *other* strategy) in this game's unique mixed-strategy Nash equilibrium. While this may appear a bit confusing at a first glance, it is actually correct and consistent with Harsanyi's "proportionality requirement" for unanimity games[10] (cf. Harsanyi, 1995, p. 106f., Lemmas I and II): The more weight player i puts on strategy Y in the mixed-strategy equilibrium, the greater is this equilibrium's geometrical distance from (X, X), the larger is X's stability

[10]For more on unanimity games see Harsanyi and Selten (1988, p. 213ff).

set, the higher is the incentive for a player to choose X over Y.[11]

The model readily extends to any "2 × … × 2" game with $n \in \mathcal{N}$ players that also has two Pareto-ranked pure-strategy equilibria, **X** and **Y**, in which either all players choose X or all choose Y, respectively, and the fixed payoffs B_i and C_i if not all players choose X are independent of the number of players who do choose X. Kim (1996, Lemma 1) shows that such a game also has a unique mixed-strategy equilibrium **M**.[12] Furthermore, this game's stability sets can once again be represented in a single dimension, with **M** separating the stability sets of the two pure-strategy equilibria on a line from **X** to **Y**. In analogy to the above reasoning, the theoretical probability p that all players choose X is therefore:

$$p = \frac{\sqrt{\sum_{i=1}^{n} (1-\sigma_i)^2}}{\sqrt{\sum_{i=1}^{n} (1-\sigma_i)^2} + \sqrt{\sum_{i=1}^{n} \sigma_i^2}} \tag{2.3}$$

At the mixed equilibrium **M**, player i is indifferent between the pure strategies X and Y, but if any other player were to change his own mixed strategy only slightly, either X or Y would immediately become a best response. Consequently, assuming that all other players choose their strategies independently, so that, e.g., player j plays X with probability σ_j, player i faces the following decision problem:

	$(X : \prod_{j \in \mathcal{N} \setminus \{i\}} \sigma_j, Y : 1 - \prod_{j \in \mathcal{N} \setminus \{i\}} \sigma_j)$
X	$(\prod_{j \in \mathcal{N} \setminus \{i\}} \sigma_j) A_i + (1 - \prod_{j \in \mathcal{N} \setminus \{i\}} \sigma_j) C_i$
Y	B_i

The break-even point, for which X and Y yield the same expected payoff to player i and which characterizes the mixed-strategy equilibrium, is given by the following set of equations:

$$\forall i \in \mathcal{N} : \prod_{j \in \mathcal{N} \setminus \{i\}} \sigma_j = \frac{B_i - C_i}{A_i - C_i} \tag{2.4}$$

Solving this set of equations for an explicit expression for the mixed strategy σ_i yields the following result:

[11] Harsanyi (1995) shows (Lemma I) that using the size of the stability set directly as a proxy does not necessarily work if there are more than two available strategies, making this round-about approach necessary.

[12] Technically, the game described here does not belong to the set of games Π to which the lemma applies, since $\pi_k^H = \pi_{k-1}^H, \forall k < n$. Palfrey and Rosenthal (1984) show a similar result (Proposition 10) for a binary ThrPG.

Lemma 2.1. *In the n-player two-strategy normal-form game defined above, the equilibrium mixed strategy for player i is given by:*

$$\sigma_i = \frac{A_i - C_i}{B_i - C_i} \sqrt[n-1]{\prod_{j=1}^{n} \frac{B_j - C_j}{A_j - C_j}} \tag{2.5}$$

Proof: For any two players i and j, divide the respective equations in Eq. (2.4) by each other to receive a new equation containing only σ_i and σ_j. Repeating the process for the same i, but in combination with other players, yields $n - 1$ such two-variable equations. Substituting these equations back into Eq. (2.4), namely into the equation generated from for player i's choice between X and Y, and solving for σ_i yields the above expression. □

For the homogeneous case with n players we can use Eqs. (2.3) and (2.5) to derive a theoretical probability p that all players choose X of

$$p = 1 - \sigma = 1 - \sqrt[n-1]{\frac{B - C}{A - C}}. \tag{2.6}$$

Consequently, p decreases in larger groups, approaching zero if n approaches infinity, which conforms to the intuition that coordination is more difficult with more players. In the geometric interpretation of the model, increasing the number of players moves **M** closer to **X**, implying that, for any particular player, Y's stability set becomes increasingly larger relative to X, so that this player has an increasingly lower incentive to choose X over Y.

This generalization to n players also yields a more general definition of risk dominance based on the size the pure strategies' stability sets:[13] Even for more than two players we can say that equilibrium **X** risk dominates equilibrium **Y** if $p > 0.5$, that is, if **X** has the larger stability set. For the game discussed here, this is the case if

$$\forall i \in \mathcal{N} : A_i + (2^{n-1} - 1)C_i > 2^{n-1}B_i. \tag{2.7}$$

2.3 The Simplified ThrPG

While this approach seems to work well for games with only two pure strategies, this may still seem a long way away from a descriptive model for success rates in ThrPGs with continuous contributions. However, I will argue that a model based on a 2 × 2 normal-form game is already rich enough to provide a basic understanding of what goes on in even a complicated game like a ThrPG.

[13] This corresponds to one of the characterizations of n-player risk dominance given by Kim (1996) which refers to the relative size of the pure-strategy equilibria's basins of attraction. Mailath (1998) (p. 1370) furthermore provides arguments to the effect that the basin of attraction of **Y** increases with n. See also Section 2.5.

Given that the general idea behind a ThrPG is very simple, it will be helpful to look separately at the two main components of this game:

1. Does the group reach the threshold or not?

2. Among the large number of possible threshold allocations, which one (if any) does the group choose?

You may notice that the first question is binary: the group either does or does not reach the threshold. Assuming that "not reaching the threshold" is the same as an overall and individual contribution of zero (so as not to waste any contributions), this translates into the two strategies of Z (for "zero"), which is to contribute zero ($q_i = 0$), and Q_{α_i} (to indicate a positive total contribution "quantity"), which has a particular player i contribute his "fair" (or otherwise assigned) share of the threshold, denoted by α_i, so that $q_i = \alpha_i T$. If all players contribute their assigned share, the threshold value is reached exactly. However, different groups (or the same group at different points of time) may give different answers to these two questions. Most importantly, we can only expect that the threshold is reached with probability, and not with certainty, especially if one or more groups are observed repeatedly.

Note that this reasoning transforms the predominantly normative and deterministic message from the preceding section, to wit,

Normative statement A utility-maximizing player *should* contribute zero (and do nothing else) if this is his risk-dominant strategy.

to the following descriptive and probabilistic statements:

Descriptive Statement (individual) The probability that an individual player contributes zero is positively correlated with the relative size of Z's stability set.

Descriptive Statement (group) The success rate, i.e., the observed frequency with which the threshold is reached, is negatively correlated with the relative size of the stability sets of the zero-contributions equilibrium.

There remains the problem that there are actually many threshold equilibria, all of whose positions relative to zero contributions must be determined in order to accurately predict success rates. However, if all players agree on what a "fair share" is, we can restrict our analysis to a comparison of only this threshold allocation with the zero-contributions equilibrium. To be true, this is usually not the case in an experimental session where the group members have just come together for the first time for an unfamiliar task. But theoretical concepts like focal points (Schelling, 1980) or collective rationality (Sugden, 1995) as well as data from previous experimental studies can be used to single out the threshold allocation(s) that will be the most attractive to experimental subjects. Chapter 4 will discuss in more detail how selection criteria based on fairness principles can be used for this very purpose. For the moment, I simply assume that any feasible threshold allocation, i.e., any efficient pure-strategy equilibrium of the original ThrPG, is a possible candidate for a "fair" outcome. This generalizes the approach by Wang, Fu, Wu, and Wang (2009) who only consider an equal allocation of the threshold value in their symmetric game.[14]

Based on the general model of a ThrPG presented in Chapter 1, Section 1.1, we can then specify a "Simplified ThrPG"[15] for this particular threshold allocation $\alpha = (\alpha_1, \ldots, \alpha_i, \ldots, \alpha_n)$, where $0 < \alpha_i < 1$ is the relative share of the threshold value provided by player i, resulting in a contribution of $q_i = \alpha_i T$.[16] Obviously, $\sum_{i=1}^{n} \alpha_i = 1$. The payoff matrix of an individual player i playing this Simplified ThrPG against the "rest of the group", whose choices are represented by the total contribution $Q_{-i} := \sum_{j \in \mathcal{N} \setminus \{i\}} q_j$, is displayed in Figure 2.3.

		Rest of the Group	
		$Q_{-i} = T - \alpha_i T$	$Q_{-i} < T - \alpha_i T$
Player i	$Q_{\alpha_i}(q_i = \alpha_i T)$	$e_i - c_i \alpha_i T + v_i$	$e_i - (1-r) c_i \alpha_i T$
	Z $(q_i = 0)$	e_i	e_i

Figure 2.3: A simplified threshold public goods game with two pure-strategy Nash equilibria. The matrix displays the payoffs for a typical player i given a total contribution Q_{-i} provided by the rest of the group.

Similar to the two-player game shown in Figure 2.1, each player i has a safe strategy (Z), the payoff for which falls between the two possible outcomes for player i's other, risky, strategy Q_{α_i}: If $c_i \alpha_i T < v_i$ for all $i \in \mathcal{N}$ and $r < 1$, Z yields a guaranteed payoff of e_i to player i, whereas Q_{α_i} yields either strictly more than e_i if the rest of the group chooses the complement share

[14] Alternatively, a pairwise comparison of all threshold allocations with the zero-contributions equilibrium, similar to the procedure described by Harsanyi and Selten (1988), could be used to determine parameter settings under which zero contributions either risk-dominates or is risk-dominated by all threshold allocations.

[15] This simplified game is not the same as the "reduced game" discussed by Harsanyi and Selten (1988) and Harsanyi (1995) which eliminates only clearly non-essential game components like dominated or duplicate strategies or players. However, there is a similarity to the "simplified collective risk-dilemma" considered by Hilbe et al. (2013), who analyze a game variant in which simultaneous individual contributions occur repeatedly over several rounds and are accumulated towards a single threshold value at the end.

[16] Since no individual player can reach the threshold value on his own, $\alpha_i = 1$ is ruled out for any player i. Assigning to any particular player i a share of $\alpha_i = 0$ is tantamount to removing this player from the game and thus equivalent to reducing the number of players by one to only those with strictly positive shares.

$Q_{-i} = T - \alpha_i T$, which is only possible if every other player j plays his own risky strategy Q_{α_j}, or strictly less than e_i if even a single other player chooses Z.[17] The first qualifying assumption implies that the benefit from providing the public good, v_i, is strictly greater than the costs a player incurs by contributing his share, $c_i \alpha_i T$, which merely means that participation in this game must be individually rational. In addition, if $r = 1$, that is if a full refund is granted, any player i always earns at least e_i, even if he contributes and the others do not, making this a riskless choice between Q_{α_i} and Z and thus a case to which the model does not apply. For this reason, it is also assumed that $r < 1$.

Accordingly, the here derived theoretical probability with which the threshold in a public goods game is reached, i.e., its predicted success rate, likewise depends on the stability sets of two pure strategies. The predicted (or theoretical) success rate then corresponds to the probability with which the pure-strategy equilibrium associated with Q_{α_i} is played. For reasons of simplicity, I will call the equilibria associated with these two pure strategies $\mathbf{Z}$ and $\mathbf{Q}_\alpha$.

As before, we only need to determine the mixed-strategy equilibrium, $\mathbf{M}_\alpha$, in order to calculate the theoretical probability p_α that the associated pure-strategy equilibrium $\mathbf{Q}_\alpha$ is played, which due to the impossibility of overcontribution in this simplified game also equals the theoretical success rate. Let $\sigma_i(\alpha)$ denote the probability with which player i plays Q_{α_i} in the mixed equilibrium $\mathbf{M}_\alpha$ given a particular allocation α. The theoretical success rate p_α is then equal to the distance between $\mathbf{Q}_\alpha$ and $\mathbf{M}_\alpha$ relative to the total distance between $\mathbf{Q}_\alpha$ and $\mathbf{M}_\alpha$ as well as $\mathbf{M}_\alpha$ and $\mathbf{Z}$:

$$p_\alpha = \frac{\sqrt{\sum_{i=1}^{n} (1 - \sigma_i(\alpha))^2}}{\sqrt{\sum_{i=1}^{n} (1 - \sigma_i(\alpha))^2} + \sqrt{\sum_{i=1}^{n} \sigma_i^2(\alpha)}} \tag{2.8}$$

By letting $A_i = e_i - c_i \alpha_i T + v_i$, $B_i = e_i$, and $C_i = e_i - (1 - r) c_i \alpha_i T$, we can use Lemma 2.1 to derive the following:

Corollary 2.1. *In a simplified ThrPG, the equilibrium mixed strategy for player i is given by:*

$$\sigma_i(\alpha) = \sqrt[n-1]{\frac{1 - r}{\prod_{j=1}^{n} \left[\frac{v_j}{c_j \alpha_j T} - r\right]}} \left[\frac{v_i}{c_i \alpha_i T} - r\right] \tag{2.9}$$

Although, strictly speaking, the model is not defined for the case of a full refund, that is if $r = 1$, taking the limit of Eq. (2.9) for r approaching 1 gives $\sigma_i(\alpha) = 0$ and a success rate of $p_\alpha = 1$. This means that $\mathbf{Q}_\alpha$ is the only equilibrium predicted to occur by this theoretical approach in this special

[17] Here it becomes most apparent what is behind this simplification process, and what is potentially lost in comparison to a more general analysis: In the original game, the threshold can often still be reached if some players "free-ride" and contribute zero, namely if the other players are able to increase their contributions to make up for the difference.

case, because $\mathbf{M}_\alpha$ moves closer and closer to $\mathbf{Z}$ as r approaches 1, being located at the same point as $\mathbf{Z}$ in the limit. This is consistent with the fact that $\mathbf{Z}$ is just a "weak" Nash equilibrium in this case and therefore presumably less attractive than the strict equilibrium $\mathbf{Q}_\alpha$, no matter how the game parameters are chosen. Obviously, this establishes a limitation of this model to the class of ThrPGs with no or only a partial refund. In Appendix 2.A.1, I will introduce a possible work-around that involves a disutility from receiving a refund, e.g., in the form of a transaction cost that slightly reduces the refunded amount.

2.4 Success rates for homogeneous games

If the players are homogeneous, so that $e = e_i = e_j, v = v_i = v_j$, and $c = c_i = c_j$ for all players i and j, it is once again possible to simplify Eq. (2.8) further in order to better identify the effects of the particular game elements on success rates. Symmetry can then be used as a justification to also assume $\alpha_i = \alpha_j = {}^1\!/\!_n$ as a (unique) focal allocation. Similar to the example in Section 2.2, the mixed-strategy probabilities will consequently be the same for all players as well, i.e., $\sigma = \sigma_i = \sigma_j$. Furthermore, the theoretical success rate is then given by

$$p_{1/n} = 1 - \sigma = 1 - \sqrt[n-1]{\frac{1-r}{\frac{nv}{cT} - r}}. \tag{2.10}$$

Realizing that ${}^{nv}\!/\!_{cT}$ is the step return SR (Croson and Marks, 2000), the theoretical success rate for a ThrPG with homogeneous players appears to depend only on the step return, the number of players, and the refund rate:

$$p_{1/n} = 1 - \sqrt[n-1]{\frac{1-r}{SR - r}} \tag{2.11}$$

Alternatively, we can define $\rho := {}^T\!/\!_{ne}$ as the proportion of total endowments required to provide the public good,[18] so that the success rate can also be stated as

$$p_{1/n} = 1 - \sqrt[n-1]{\frac{1-r}{\frac{ne \cdot v}{T \cdot ec} - r}} = 1 - \sqrt[n-1]{\frac{1-r}{\frac{1}{\rho} \cdot \frac{v}{ce} - r}}. \tag{2.12}$$

The probability given in Eq. (2.11) also results by translating the "unanimity rule" variant in Palfrey and Rosenthal (1984) into the notation used in this thesis.[19]

[18] Since $e < T \leqslant ne$, we have ${}^1\!/\!_n < \rho \leqslant 1$. In a linear public goods game, with $T = 0$, ρ would be equal to 0.

[19] Their model assumes that the valuation v is normalized to 1. If $q = \sigma$, $M = n$ and $c = {}^1\!/\!_{SR}$ and no refund is granted ($r = 0$), Eq. (2.11) is the same as the equation $q = c^{1/(M-1)}$ in Proposition 10 (Palfrey and Rosenthal, 1984, p. 185).

2.5 Equilibrium convergence

In the introduction to this chapter, I have criticized previous theoretical approaches for ignoring the possibility of equilibrium convergence. At a first glance, the model presented above is similarly flawed, because Harsanyi (1995) only discusses one-shot (normal-form) games. However, there has been extensive theoretical work in the literature on evolutionary game theory about the relation between risk dominance according to Harsanyi and Selten (1988) and stochastically stable strategies (e.g., Kandori et al., 1993; Kim, 1996; Samuelson, 1997; Peski, 2010).

This makes it possible to apply the Simplified ThrPG to a dynamic context. More precisely, assume that the simplified (two-strategy) game describes the stage game of the repeated interaction of a population or group of players. For any selection dynamics modeling the behavior in the repeated game that has stable stationary states at the stage game's two pure-strategy Nash equilibria, as well as an unstable stationary state in between, the relative position of these three stationary states in the stage game's strategy space yields a prediction for the probability with which either of the stable states is attained. Kim (1996) discusses several different selection dynamics – based on the dynamic equilibrium selection concepts of Matsui and Matsuyama (1995), Kandori et al. (1993), and Foster and Young (1990) – all of which generate different conditions for when the payoff-dominant equilibrium can be expected to be played in groups with more than two players. Similarly, all of these models could be used to derive competing models of theoretical success rates in ThrPGs, whereby the Kandori et al. (1993) dynamics yields the same prediction as the Simplified ThrPG.[20]

The selection dynamics assumed by Kandori et al. (1993) models a learning process in which the players react myopically, but not necessarily immediately (the process has "inertia"), and on occasion even change their strategy at random (cf. ibid., p. 30f.). This third property is referred to by the authors as "mutation" or "experimentation." The learning process occurs in a finite population of size N, from which two[21] players are selected at random in each period t to play the stage game. If $z_t \in \{1, \ldots, N\}$ players play strategy $Q_{1/2}$ in period t, then the expected payoff for one of these players in a randomly determined match with one other player from the population is

$$E[\pi_{Q_{1/2}}(z_t)] = \frac{z_t - 1}{N - 1}(e - \frac{T}{2} + v) + \frac{N - z_t}{N - 1}(e - \frac{T}{2}), \tag{2.13}$$

[20] To see that this is true for homogeneous game with no refund, use the condition [KMR] given by Kim (1996, p. 215) to calculate $SR > 2^{(n-1)}$ as a condition for selecting $\mathbf{Q}_{1/n}$ over $\mathbf{Z}$. The same condition results from Eq. (2.11), by postulating $p_{1/n} > 1/2$ and then solving for SR.

[21] Kim (1996) generalizes the model to n-player games, assuming in doing so that N is divisible by n.

compared to the expected payoff for a player playing strategy Z of

$$E[\pi_Z(z_t)] = e. \tag{2.14}$$

Kandori et al. (1993) then define a Markov process which yields z_{t+1}, i.e., the number of players who play $Q_{1/2}$ in period $t+1$, as follows:[22]

$$z_{t+1} = b(z_t) + x_t - y_t \tag{2.15}$$

Here, $b(z_t)$ is a best-response dynamics with three possible outcomes: 1) if $E[\pi_{Q_{1/2}}(z_t)] > E[\pi_Z(z_t)]$, all N members of the population switch to $Q_{1/2}$ as this yields the higher expected payoff, 2) if $E[\pi_{Q_{1/2}}(z_t)] < E[\pi_Z(z_t)]$, all N members of the population switch to Z as this yields the higher expected payoff, 3) if $E[\pi_{Q_{1/2}}(z_t)] = E[\pi_Z(z_t)]$, the composition of the population remains unchanged ($z_{t+1} = z_t$). However, the learning process is also randomly perturbed by the two stochastic components x_t and y_t, both of which are binominally distributed:

$$x_t \sim Bin(N - b(z_t), \epsilon) \quad \text{and} \quad y_t \sim Bin(b(z_t), \epsilon) \tag{2.16}$$

Accordingly, whenever the best-response dynamics requires a shift of the entire population to strategy Z, each individual player instead shifts to (or remains at) $Q_{1/2}$ with probability ϵ, so that the overall number of players who play $Q_{1/2}$ (i.e., *not* Z) is still positive with some probability and takes on the realization of the random variable x_t, i.e., $z_{t+1} = x_t$. On the other hand, whenever the best-response dynamics shifts the entire population to strategy $Q_{1/2}$, each individual player instead shifts to (or remains at) Z with probability ϵ, so that the overall number of players who play $Q_{1/2}$ is given by y_t, i.e., $z_{t+1} = y_t$.

Kandori et al. (1993) also apply this stochastic dynamics directly to 2×2 coordination games, where they state (ibid., p. 43f.) that the basins of attraction of the dynamics' two stable states $z_t = N$ and $z_t = 0$ are separated at a critical value z^*, which for a ThrPG calculates as $z^* = (N-1)^T\!/_{2V} + 1$. Furthermore, "$z^*$ corresponds to the mixed strategy equilibrium, which puts probability [$\sigma = {}^T\!/_{2v}$] on strategy [$Q_{1/2}$]," (ibid., p. 44), just as the Simplified ThrPG does.

Both Kandori et al. (1993) and Kim (1996) also repeatedly draw a connection between the relative size of the pure-strategy equilibria's basins of attraction and the outcome of the selection process, which however is always deterministic in the sense that the equilibrium with the larger basin of attraction is always selected with certainty. Note that the relevant theoretical result – Theorem 3 in Kandori et al. (1993) – pertains even to small populations, including the case of $N = 2$ where essentially the same group of two

[22] Apart from the application to a ThrPG, all of these results, including the notation, are taking from (Kandori et al., 1993, p. 37ff.). See also (Fudenberg and Levine, 1998, p. 142ff.).

players meets in every period. A generalization of this result to games with n players with asymmetric (but finite) strategy sets is derived by (Peski, 2010, Section 3.3).[23]

These findings are reason enough to at least consider the relative location of the mixed-strategy equilibrium of the stage game as a predictor of success rates in repeated ThrPGs with fixed group compositions. All this final step seems to require is that the players in the group hold a belief about the number of contributors z_{t+1} in period $t+1$ that does not completely reflect the observed number of contributors z_t in period t. And this is certainly the case, if some players "experiment", as Kandori et al. (1993) put it, and on occasion do *not* select their best response. Peski (2010) even takes it as a given that the players have "conjectures" about their fellow players' strategy profiles, which assign a probability of being played to every possible strategy.

How does the existing literature on evolutionary processes in threshold public goods games fit into this? There are in fact a considerable number of studies[24] which are primarily concerned with the evolution of cooperation and therefore look for parameter constellations and critical values for which $\mathbf{Q}_{1/n}$ is evolutionarily stable, though not necessarily the unique stable state.[25]

In the model by Wang, Fu, Wu, and Wang (2009), who investigate a ThrPG in which damages from not reaching the threshold are calculated as a percentage of the remaining endowment $(e - T/n)$, $T/ne =: \rho$ constitutes a critical point for this percentage, at which the "evolutionary dynamics transits from the dominance of defectors [...] to the bistability between defectors and fair sharers ..." (ibid., p. 4). In other words, if the percentage of lost remaining endowments is less than this value, zero contributions is the only evolutionarily stable state, whereas both zero contributions and a successful allocation of the threshold can result as stable states otherwise (cf. ibid, Table 1). Wang, Zhu, Ren, and Wang (2009) show for the same game by means of replicator dynamics that the main parameters (including n and T) affect the size of the basin of attraction of the "cooperative" strategy, but again relate these findings only to the possible "emergence of cooperation" and not the probability with which an efficient stable state is attained. Dragicevic and Engle-Warnick (Unpublished) go as far as investigating "ambiguous survival" (cases in which both strategies, Z and $Q_{1/n}$, exist in the population), but stop at calculating the unstable state of their replicator dynamics. Hilbe et al. (2013), who apply the (determin-

[23] An earlier result – Proposition 2 in Kim (1996) – only holds for sufficiently large populations.

[24] These include, but probably are not limited to Wang, Fu, Wu, and Wang (2009); Wang, Zhu, Ren, and Wang (2009); Boza and Számadó (2010); Wang, Fu, and Wang (2010); Abou Chakra and Traulsen (2012); Du, Wu, and Wang (2012); Archetti and Scheuring (2013); Hilbe, Abou Chakra, Altrock, and Traulsen (2013); Vásárhelyi and Scheuring (2013); Vasconcelos, Santos, and Pacheco (2013); Pacheco, Vasconcelos, and Santos (2014); Sasaki and Uchida (2014); Archetti, Ferraro, and Christofori (2015); Zhang, Zhang, and Cao (2015); Dragicevic and Engle-Warnick (Unpublished).

[25] Similarly, the models by Offerman et al. (1998) and Alberti et al. (Unpublished) have multiple theoretical solutions towards which gameplay can converge.

istic) replicator dynamics to their more complicate sequential game (see also Abou Chakra and Traulsen, 2012), even realize that which of their game's evolutionarily stable equilibria is selected "depends on the initial behavior of the individuals: populations with a sufficient initial number of fair-sharers eventually succeed in coordinating on the beneficial fair-share equilibrium, whereas populations mostly consisting of defectors [who contribute zero] end up in the detrimental equilibrium." (Hilbe et al., 2013, p. 2), but are only able to gain rough estimates for the size of the basins of attraction by means of computer simulations. The other studies are less closely related to the Simplified ThrPG and in part deviate even more from the conception of a ThrPG that I assume here.

I should also briefly mention the concept of a strategy's "fixation probability" (e.g. Antal et al., 2009), which is the probability with which a single representative of a strategy (a mutant) can take over a finite population of players. Theoretical biologists commonly employ this concept in situations with "weak selection" (e.g. Nowak, 2006, Chapter 7), meaning that the stochastic component of the evolutionary process, and not the selection component, is the main determinant of the dynamics' course. However, this is more applicable to large populations, from which players are randomly drawn each period to play the game that determines selection. If instead the same small group of players interacts several times, selection should be strong and thus more likely to immediately eliminate individual "mutants". Still, connecting the theoretical success rate to the fixation probability of zero contributions in a suitable learning process could yield interesting new insights for ThrPGs.

Apart from these various approaches to model the evolution of cooperation, there exists also a more economically motivated study by Myatt and Wallace (2008), who analyze a binary ThrPG with randomly distributed contribution costs (cf. Palfrey and Rosenthal, 1991a) and show that their Markov process selects an efficient allocation of the threshold if and only if the most efficient players can afford to reach the threshold, i.e., if their valuation of the public good is higher than their contribution costs.

Returning to the static approach to equilibrium selection I have pursued in the preceding sections, it appears that the stability sets of a pure strategy are closely related to the respective equilibrium's basin of attraction, meaning that a measure of their size will also be a predictor of equilibrium convergence.[26] In other words, if there is a high probability that equilibrium $\mathbf{Q}_{1/n}$ is played in initial rounds of the experiment, game-play will likely also converge to $\mathbf{Q}_{1/n}$ in the long run. Convergence to a threshold equilibrium may or may not increase success rates, though, depending on the remaining volatility of total contributions. Even groups that are very efficient in terms of total contributions may

[26]In Figure 2.2, for example, the basin of attraction of equilibrium (X, X) corresponds to the interior of the quadrangle demarcated by the four points (X, X), (X, Y), $\mathbf{M}$, and (Y, X), i.e., all mixed-strategy profiles, at which either player can increase his own payoff by switching to the pure strategy X.

have only low success rates, because the total contribution can just as likely be marginally above or below the threshold. Similarly, some groups may converge more quickly than others and therefore make fewer coordination errors, which then also affects empirical success rates. The model presented here cannot capture this kind of convergence behavior (and the associated effect on success rates), because this behavior appears to be concerned with the coordination process on how exactly the threshold should be allocated among the group members. Convergence to zero contributions, on the other hand, is a clear indicator for a collective unwillingness to take the risk involved in providing the public good, and it will obviously lead to significantly lower success rates than if game-play converges to the threshold.

In the original ThrPG, assuming that a suitable selection dynamics can be defined to deal with a continuous strategy space, the basins of attraction of the threshold equilibria should actually be infinitesimally small – even though these equilibria are strict[27] – because the set of threshold allocations is convex and the next closest equilibrium is reached in just two infinitesimally small steps.[28] On the other hand, $\mathbf{Z}$'s basin of attraction still has a strictly positive volume (unless $r = 1$), which again varies with the location of the symmetric mixed-strategy equilibrium, suggesting this basin's relative size as a suitable measure for the predicted success rate, that is, the smaller the basin, the higher the success rate.

2.6 Comparative statics

Is the theoretical success rate consistent with the results reported in the experimental literature? A first benchmark in this regard is the meta-study by Croson and Marks (2000). Table 2.1 translates their main empirical findings[29] into the notation used in this model, whereby + and − denote, respectively, a positive or negative effect on success rates and * denotes statistical significance ($p < 0.05$).

Except for SR, n, and ρ, the independent variables in this meta-analysis are dummies, indicating whether or not a particular treatment has this property. "Binary" refers to treatments that allow only binary contributions. "Refund" applies only to treatments with a full refund ($r = 1$). "Rebate" refers to a return on contributions beyond the required threshold value. Obviously, "Homogeneous" indicates groups with homogeneous players. In the Croson and Marks (2000) meta-study, "Communication" applies to any treatment in which the groups have a face-to-face discussion about the individual contributions, which at that point in time had only been done in two treatments from the

[27] Under the replicator dynamics strictness usually implies asymptotic stability (cf. Samuelson, 1997, Proposition 2.11 on p. 75).

[28] The first subtracts a negligible amount $\delta > 0$ from the contributions of player i, the second adds the same amount δ to the contribution of any other player j.

[29] See Croson and Marks (2000, Table 2).

Table 2.1: Empirical findings by Croson and Marks (2000).

	SR	n	ρ	Binary
Success rate	$+^*$	$-^*$	$-$	$-^*$

	Refund (r)	Rebate	Homogeneous	Communication
Success rate	$+^*$	$+$	$+$	$+^*$

* denotes statistical significance ($p < 0.05$)

study by van de Kragt et al. (1983), however.

As most of the literature is concerned with homogeneous groups (as well as marginal costs of $c = 1$), I shall restrict the comparative statics analysis to this special case. In Eq. (2.11), the step return SR is in the denominator of a negative term and therefore positively correlated with the success rate. Letting the refund rate r approach 1 makes the fraction it is contained in converge to 0, so that the success rate converges to 1. In other words, the success rate increases with r and the selection of a threshold allocation is guaranteed in the case of a full refund.[30]

The effect of the number of players n is more difficult to determine, because this is also a component of the step return. SR increases in n, because more players receive the same valuation v at the same cost T. However, this upward impulse on success rates is more than compensated in larger groups by the increasing risk of coordination failure. Mathematically, the increasing power of the root term means that the success rate ceteris paribus decreases in larger groups, approaching 0 as n approaches infinity.

In order to determine the effect of the proportion of the threshold value to total endowments ρ, we need to refer to Eq. (2.12) for $p_{1/n}$. Realizing that ρ is inversely proportional to the step return, but otherwise placed in a similar position as SR is in Eq. (2.11), we should expect lower success rates if this parameter is increased. In binary ThrPGs, equal contributions can only be reached in mixed strategies, so that the Simplified ThrPG cannot be directly applied to this case. However, the negative effect on success rates suggested by the Croson and Marks (2000) meta-analysis could certainly be caused by a higher variability of outcomes, associated with subjects attempting to alternate their contributions in order to reach the threshold efficiently.

The results are accordingly quite consistent with the meta-study by Croson and Marks (2000), as shown in Table 2.1. Only the effect of ρ is not statistically significant, although it has the predicted sign. As Croson and Marks (2000)

[30]In Appendix 2.A.1, I will use a variation of the model to address the nevertheless reported variability of observed success rates in experimental investigations, which can also be traced back to variations of the number of players as well as the valuation from reaching the threshold.

include a large number of treatments in their sample that grant a full refund ($r = 1$), to which the model presented in this study does not apply, it is still possible, though, that a significant effect of ρ on success rates appears in a sub-sample of treatments with partial or no refund.

The other dummy variables included in the Croson and Marks (2000) analysis are not fully accounted for in the simplified ThrPG. Simplifying the ThrPG abstracts from any effects of a rebate rule on success rates, even if the Nash equilibrium is unaffected, because overcontribution cannot occur. Homogeneous groups may have an advantage over heterogeneous groups playing a simplified ThrPG as well, given that the only focal allocation in a symmetric game is equal contributions, which is likely to have a comparatively high success rate, because it spreads the contribution costs equally among all players. Interestingly, though, the most frequent type of heterogeneity investigated in the literature, heterogeneous endowments, leads to the same theoretical success rate in the simplified ThrPG as the homogeneous case, provided that the players also coordinate on equal contributions, because the players' endowments prove irrelevant in the analysis. As experimental subjects often do not coordinate on this allocation (see also the literature reviewed in Chapter 4, Section 4.2), the frequently observed lower success rates in heterogeneous groups are in part compatible with the theoretical model, however.

2.7 Literature review

Given that Croson and Marks (2000) also include studies with a full refund of contributions in their meta-study, it seems prudent to in addition consult individual studies that specifically examine ceteris paribus variations for the parameters and design elements that may affect success rates. This is the focus of the following literature review, which examines the presumed explanatory variables discussed in the previous section on a case-by-case basis. Table 2.2 summarizes the main findings from this literature review. Note that, for the sake of completeness, the literature review also contains studies that grant a full refund ($r = 1$) even though the Simplified-ThrPG model does not apply to this case. Some studies only find a tentative effect, which is indicated by brackets. See the respective section for more details.

2.7.1 Step return and more general variations of payoff stakes

The effect of varying payoff stakes has been analyzed by a large number of studies. The step return, as a measure that normalizes the game parameters in a way that allows for comparison of payoff stakes between different studies, figures prominently in the meta-study by Croson and Marks (2000), who report increasing success rates for higher step returns, albeit for only a small sample of three treatments with four groups each. A concept similar to the step return,

Table 2.2: Variables shown to affect success rates in a controlled variation. A bracketed positive or negative effect, e.g., "(+)," indicates an only tentative effect (see text for more details).

Variable	Refund rate r	Observed effect	Study
Step return SR	0	$+$	Dawes et al. (1986)
	$0, 1$	$+$	Isaac et al. (1989)
	0	$+$	Offerman et al. (1996)
	0	$+$	Cadsby and Maynes (1998a)
	$0, 1$	$+$	Cadsby and Maynes (1999)
	1	$+$	Croson and Marks (2000)
	1	$+$	Cadsby et al. (2008)
	0.5	$-$	Czap et al. (2010)
Number of players n	1	$(-)$	Bagnoli and McKee (1991)
	0	$(+)$	Offerman et al. (1996)
	0	$-$	Feltovich and Grossman (2015)
Proportion threshold / total endowment ρ	$0, 1$	$-$	Dawes et al. (1986)
	$0, 1$	$-$	Isaac et al. (1989)
	$0, 0.5, 1$	$-$	Rauchdobler et al. (2010)
	1	U-shape	Alberti and Cartwright (2015)
	0	$-$	Cartwright and Stepanova (2015)
Refund rate r	$0, 0.5, 1$	$+$	Isaac et al. (1989)
	$0, 1$	$+$	Rapoport and Eshed-Levy (1989)
	$0, 1$	$(+)$	Cadsby and Maynes (1999)
	$0, 1$	$+$	Coats et al. (2009)
	$0, 0.5, 1$	$+$	Rauchdobler et al. (2010)
	$0, 1$	$(+)$	Cartwright and Stepanova (2015)
Rebate rule (y/n)	1	o	Marks and Croson (1998)
Homogeneous players (y/n)	1	o	Bagnoli and McKee (1991)
	0	$+$	Suleiman and Rapoport (1992); Rapoport and Suleiman (1993)
	1	o	Croson and Marks (1999, 2001)
	0	$+$	Bernard et al. (Unpublished)
	1	$(+)$	Alberti and Cartwright (2016)
Communication (y/n)	0	$+$	van de Kragt et al. (1983)
	0	o	Palfrey and Rosenthal (1991a)
	1	$(+)$	Alberti and Cartwright (2016)

the net reward ($v - T/n$), is defined by Cadsby and Maynes (1999) for the same purpose, but appears to have less predictive power than the step return, at least on average over all rounds (Cadsby et al., 2008). Both Croson and Marks (2000) and Cadsby et al. (2008) grant a full refund of contributions.

In an earlier study, Cadsby and Maynes (1998a) find a steady increase of average success rates for increasing valuations in four different treatments with no refund. Cadsby and Maynes (1999) offer mostly anecdotal evidence, because the study investigates a total of thirty different parameter settings, each with at most three groups. Nevertheless, the results once again support the idea that higher payoff stakes (here in the form of higher valuations) increase the likelihood of successful coordination. Moreover, Offerman et al. (1996) report the same effect for binary contributions and a strangers matching.

Czap et al. (2010) combine an increase of the valuation with an increase of the threshold value, for a net increase of the step return, in a game with a partial refund rate ($r = 0.5$). Interestingly, although the combined effect of raised valuations leads to an increase of contributions as expected, the success rates do not follow suit, but are actually higher in the treatment with lower stakes. This result shows that the model does not yet cover all factors that are relevant to success rates. It appears that the effect that changing the threshold value has on the difficulty of coordinating on a focal threshold allocation may be stronger than the effect of changing the payoff stakes, at least in this range of parameters.

Other studies in which the variation of the payoff stakes is not central to the research question are Dawes et al. (1986) and Isaac et al. (1989).

2.7.2 Number of players

That the coordination on a payoff-dominant, but risky outcome will become more difficult, if more players are involved, seems to be a reasonable expectation, which has also been observed for other types of coordination games (e.g., van Huyck et al., 1991). Feltovich and Grossman (2015) have recently conducted a systematic investigation of group-size effects in one-shot ThrPGs with no refund that corroborates one of the predictions of the Simplified-ThrPG model, namely that success rates are lower in larger groups if the step return is held constant. As the authors achieve this in their binary contributions game by setting the threshold equal to the players' total endowment, their experimental design exactly matches the specifications of this theoretical model: Each player has only two pure strategies, namely to contribute nothing or to contribute an equal share of the threshold value. With group sizes ranging from two to fifteen players, this has likely exhausted the spectrum that can be investigated in a controlled laboratory environment.

However, Feltovich and Grossman (2015) cover by no means all aspects of how the number of players affects success rates. This is because Offerman et al. (1996), who do *not* keep the step return constant, report increasing success rates in larger groups in a binary game with a strangers procedure and group sizes of either five or seven players. Yet the same authors state in a later paper (Schram et al., 2008) that this is because the threshold remains the same, making it easier for the larger groups to reach it. Ceteris paribus, larger groups in fact have lower success rates in their setting, again corroborating the Simplified-ThrPG model.

There is also still no systematic investigation of group-size effects in ThrPGs with a full refund, apart from the two-vs.-two-group comparison in a setting with full refund conducted by Bagnoli and McKee (1991). This study has two groups of five and ten players, respectively, all of which manage to reach the threshold efficiently by the final round, although average success rates up to that point are slightly lower in the larger groups.

Considering that ThrPGs in real life can involve groups of several hundred contributors (and conceivably even more inactive "players"), experimental research still has a lot of room in the dimension of group size, as well. In addition to the above-mentioned laboratory experiments, there also exist a few studies to that effect, with very large groups outside of the controlled laboratory environment. For example, Rose et al. (2002) describe a class-room experiment with one hundred student participants playing a one-shot binary ThrPG with heterogeneous valuations, a full refund, and a utilization rebate (see Section 2.7.6 below). The valuations of sixty of the players are actually below or equal to the contribution costs, meaning that these individuals should prefer not to contribute. Accordingly, the threshold value of forty participants is set very high, because this is exactly the number of players that benefit from providing the public good. With an observed number of forty-seven contributors, the experiment shows that successful public good provision is also possible in large groups of simultaneous contributors. In an earlier study, Rondeau et al. (1999) use a similar design with groups of forty-five players, but uncertain information about the number of players or the threshold value, making it difficult to compare the results to more "typical" ThrPGs.

Rose et al. (2002) also discuss a field experiment with a potentially much larger group of players (1.2 million) asked to give a donation to a public project, but are only able to contact roughly two hundred of these subjects directly in a telephone survey (see also Poe et al., 2002). In addition to the difficulty of keeping track of all of the participants' decisions, field experiments involving ThrPGs also cannot easily guarantee that contributions are chosen simultaneously. Most crowdfunding campaigns are in fact more similar to sequential ThrPGs and therefore do not involve a coordination problem (see also Chapter 1, Section 1.1.3).

Finally, Kerr (1989) examines how a player's perceived "self-efficacy" (referring to the pivotalness in the provision of the public good) varies with group size, providing arguments in favor of the hypothesis that contributions decrease in larger groups as each individual player becomes less pivotal to reaching the threshold. Although the study's experimental investigation is difficult to compare to the other experiments discussed here (e.g., opponent choices in large groups are determined at random; only one (randomly selected) subject of each group receives a payoff from the game), it nevertheless provides an interesting overview over psychological factors that could affect contribution behavior, thus complementing the mainly strategic arguments given in this thesis.

2.7.3 Proportion of threshold value to total endowments

The proportion of the threshold value to the sum of all endowments is easily calculated, and its effect on success rates is apparent in a large number of studies. However, it is rarely the main focus of a single study, usually being overshadowed by a variation of the threshold in order to affect payoff stakes (i.e., the step return). The reason for this may be that the effect of this design element on success rates is difficult to analyze theoretically for ThrPGs in general. Although the model presented in this chapter predicts a decrease of success rates if a larger proportion of maximum contributions must be invested to reach the threshold, this applies only to games that do not offer a full refund. Furthermore, once the proportion approaches the permissible bounds, individual players become more pivotal in reaching the threshold, either because they have to contribute at least part of their endowment so that the threshold can be reached (ρ close to 1) or because they can reach the threshold on their own or in cooperation with only a few number of players (ρ close to $1/n$).[31]

Cartwright and Stepanova (2015) vary the players' endowments in several treatments with no refund, which leads to significant changes in success rates that are not predicted by the model presented in this chapter. This again indicates that the relative size of endowments compared to the threshold value may affect the process of equilibrium convergence and, indirectly, the empirical success rates. However, this effect is less clear for the remaining treatments of this study, which all grant a full refund. Here the authors in fact establish a U-shape relation for ρ, which fits with the notion of pivotalness described above.

Dawes et al. (1986), employing a one-shot game with binary contributions, report lower success rates for higher threshold values, for both a full and no refund. Isaac et al. (1989) also observe lower success rates for higher threshold values in the case of no refund, but slightly higher success rates with the same parameter variation, if a money-back guarantee is given. The statistical significance of these results is questionable, however, again due to the small number of independent observations (six groups per treatment). A similar pattern is also observed by Suleiman and Rapoport (1992) and Rapoport and Suleiman (1993) (the latter involving heterogeneous endowments).

Rauchdobler et al. (2010) vary the threshold value exogenously and endogenously (by means of a vote). By having their subjects make contribution

[31] The effect of pivotalness on contributions is also examined by McBride (2010), but in the context of threshold uncertainty (see Section 2.7.9, as well as Chapter 6).

choices for every possible threshold value, the authors are able to conduct a within-group comparison. Again, average success rates display a significant decrease for higher thresholds (from 75% to 17%) if there is no refund, but the effect becomes less pronounced with an increasing refund rate: Groups with a partial refund only drop from 73% to 27%; groups with full refund still have a success rate of 55% for the highest threshold.

The extreme case of $\rho = 0$ corresponds to a linear public goods game, which does not have a threshold (or provision point). As reaching the threshold is automatic in this case, speaking of success rates makes no sense. The respective studies therefore focus on a comparison of total contributions. Marwell and Ames (1979, 1980), describing one of the earliest ThrPG experiments, find that including a provision point in their payoff table does not significantly affect average contributions, probably because this "threshold" is not explicitly advertised to the subjects and there is still a gradual payoff increase even for contributions below this contribution level. In contrast, Isaac et al. (1989) find higher contributions in their analysis for at least some of their provision-point treatments. Not unexpectedly, this includes the treatments that grant a full refund (money-back guarantee), but even without a refund, those groups that converge on a threshold equilibrium contribute consistently more than groups in the linear public goods game. Krishnamurthy (2001) reports similar findings for "voluntary contribution mechanisms" targeted at different provision points.

2.7.4 Binary contributions and mixed-strategy focal allocations

To my knowledge, a systematic comparison of binary ThrPGs with games with continuous or discrete contributions has not yet been attempted in an experimental study, although Cadsby and Maynes (1999) provide some evidence for the hypothesis that a restriction of the strategy set to binary contributions leads to lower success rates than discrete or continuous contributions in the game parameter setting. A potential problem with their experimental approach is in particular that the relevant sample of 28 groups ranges over several treatment dimensions, including the refund rate, the valuation, and the number of rounds. What appears as an overall significant difference in the regression results reported in Tables 2 and 3 of this paper, is not always as clear in a ceteris paribus comparison. For example, at a valuation of 20 and a threshold of 50, the single group with continuous contributions that played for 14 rounds is equally successful as the only comparison group with binary contributions (namely in 3 of the 14 rounds). And the latter group is even successful one more time in the last five rounds (to whose results the regression is applied) and contributes marginally more on average in these rounds as well.

Asch et al. (1993) compare a binary ThrPG to a linear public goods game with continuous contributions, finding no significant difference in average contributions. However, the authors report a higher frequency of "free rides" (i.e., instances of zero contribution) in the ThrPG, which is less surprising than the study suggests, because after all the only feasible pure-strategy equilibria in binary ThrPGs prescribe that a share of $n-T$ players does indeed contribute zero.

Guillen et al. (2006) provide an example for a ThrPG with discrete contributions, in which allocating the threshold value equally among all players (the supposed focal point for homogeneous ThrPGs) is not feasible in pure strategies. In their case, a group of five players must reach a threshold of $T = 31$, but each player can only contribute integer amounts, so that an equal share of 6.2 for each player is not feasible. The authors indeed observe convergence to zero contribution, and correspondingly low success rates, in their "baseline" treatment. However, in the absence of a counterpart treatment with a pure-strategy focal point, this result alone cannot corroborate the conjecture that focal points in mixed-strategies are more difficult to obtain and therefore involve reduced success rates.

2.7.5 Refund rate

The most critical parameter in the light of the previous theoretical analysis seems to be the refund rule. Games with a full refund should be expected to result in a completely different coordination behavior than those with no or only a partial refund, because the zero-contribution equilibrium is evolutionarily stable only in the latter two cases. The experimental literature is roughly split in half into studies that grant a full refund and those that do not. But also a controlled variation of the refund rate has been repeatedly investigated.

In a one-shot binary ThrPG, Rapoport and Eshed-Levy (1989) equate the conditions of "no refund" and "full refund" with paradigms called "fear plus greed" and "no fear",[32] appellations that perfectly characterize these two conditions in the context of this chapter, which is concerned with the fear (or risk) of wasting one's contribution. In this study, the treatments with a refund rate result in higher average success rates.

Isaac et al. (1989) make comparisons at different threshold values for a full, a partial ($r = 0.5$), and no refund. Although groups enjoying a full refund of contribution costs display significantly higher average success rates than those with no or only a partial refund, a partial refund does not appear to result in higher success rates than no refund. However, the sample is very small with respect to this last comparison, because the study includes only two groups with a partial refund. Employing a repeated game with fixed group compositions, Isaac et al. (1989) are able to observe convergence to zero contributions under both a partial and no refund, but not in all groups. In

[32] The study also investigates a third, "no greed", condition in which, if the threshold is reached, everybody loses their remaining endowment, so that nobody has an incentive to "hold back." See also van de Kragt et al. (1983) and recently Cartwright and Stepanova (Unpublished).

contrast, a full refund never leads to zero convergence in this study, which also supports the Simplified-ThrPG model. Similar results are also observed by Cadsby and Maynes (1999) and, more recently, Rauchdobler et al. (2010). Cartwright and Stepanova (2015) find that the effects of a refund rule on success rates may actually interact with the difficulty of reaching the threshold. More specifically, if the threshold is very easy to reach, as in their study if endowments are relatively high, success rates are as high (or possibly even higher) in groups with no refund as in those with full refund.

Coats et al. (2009) employ a strangers procedure, but are nevertheless able to replicate the refund effect as well: Average success rates are significantly lower, if no refund is granted. Interestingly, the authors also investigate a game with sequential contributions, again with and without refund, but do not find a difference here. This underlines the conjecture that the refund rate is of special importance in the ThrPG, precisely because it makes contributing less risky only if all players must act simultaneously. In the sequential game, there is no risk of coordination failure, because the last player(s) know exactly what the others have already contributed.

2.7.6 Rebate rule for excess contributions

Marks and Croson (1998) is currently the only study that directly compares different rebate rules and it does so only for the case of a full refund. The study discusses two variants of rebates in contrast with the classical "no rebate" scenario: a proportional rebate, in which the excess contribution is returned to the contributors in proportion to their contribution, and a "utilization" rebate, in which the excess contribution is multiplied by a positive constant $w < 1$ and then redistributed equally among all players, independently of their contribution.

None of these rules makes overcontribution individually optimal in the original ThrPG, because the return on each additional contribution unit is always less than the contribution costs for this extra unit. The two rebate rules differ with respect to the socially optimal outcome, however, as well as with respect to the possibility of welfare redistribution, although this is not discussed by Marks and Croson (1998), because their experiment assumes homogeneous players.

A proportional rebate neither increases nor decreases the group's total payoff, which makes it superior to the welfare loss suffered through overcontribution if no rebate is granted. Moreover, only players with positive contributions receive a rebate, which furthermore preserves the relative share of the contribution burden. Accordingly, this rule can reduce the repercussions of overcontribution and may increase success rates as a consequence. In any event, the attractiveness of a focal threshold allocation is reduced by this rebate rule, which constitutes a counter-effect to the expected increase in success rates due to a reduced fear of overcontribution.

Excess contributions under a utilization rebate work similarly to a linear public goods game, meaning that the socially optimal outcome has all players contribute their entire endowment. Apart from this possible welfare increase, utilization also entails a (likely unwelcome) redistribution in the form of a subsidization of players that contribute less than average or even nothing at all. Overall, the attractiveness of a focal threshold allocation will be even less than under a proportional rebate, although average total contributions (and thus success rates) could turn out the highest under this rule, given the experimental support for positive contributions in linear public goods games (Ledyard, 1995).

In their experiment, Marks and Croson (1998) find no consistent effect on success rates, a proportional rebate rule actually leading to lower average success rates than no rebate, maybe due to the reduced incentive for norm compliance. As expected, a utilization rebate results in significantly higher total contributions and success rates. However, the variance of total contributions is larger if the subjects can expect a return on contributions in excess of the threshold value. This result conforms to the idea (also supported by impulse balance theory, cf. in particular Alberti et al., Unpublished) that the rebate rule may affect the speed with which equilibrium convergence is attained.

Isaac et al. (1989), Rose et al. (2002), Rauchdobler et al. (2010), and Corazzini et al. (2015) also employ a utilization rebate.

2.7.7 Heterogeneity

Player heterogeneity in ThrPGs usually takes the form of heterogeneous endowments, but can also refer to valuations and (marginal) contribution costs. A direct comparison of heterogeneous and homogeneous treatments takes place in the studies by Bagnoli and McKee (1991), Croson and Marks (1999, 2001), and more recently Alberti and Cartwright (2016) and Bernard et al. (Unpublished).

Even though Rapoport and Suleiman (1993) are concerned only with heterogeneous groups (with differing endowments), they relate their results to an earlier study with a similar design but homogeneous players (Suleiman and Rapoport, 1992). In all three treatment conditions (low, medium, and high threshold values), they observe lower average success rates in heterogeneous groups, although this difference is statistically significant only for the high threshold value.

Croson and Marks (1999) (see also Croson and Marks, 2001) report slightly higher average success rates in their homogeneous treatment (55.2% compared to 48%), but this difference is not statistically significant. Yet the variance of contributions is significantly higher in their treatment with heterogeneous endowments. Bagnoli and McKee (1991) also cannot establish an advantage of homogeneous groups in their small sample of groups with heterogeneous endowments or valuations. All of these treatments grant a full refund of contributions, however.

In contrast, Bernard et al. (Unpublished) do not give a money-back guarantee in their comparison of treatments with heterogeneous endowments and valuations, respectively, to the homogeneous baseline. Both heterogeneity treatments, with average success rates of 55% for heterogeneous endowments and 53% for heterogeneous valuations, exhibit a significant drop in success rates compared to the homogeneous treatment (78%).

Alberti and Cartwright (2016) conduct a within-group comparison in a game with full refund by increasing the degree of endowment heterogeneity in three stages from completely homogeneous groups via a medium degree of heterogeneity to very asymmetric groups. The authors report varied effects of heterogeneity on average success rates: While the groups with very different endowments have the lowest average success rates, the highest average rates are actually attained in groups with only a medium degree of heterogeneity.

The aspects of distributive fairness and focal allocations, which also figure prominently in experiments with player heterogeneity, are discussed in more detail in Chapter 4. Additional relevant studies here are Rapoport (1988), van Dijk and Grodzka (1992), and van Dijk et al. (1999).

2.7.8 Communication and feedback

Communication in ThrPGs usually takes the form of pre-play signaling, for example via proposed contribution targets (e.g., Barrett and Dannenberg, 2012, 2014). While communication is strictly controlled (computerized) in most contemporary studies, van de Kragt et al. (1983) allow a face-to-face discussion about contributions. All of these methods have in common that the communication is "cheap-talk", i.e., it has no direct influence on this game's payoffs. Nevertheless, pre-play signaling can be very effective in a coordination game like the ThrPG, if it helps establish focal allocations and thus select particular equilibria. Accordingly, communication can be expected to increase success rates if players are undecided between several threshold allocations or between zero contributions and a particular threshold allocation.

In the van de Kragt et al. (1983) study, a discussion before the contribution choice basically guarantees that the public good is provided successfully, although in some cases there are more contributors than necessary in this binary ThrPG. Without discussion, average success rates range from 61% to 73%, depending on the threshold value.

Palfrey and Rosenthal (1991a) ask their subjects to send messages indicating their intent to contribute. In this binary ThrPG, messages of this form conceivable facilitate the coordination on asymmetric threshold equilibria, in which some players contribute and some do not. Although the authors do not report success rates for their treatments, they do state that overall "efficiency" is similar with and without communication, even though the players apparently condition their contributions on the received signals.

Croson and Marks (2001) give their subjects non-binding recommendations on how to contribute. Although this "signal" is not provided by the players, but the experimenters, the principle is the same: Suggesting a particular allocation in advance should speed up the convergence process. In the Croson and Marks (2001) study, this only marginally improves average success rates in homogeneous groups, but significantly increases success rates in groups with heterogeneous endowments.

Feltovich and Grossman (2015) find that the effectiveness of pre-play communication or signaling decreases in larger groups, a result which leads them to question the validity of experiments with small groups of communicating players in comparison to real-life communities, which have a much larger number of members.

In a repeated game with fixed groups, contribution choices in early rounds can also signal likely contribution behavior in later rounds. For this reason, the amount of feedback given to the subjects after each round has a similar impact on success rates as the opportunity for pre-play signaling.

Croson and Marks (1998) report for a game with a full refund that giving the subjects information on individual contributions that cannot be associated with particular players yields lower success rates than giving identifiable information or even only aggregate information. However, the low number of independent observations in this study (only five groups per treatment) means that these results provide an insufficient basis for claiming a general information effect on success rates. In a similar study with multiple thresholds and no refund, Hashim et al. (Unpublished) find that providing information only in select cases, such as only to players contributing less than the group average, increases average contributions compared to providing feedback randomly or not at all.

Alberti and Cartwright (2016) are concerned with both signaling and feedback during the course of their experiment. The study compares two "standard" treatments with and without feedback on individual contributions[33] with two treatments in which the players submit contribution vectors. In the first of these treatments, only a player's own individual contribution is relevant for the calculation of payoffs – the values concerning the other players' contributions are "cheap talk." The second, "full agreement," treatment requires that all players submit *identical* contribution vectors in order to successfully contribute. In two variants to these two treatments, the players' labels are scrambled so that the suggested contributions cannot be addressed directly at particular players. Although average success rates increase in this study in groups given feedback, signaling provides less of an advantage and even seems to be counterproductive in groups with heterogeneous endowments. Not unexpectedly, the full agreement treatment results in the lowest average success rates overall, even though it proves relatively successful after the players have spent a few rounds coordinating their behavior. Scrambled labels have mixed

[33] The players are always told at least their group's total contribution after every round.

effects on success rates, but appear to be most helpful in the third part of the experiments, either because endowments are very asymmetric or because the groups have enough experience at this point to coordinate their behavior. All of these treatments grant a full refund if the threshold is missed (or if no agreement is reached).

Although the Simplified ThrPG does not explicitly account for the possibility of communication or the degree of feedback, these design elements appear to affect the subject's learning rate and consequently the speed of equilibrium convergence. More communication and feedback makes coordination easier. This also implies that increasing the time horizon should further facilitate coordination if feedback is provided, which is why equilibrium play can be expected in repeated games, but not in one-shot games. However, given the possibility of coordination on zero contributions, an increased frequency of equilibrium play does not necessarily lead to higher success rates.

The ultimate form of communication in a ThrPG is a collective decision (usually by means of a vote). As this fundamentally changes the nature of this game, the respective experimental literature will not be discussed here. However, since voting on contributions to ThrPGs is a central feature of my own experimental research, this discussion will simply be postponed to the following chapters.

2.7.9 Other effects on success rates

A number of design elements that are not analyzed by Croson and Marks (2000) have been shown experimentally to affect success rates as well:

Guillen et al. (2006) study a punishment mechanism according to which any individual contribution below a specified value is sanctioned with a deduction from this person's payoff. The mechanism is either removed automatically or by majority agreement after a few rounds. The threat of punishment is sufficient to increase success rates in both situations compared to the control treatment. Interestingly, all groups that are given a choice, vote in favor of abandoning the punishment mechanism, but then rapidly decrease their contributions and ultimately converge to the zero contributions equilibrium. Andreoni and Gee (2015) take a converse approach and exogeneously implement the punishment mechanism after the subjects have already played the game without punishment for a number of rounds. The authors find a similarly beneficial effect on success rates, even though they punish only the most severe deviation from the specified contribution. However, a weaker form of punishment targeting the lowest contributor only if the threshold is not reached does not appear to significantly increase success rates.

Cadsby and Maynes (1998b) find that nurses have higher success rates in a game with no refunds than economics and business students, because the latter are more likely to converge to zero contributions in their study. The observations by Cadsby and Maynes (1998a) suggest that women coordinate on an equilibrium more quickly than men, which as mentioned can also affect success rates. Similarly, Cadsby et al. (2007) find that all-female Canadian groups have the highest success rates in a comparison with all-male Canadian, as well as either all-male or all-female Japanese groups. De Cremer and van Vugt (1999) observe that selfish ("pro-self") players contribute less frequently than pro-social players,[34] but only if these players have a low identification with their group. Interestingly, selfish players who highly identify with their group make average contributions near or even above what is necessary to reach the threshold. All of these results show that differences in personality (e.g., inclination towards pro-social behavior) and/or educational background (e.g., mathematical knowledge) are also relevant to the outcomes of ThrPGs.

Normann and Rau (2015) vary the number of thresholds in a repeated two-player game with strangers matching (there are either one or two thresholds), but this change barely affects average success rates. A similar study, Hashim et al. (Unpublished), also has multiple thresholds, but keeps these values constant in all their treatments. Both studies do not grant a refund of contributions if any of the thresholds are missed, although a combination of rebate and refund would certainly be possible for total contributions between two threshold values.

In the experiment by Corazzini et al. (2015) the subjects have a choice between several public goods, each with a separate threshold value, but their total endowment is sufficient to provide at most one of these public goods. The players are homogeneous and the public goods differ only with respect to the valuation (and this only in some treatments). No refund is granted, but there is a rebate in case of overcontribution. Interestingly, the presence of multiple public goods does not adversely affect the success rate (here of reaching at least one of the thresholds).[35] However, if the public goods are identical (and therefore indistinguishable), success rates are significantly lower in the initial rounds until the groups have coordinated on one particular public good.

Bchir and Willinger (2013) compare the typically studied case of a public good, which benefits everyone in the group even non-contributing players, with that of a "club good", which benefits only those players whose contributions exceed a specific "contribution fee". The authors find that introducing such an individual minimum contribution increases success rates significantly, unless the threshold value is comparatively high, a result which is caused by a reduced number of free-riders (who do not benefit from the club good).

Sonnemans et al. (1998) report a framing effect on success rates. In their study, giving contributions to a common pool in order to earn a positive reward leads to higher average success rates than taking contributions from a similar pool with the risk of incurring a negative (damage) payment. However, Kotani et al. (2014) replicate this study and find a higher propensity for co-

[34]Whether a player is pro-social or pro-self is determined by the authors by means of a social value orientation measure conducted before the game is played.

[35]Compare Corazzini et al. (2015), Table E.5 in the online supplement.

operative behavior under a negative framing. Iturbe-Ormaetxe et al. (2011), who assume randomly determined endowments (their "contribution costs") in a binary ThrPG (see also Palfrey and Rosenthal, 1991a), first theoretically derive and then experimentally observe that the direction of the framing effect depends on the the difficulty of reaching the threshold. Observed contributions are higher under a "loss" framing for a high threshold value, but higher under a "gain" framing for a low threshold value. See also Section 2.A.2, which extends the Simplified ThrPG in a way that accounts for loss aversion.

Offerman et al. (2001) extend their earlier study involving a binary ThrPG (Offerman et al., 1996) by conducting both strangers and partners treatments. In a third treatment, the subjects face a randomly generated "group contribution", but do not directly interact with other players. Interestingly, contribution behavior does not differ significantly among the three treatments. Based on additional belief elicitation, the authors come to the conclusion that the subjects do not employ sophisticated strategies, but rather decide myopically, consistent with Bayesian belief learning (see, e.g., Fudenberg and Levine, 1998). Accordingly, this study gives support to the idea that models based on evolutionary dynamics, which also assume myopic "decision-making," can accurately predict experimental success rates.

Finally, the detrimental effect of being uncertain about the exact threshold value on success rates is documented in several studies, including Suleiman et al. (2001), McBride (2010), and Barrett and Dannenberg (2012, 2014). Incomplete information about other game parameters, like the valuation (Barrett and Dannenberg, 2012) or the endowment of other players (Marks and Croson, 1999) appears to have no clear effect on success rates. Additional studies employ uncertainty or private information in all their treatments, including Palfrey and Rosenthal (1991a,b, 1994), Rondeau et al. (1999), and van Dijk et al. (1999). Chapter 6 describes in more detail how threshold uncertainty affects the equilibria of this game.

2.8 Conclusion

In summary, the main finding of this chapter is that success rates in ThrPGs appear to be determined by three different major components:

1. the relative size of the basin of attraction of the zero contribution equilibrium, or respectively this equilibrium's stability sets
2. the selection process of a unique (focal) equilibrium from the set of threshold equilibria
3. the convergence process (speed and volatility) towards coordination on a specific equilibrium

The first of these components is analyzed in more detail, resulting in a model that sets the most prominent parameters of the game in explicit relation to the success rate. As a secondary finding it follows that, in theory, granting a full refund of contribution costs, if the threshold is not reached, removes the possibility of convergence to zero contributions, suggesting that games with this parameter setting should be treated as an altogether different type of game and be investigated separately.

It should be pointed out that this mathematical model is nothing more than an approximation, a factor that correlates with observed success rates, but is not intended to provide a formula to directly calculate these rates (like a physical model), let alone explain why some groups are successful, while others are not. What it *can* do is give support for more general behavioral theories which might predict that coordination is more difficult in larger groups or that larger incentives increase the willingness to contribute, but do not exactly state how these two factors will interact. As a consequence, this model may give rise to additional experimental work, like examining the effect of the step return in larger groups of, say, thirty or even forty players, or at least methodically varying both the number of players and the step return in smaller groups.

Computer simulations, like those conducted by Wang, Fu, Wu, and Wang (2009), can provide a test of the model under ideal circumstances, similar to testing Galileo's empirical model of falling bodies in a vacuum where air resistance does not matter. Such a test could be used to measure the predictive accuracy of the Simplified ThrPG in comparison to a model based on a more precise measurement of the basins of attraction. If the simplification process is shown to entail a too severe loss of predictive accuracy, however, this can outweigh the gain from having a more easily applicable model.

Future work should also extend the model to cover the other two components as well as other design variations. This extension is likely to create additional "novel" predictions (cf. Lakatos, 1970) to be tested experimentally in order to corroborate (or refute) the model. As this model assumes that a focal threshold allocation can be reached by playing pure strategies, it complements the studies by Palfrey and Rosenthal (1984), Offerman et al. (1998), and Goeree and Holt (2005) who (at least implicitly) assume that the focal equilibrium can only be attained by playing mixed strategies, a fact which makes it difficult for groups to coordinate their behavior and reach the threshold.

2.A Extensions of the model

2.A.1 Full refund

This appendix discusses a possible extension of the Simplified ThrPG to include a full refund of contributions of the threshold value is not reached, meaning that $r = 1$. In this case, Equation (2.9) yields a theoretical success rate of $p_\alpha = 1$ no matter how the other game parameters are chosen. This means that $\mathbf{Q}_\alpha$ is the only equilibrium predicted to occur by this theoretical approach, which is plausible, because $\mathbf{Z}$ is just a "weak" Nash equilibrium in this case and therefore presumably less attractive than the strict equilibrium $\mathbf{Q}_\alpha$.

The difficulty of analyzing a ThrPG with a full refund with the Simplified-ThrPG model arises from the tie with respect to payoffs that results among the two candidate strategies (Z and Q_{α_i}) if the threshold is not reached. It is this tie that makes $\mathbf{Z}$ a "weak" Nash equilibrium. However, resolving the tie requires only a minute perturbation of payoffs which can tip the scale to one of two possible sides. The first possibility is that contributing one's allocated share now becomes a strictly dominant strategy (as opposed to being only weakly dominant), because the failure of reaching the threshold after having contributed nevertheless comes with a minor positive utility (maybe the satisfaction of having tried one's best). The second possibility causes a slight disutility from failing to reach the threshold, which could be attributed to feelings of anger or frustration towards players who did not cooperate (cf. Falk and Fischbacher, 2006, who expect reciprocal behavior to arise from this kind of disutility). In this case, zero contributions becomes a strict Nash equilibrium, even though a full refund of contribution costs is guaranteed. While the players still do not fear a potential loss of their contributions, they may be averse to becoming angry or frustrated, so that positive contributions entail a risk of being disappointed. Contributing nothing, however, is a safe choice, because in this case the expectations of other players are so low that they cannot be disappointed. An alternative, and entirely unemotional, interpretation of this disutility is that refunding the contribution incurs transaction costs which reduce the payoff for this outcome.

		Rest of the Group	
		$Q_{-i} = T - \frac{T}{n}$	$Q_{-i} < T - \frac{T}{n}$
Player i	$q_i = \frac{T}{n}$	$e - \frac{T}{n} + v$	$e - \delta$
	$q_i = 0$	e	e

Figure 2.4: A simplified threshold public goods game with a full refund of contributions, but small disutility $\delta > 0$ if contribution costs are refunded.

For the following analysis I assume that the players are homogeneous with respect to all game parameters in order to reduce complexity. As shown in Figure 2.4, the game with n players is again completely characterized by a game matrix that displays only the payoffs of a single (prototypical) player facing possible contributions of the rest of the group. Here $\delta > 0$ refers to a small disutility that the players incur if their contribution costs are refunded. This game's theoretical success rate $p_{1/n}(\delta)$ calculates as follows:

$$p_{\frac{1}{n}}(\delta) = 1 - \sqrt[n-1]{\frac{\delta}{v - \frac{T}{n} + \delta}} = 1 - \sqrt[n-1]{\frac{\delta}{NR + \delta}} \tag{2.17}$$

The theoretical success rate decreases as the disutility from a refunded contribution increases. Yet since δ is small, $p_{1/n}(\delta)$ will be close to, but not equal to, 1. Accordingly, the group is almost certain to be successful, but its actual success now also varies in the valuation v and the number of players n. More precisely, the success rate depends on the "net reward" $NR := v - T/n$, a concept introduced by Cadsby and Maynes (1999) (see also Cadsby et al., 2008). Just as in the case of $r < 1$, the theoretical success rate is higher for a larger valuation, but smaller in larger groups, meaning that this model's predictions are consistent with experimental observations (cf. the meta-study by Croson and Marks, 2000, and the literature review in Section 2.7).[36]

There are also a number of ways in which such a disutility can be exogenously imposed on the players:

- A contribution fee that is paid by anyone who contributes a positive amount can be set off against the valuation if the threshold is reached (so that the game above actually refers to the "net" valuation $\hat{v} = v - \delta$), but is perceived as a reduction of one's endowment if the contribution costs are refunded. This scenario applies mostly to "club goods", of which only a select group of players benefit, namely those who have paid the fee.

- A lump-sum tax on contributions works in the same way as a contribution fee, but such a tax will generally be collected for a more general reason and is therefore more similar in function to (exogeneous) transaction costs.

- A mandatory insurance against wasted contributions *instead of* a money-back guarantee also results in the game described above.[37]

What all of these options have in common is that they turn $Q_{1/n}$ into a risky strategy, which in turn results in $\mathbf{Z}$ becoming a strict equilibrium that is a stable stationary state of a deterministic selection dynamic. Although the possibility of convergence to this inefficient equilibrium is a potential downside of these design elements, the large set of weak equilibria around zero contributions is eliminated at the same time. As this equilibrium set can occupy a

[36]Although the observation that success rates depend on these parameters even if a full refund is granted suggests that the players may have indeed incurred a disutility that the experimenters did not account for, it is just as plausible to assume that both the valuation and the number of players affect the success rates in ways that are not (yet) captured by this very simple model. For example, both parameters should affect the time it takes the group to coordinate on a threshold allocation – i.e., the group's speed of equilibrium convergence, which in turn should be positively correlated with the group's success rate – in just the same way: larger groups take longer to coordinate, whereas larger incentives speed up coordination.

[37]The effects of a *voluntary* insurance on "altruistic provision in threshold public goods games" have been investigated by Zhang et al. (2015), whose computer simulations indicate that this option can increase contribution levels.

considerable fraction of the strategy space – whose size can be shown to depend on the number of players n as well as either the Step Return SR or the term ${}^{ne}\!/_{T} = {}^{1}\!/_{\rho}$, called "Endowment Multiple" by Cartwright and Stepanova (2015)[38] – its removal can increase the relative size of the basin of attraction of a focal threshold allocation and therefore conceivably increase the theoretical success rate as well.

2.A.2 Framing and loss aversion

This section extends the Simplified ThrPG model in several ways. The first extension takes up the negative framing introduced in Chapter 1, Section 1.1. In this framing the players avoid damages, if the threshold is reached, instead of earning valuations. By drawing on the concept of loss aversion (Kahneman and Tversky, 1979), it can be shown that the theoretical success rate is the same, independently of the framing. As this analysis makes use of reference-dependent equilibrium concepts, referring mostly to loss aversion equilibrium (Shalev, 2000), but also to the more general approach by Köszegi and Rabin (2006), it also suggests that these concepts may be applicable in a dynamical context of learning or cultural evolution, as well.

Recalling Section 1.1 in Chapter 1 and assuming for reasons of simplicity that the players are homogeneous and have costs $c = 1$ as well as that $r = 0$ (no refund), the payoff of a particular player i in a ThrPG can be defined in the following two ways (with $d = v$ and $\hat{e} = e + v$):

$$\pi_i(\mathbf{q}) = \begin{cases} e - q_i + v & \text{if} \quad Q \geqslant T \\ e - q_i & \text{if} \quad Q < T \end{cases} \tag{2.18}$$

$$\pi_i(\mathbf{q}) = \begin{cases} \hat{e} - q_i & \text{if} \quad Q \geqslant T \\ \hat{e} - q_i - d & \text{if} \quad Q < T \end{cases} \tag{2.19}$$

Now, following Köszegi and Rabin (2006), assume that the players are sensitive to gains and losses. This means that each player i compares his payoff π_i to a specific reference point R. If $\pi_i > R$, the player enjoys an additional gain utility of $\eta(\pi_i - R)$, where $\eta \geqslant 0$ is the player's sensitivity to gains and losses. If $\pi_i < R$, the player instead suffers a disutility of $-\eta\lambda(R - \pi_i)$, where $\lambda \geqslant 1$ is the player's extent of loss aversion. The utility u_i of a particular player i is therefore given by:[39]

$$u_i(\pi_i) = \begin{cases} \pi_i + \eta(\pi_i - R) & \text{if} \quad \pi_i \geqslant R \\ \pi_i - \eta\lambda(R - \pi_i) & \text{if} \quad \pi_i < R \end{cases} \tag{2.20}$$

[38]Cartwright and Stepanova (2015) also report a correlation between the Endowment Multiple and the success rate in their experimental investigation of games with a full refund.

[39]I here assume that all players have the same utility function, represented by η and λ. A generalization to individual differences in preferences should not change the results, however, just make their presentation more complicated.

As this utility function preserves the players' ordinal preference ranking, the set of pure-strategy equilibria of a ThrPG is unchanged. This allows us to simplify the game as before – to only the two most focal pure-strategy equilibria, namely zero contributions (**Z**; for all i: $q_i = 0$) and equal contributions (**Q**; for all i: $q_i = T/n$) – and then determine the theoretical success rate. Figure 2.5 shows this game with both a positive (gain) and negative (loss) framing (Subfigures a) and b)). First note that the "safe" payoff generated by strategy Z is the reference point of the simplified game, $R = e = \hat{e} - d$, because this is equal to the payoff achieved in the game's mixed-strategy equilibrium, which is therefore a "myopic loss aversion equilibrium" (Shalev, 2000). Any positive contribution, including $q_i = T/n$, is a risky strategy, because this only leads to a higher payoff than e if the public good is provided, combined with the joy about this success. Otherwise, the player suffers a relative loss, combined with an additional disutility. The risk involved in a positive contribution is the reason why reference-dependent preferences can be applied to this game in the first place. However, we keep the argumentation simple by assuming that all players are risk neutral.

a) Player i

	Rest of the Group: $Q_{-i} = T - \frac{T}{n}$	Rest of the Group: $Q_{-i} < T - \frac{T}{n}$
$q_i = \frac{T}{n}$	$e - \frac{T}{n} + v + \eta(v - \frac{T}{n})$	$e - \frac{T}{n} - \eta\lambda\frac{T}{n}$
$q_i = 0$	e	e

b) Player i

	Rest of the Group: $Q_{-i} = T - \frac{T}{n}$	Rest of the Group: $Q_{-i} < T - \frac{T}{n}$
$q_i = \frac{T}{n}$	$\hat{e} - \frac{T}{n} + \eta(d - \frac{T}{n})$	$\hat{e} - d - \frac{T}{n} - \eta\lambda\frac{T}{n}$
$q_i = 0$	$\hat{e} - d$	$\hat{e} - d$

Figure 2.5: A simplified threshold public goods game with two pure-strategy Nash equilibria if the players have reference-dependent utilities – a) positive (gain) framing, b) negative (loss) framing.

Under either framing the following theoretical success rate results in the n-player case:

$$p_{\frac{1}{n}} = 1 - \sigma = 1 - \sqrt[n-1]{\frac{1 + \eta\lambda}{\frac{nv}{T}(1 + \eta) + \eta(\lambda - 1)}}. \tag{2.21}$$

Since this establishes that a mere redefinition of the payoff functions should not affect the contribution behavior even of loss-averse players,[40] it only remains to investigate how players that are sensitive to gains and losses compare to players without reference-dependent preferences (i.e., for which $\eta = 0$). Because the success rate depends on the players' equilibrium mixed-strategies, such an analysis can become quite complicated if a group contains players with different utility functions. For this reason, I will only compare a group consisting of entirely loss-averse players (all with the same η and λ) with a group consisting of entirely loss-neutral players (all $\lambda = 1$). The model then predicts that groups are less successful the greater the extent of loss aversion λ, because the larger λ, the greater the weight that these players place on strategy $Q_{1/n}$ in the mixed-strategy equilibrium. As a consequence, this equilibrium is closer to equilibrium $\mathbf{Q}$ than if $\lambda = 1$, which in turn means that this equilibrium's basin of attraction is smaller if the players are loss averse. Interestingly, the same comparison between gain-and-loss-sensitive groups $\eta > 0$ and insensitive groups $\eta = 0$ yields a similar, but weaker effect. The higher η, the lower also the success rate, but with a lower limit of $1 - \sqrt[n-1]{\lambda / \frac{nv}{T} + \lambda - 1}$. Accordingly, the extent of loss aversion λ is more important for the success rate than the sensitive to gains and losses η.

[40] Although Iturbe-Ormaetxe et al. (2011) manage to derive such a framing effect, their result hinges on the assumption that the player's contribution costs in their binary ThrPG are randomly distributed and that the players furthermore have a bias with respect to how they weight the probabilities of possible cost values – another component of prospect theory (Kahneman and Tversky, 1979). Another possible explanation of different behavior under positive and negative framing is that the reference point is different in the each frame for some reason, which in turn might also cause a difference in the theoretical success rate.

Chapter 3

Interlude – Voting on contributions to a threshold public goods game

This chapter serves as an additional introduction for the three chapters that follow, which are all to some extent concerned with voting on contributions to ThrPGs. First will be the definition of the unanimous voting procedure that is employed in all of these experimental studies and its theoretical solution for a general parameter setting. Moreover, the literature that is relevant to all of this experimental research is reviewed only once at the end of this chapter.[1]

3.1 Voting and coordination

As discussed in the previous chapter, ThrPGs essentially involve a coordination problem of agreeing on any one feasible threshold allocation. A number of experimental studies on ThrPGs, starting with van de Kragt et al. (1983) suggest that a good way to resolve this coordination problem is communication among the involved players. Communication will quickly lead to bargaining, however, if the players have conflicting benefits from a number of otherwise equally reasonable outcomes (like in the battle of the sexes game in Figure 3.1). In binary ThrPGs like van de Kragt et al. (1983), there are usually even more equally reasonable outcomes, in which some players pick the short straw and must contribute, while others can "free-ride." Even if there is no such conflict, as is the case if the equilibria are Pareto-ranked with one being more efficient than the other(s), but there is a chance that the same (or a similar) problem will arise again in the future, spending some time to negotiate now to agree on some kind of behavioral norm may make coordination quicker and potentially

[1] Most of what is discussed here, in particular the voting procedure and its theoretical solution, has already been presented in condensed form in Feige, Ehrhart, and Krämer (Unpublished).

less costly in the future because there will be fewer instances of coordination failure.

		Player 2	
		X	Y
Player 1	X	$0, 0$	A, B
	Y	B, A	$0, 0$

Figure 3.1: Battle of the sexes ($A > B > 0$).

As an example, think of the traffic law which requires all cars to drive on the same side of the road (the right side in most countries). This law has likely been implemented at some point in the past[2] in order to prevent accidents (coordination errors), caused by two drivers disagreeing on how to pass each other.[3] Yet (at least in democratic countries) a law is preceded by a negotiation at some point, which in politics usually ends with some kind of vote. Voting on contributions to a ThrPG can similarly establish a behavioral norm specifying how much to contribute. The procedure can furthermore be used to immediately implement the allocation implied by this norm. Chapter 4 will say more about which behavioral norms are applicable in the context of a ThrPG and how voting helps in the implementation of these norms.

3.2 Unanimous decisions in ThrPGs

While the negotiation process for resolving a coordination problem can take many forms, unanimous decisions are of particular interest in the context of a ThrPG for two reasons:

1. Unanimity has the property of favoring Pareto-optimal outcomes, in fact, given a particular status quo, only Pareto improvements to this outcome can be implemented unanimously.

2. If contributions to a ThrPG are chosen with a unanimity rule, Pareto-optimal contribution vectors that can be implemented as (subgame-perfect) Nash equilibria in the standard ThrPG can also be implemented as (subgame-perfect) Nash equilibria in this voting game.

These points will be further illustrated below. First, however, we need to define exactly how unanimous decisions are reached in the following analysis.

[2]And before that may have already been a societal convention, as suggeted for example by Guala and Mittone (2010).

[3]You will probably have encountered a similar problem on a lesser scale: Have you ever tried to walk through a narrow door at the same time as somebody else?

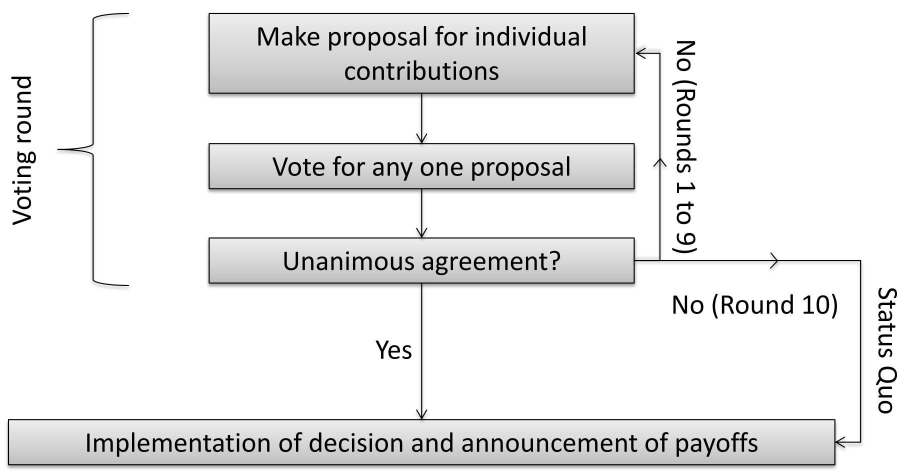

Figure 3.2: Voting procedure

3.2.1 The voting procedure

In the experiments described in the following chapters, the voting procedure consists of up to ten voting rounds, but similar arguments apply for a different (finite) maximum amount of rounds. The procedure for a particular voting round is described in Figure 3.2. In each round, every player makes a single proposal for a (technologically possible) contribution vector $\mathbf{q} = (q_1, \dots, q_n)$. These proposals are made simultaneously and without communication with other group members. If there are identical proposals, then these are combined and their votes are added up. Votes are also cast simultaneously, with every player having exactly one vote for one particular proposal. If all players vote for the same proposal (unanimous decision), this choice is implemented immediately, meaning that the players are required to make their contributions as specified in the proposed contribution vector. At that point the procedure draws on the original ThrPG for the calculation of payoffs (see Section 1.1 in Chapter 1), so that a total contribution below the threshold value can still mean that the contribution costs are refunded, if the original game offers a money-back guarantee.

However, if there is no unanimous agreement in a particular voting round, the game is played for another round with new proposals and new votes. Moreover, if the specified number of ten voting rounds pass without agreement, the game ends and the zero-contribution vector $\mathbf{q^0} = (0, \dots, 0)$ is used as the group's choice. With $\mathbf{q^0}$ as a fallback outcome, the negotiations return to the status quo, to the point where they originally started. This status quo outcome is also always added as an additional proposal.[4]

3.2.2 Voting equilibria

By applying the concept of a subgame-perfect Nash equilibrium to this voting game, we find a large set of "voting equilibria," because if for any player i $\pi_i(\hat{\mathbf{q}}) \geqslant \pi_i(\mathbf{q^0})$, then voting for outcome $\hat{\mathbf{q}}$ is the best response for that player under the expectation that all other players vote for outcome $\hat{\mathbf{q}}$ as well.

Proposition 3.1. *Under a unanimous voting scheme, every technologically possible contribution vector* $\hat{\mathbf{q}}$ *that weakly Pareto dominates the status quo* $\mathbf{q^0}$ *can be implemented as a subgame-perfect Nash equilibrium.*

Proof: In the last stage of the game, if all other players are already decided on $\hat{\mathbf{q}}$, any particular player i can only agree and implement $\hat{\mathbf{q}}$ or disagree and thereby implement $\mathbf{q^0}$, the status quo. Voting for $\hat{\mathbf{q}}$ is therefore advantageous to player i if and only if $\pi_i(\hat{\mathbf{q}}) \geqslant \pi_i(\mathbf{q^0})$. If at least one player strictly prefers $\hat{\mathbf{q}}$ over $\mathbf{q^0}$ and all other players weakly prefer $\hat{\mathbf{q}}$ over $\mathbf{q^0}$, i.e., if $\hat{\mathbf{q}}$ weakly Pareto dominates $\mathbf{q^0}$, then the group will unanimously vote for $\hat{\mathbf{q}}$ if this contribution vector is proposed as an alternative to $\mathbf{q^0}$. But a proposal of $\hat{\mathbf{q}}$ is advantageous to any player i for whom $\pi_i(\hat{\mathbf{q}}) > \pi_i(\mathbf{q^0})$, of which there is at least one. Furthermore, if player i expects all other players to vote for $\hat{\mathbf{q}}$ and at least one of these players to propose $\hat{\mathbf{q}}$, he cannot change the outcome by proposing any other contribution vector. Accordingly, proposing and then voting for $\hat{\mathbf{q}}$ is a subgame-perfect Nash equilibrium. $\square$

Note that equilibrium play involves only a single voting round because the group immediately proposes $\hat{\mathbf{q}}$ and then unanimously votes to implement this contribution vector. Further note that all feasible threshold allocations ($Q = T$) can be implemented as subgame-perfect Nash equilibria, but the equilibrium set also accesses a large number of contribution vectors with lower social welfare in which the group makes inefficiently high contributions ($Q > T$). Finally the status quo, $\mathbf{q^0}$, can also be implemented as an equilibrium, but note that voting for zero contributions is not a strictly best response in this game.

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[4] The idea of including the status quo among the list of proposals originally came about in an attempt to mirror sequential voting by veto (Mueller, 1978). This procedure is intended to replicate the efficiency of (potentially open-ended) unanimous decisions, while guaranteeing an agreement after a much shorter time, to wit $n + 1$ voting rounds, where n is again the number of players in the group. Although this feature does not affect the theoretical solution of the voting procedure described here, it gives the players the option to signal their unwillingness to achieve agreement in direct reaction to a set of unacceptable proposals.

3.3 Literature review: voting and public goods

To my knowledge, besides the experiments described in the following chapters, there is as yet no experimental study concerned with voting on contributions to a ThrPG. However, a small number of studies have their subjects vote on contributions (or their equivalent) in other types of social dilemmas, most notably Walker et al. (2000), Margreiter et al. (2005), and Bernard et al. (2013), in a common-pool resource game and Kroll et al. (2007) in a linear public goods game. Furthermore, Alberti and Cartwright (2016) employ a "full agreement" procedure in a ThrPG which, apart from the framing as a coordination game, works just like a unanimous vote on contributions. In addition, voting procedures have been used in several studies to endogenously determine game parameters or design elements in both linear public goods games and ThrPGs, including the threshold value itself (Rauchdobler et al., 2010). All of these studies will be discussed briefly in the following.

3.3.1 Voting on contributions

The closest study to the voting procedure investigated here is Alberti and Cartwright (2016) who conduct a "full agreement" treatment in a ThrPG setting with a full refund as well as heterogeneous endowments (in later stages of the experiment). Instead of a prolonged negotiation about contributions to a ThrPG that is essentially one-shot, the subjects in this study face a repeated game of a series of distinct contribution decisions. In all of these distinct rounds, the players can make one proposal each and then cast one vote each, just like in my experiments, but payoffs are then calculated immediately based on this vote, whether or not agreement is reached. This procedure, too, prescribes a status quo of zero contributions, meaning here that the players keep their endowments, but miss out on the reward payment. Interestingly, the success rates in this treatment are lower than in the control treatments with voluntary individual contributions, although the groups become more successful in later rounds.

A similar repeated-game design has also been employed in an earlier study by Walker et al. (2000), which compares unanimity voting and majority voting in a repeated common-pool resource problem with a benchmark situation of the game without voting. Both voting rules apparently work quite well in this framework, since they manage to increase efficiency compared to the voluntary-contribution benchmark. Although the groups only come to an agreement in 50.5% and 60% of all cases, respectively in the majority and unanimity treatments, the threat point of no agreement – which consists in having to make individual contributions without a vote and accordingly corresponds to the decision in the voluntary-contributions treatment – might not be too hard a fall to make consensus all that important. Margreiter et al. (2005) extend the results reported by Walker et al. (2000) for homogeneous groups to groups with heterogeneous marginal costs, but study only majority voting. The authors find no difference between homogeneous and heterogeneous groups in the case of individual contributions, but a decrease in efficiency for heterogeneous groups if a voting rule is introduced.

Bernard et al. (2013), who also investigate a common-pool resource game, use a slightly different voting rule than Walker et al. (2000), by which the median of all proposals is implemented, thus ensuring automatic agreement in their exclusively homogeneous groups. As expected by the authors, this binding voting rule significantly increases efficiency levels compared to a non-cooperative benchmark. Furthermore, without the possibility of negotiation failure, all voting groups select the socially optimal outcome, although usually without reaching unanimous agreement.

In a linear public goods game, Kroll et al. (2007) focus on a combination of voting and a punishment rule in order to point out that the result of a vote may not be enforceable without a sanctioning mechanism. The authors report only a slight increase in contributions over a baseline treatment with individual voluntary contributions if this contribution decision is preceded by a non-binding majority vote. Moreover – just as in the baseline treatments – contributions decrease in later periods. In contrast, both a binding vote – in which the agreed upon contribution vectors are immediately implemented, using the baseline treatment ("operational game") for cases of disagreement – and a non-binding vote combined with an option to punish voluntary contributions that violate the agreement, lead to significantly higher group contributions. Note, however, that the superiority of the binding vote in this experiment can be explained by game-theoretical differences between the treatments, because the stage game in the voting treatment has multiple Nash equilibria in addition to zero contributions, which is a dominant strategy in the other three treatments.

Another study by Fréchette et al. (2012) does not include a control treatment without voting. Here, the contributions are selected in a "legislative procedure" similar to the bargaining rule discussed in Baron and Ferejohn (1989), meaning that in every voting round only a single, randomly selected proposal is subjected to a majority decision and the payoffs are depreciated at a rate of δ for each round of non-agreement. Not unexpectedly, most groups require only a single voting round to reach an agreement, which favors the proposing player, but not as strongly as the theory predicts.

Finally, in another linear public goods game, Banks et al. (1988) merely ask their subjects to vote after the voluntary contribution decision on whether their group's previously pledged individual contributions should be realized or instead discarded in favor of a status quo situation in which nobody contributes. In comparison to a direct contribution treatment without a vote, the authors report that the presence of a unanimous voting rule increases the sum of pledged contributions, but lowers overall efficiency, because the groups rarely reach agreement. Fischer and Nicklisch (2007) conduct a similar experiment with both majority and unanimity rules. Again a higher contribution average in the unanimity treatments goes hand in hand with a low acceptance rate, resulting in the lowest average overall efficiency of all investigated treatments. In a recent study by le Sage and van der Heijden (Unpublished), the subsequent vote is not directly concerned with the implementation of contributions to the public good, but with destroying any remaining endowments, i.e., unrealized contributions. Here the authors report that requiring a majority (2 out of 3) or unanimous (3 out of 3) decision in favor of saving any uninvested endowments increases average contributions to the public good.

3.3.2 Voting on parameters and design elements

In applying the collective decision not to the contribution choice itself, but to game elements that only indirectly affect contributions, many studies seemingly attempt to reduce the theoretical complexity of the investigated game. While a binding vote on contributions may turn a single-equilibrium social dilemma like a linear public goods game into a multi-equilibria coordination game (e.g., Kroll et al., 2007), a binding vote on the implementation or the abolition of a sanctioning mechanism (Guillen et al., 2006; Putterman et al., 2011) or on a particular burden-sharing rule in a voluntary contributions mechanism (Gallier et al., forthcoming) are not expected to change the original game's equilibrium set.

In a one-shot ThrPG with groups of three players and a utilization rebate, Rauchdobler et al. (2010) employ a sequence of pairwise majority comparisons between possible threshold values in order to determine the exact value of the threshold. The subjects make contribution decisions for all possible voting outcomes before they are told which threshold has been selected. For a partial refund ($r = 0.5$) or no refund, the lowest positive threshold proves to be the collectively preferred outcome, whereas a full refund induces groups to agree on the highest possible threshold. As the authors state, this choice shows that the subjects are conscious of the risk of coordination failure under no or only a partial refund. However, although voters that prefer a particular threshold value contribute more (if this is indeed the outcome) than those that vote against it, voting appears to have no significant effect on aggregate contributions compared to the baseline treatments with exogenously determined threshold values.

Guillen et al. (2006) investigate the effect of a sanctioning scheme on contributions in a ThrPG. In one of their treatments, the groups can collectively decide to abolish this sanctioning scheme after the first half of the game, which all of the groups do, in another the sanctioning scheme is removed automatically. In both cases, average contribution levels fall below the threshold value after the sanctioning scheme is removed. However, the decrease is more pronounced in the voting treatment, although average contributions here are still higher than in the baseline treatment without sanctions. Accordingly, the positive effect on contributions may be more the result of the sanctions than the collective decision. Studies that investigate voting on sanction schemes in the context of linear public goods games, like e.g. Putterman et al. (2011), find a similar increase of contribution levels, which again is more likely caused by the threat of sanctions than the vote. See also Chapter 5 for additional literature on sanctioning in public goods games.

Balafoutas et al. (2013) model a cooperative redistribution decision in a linear public goods game with heterogeneous endowments. In their experiment, the players can vote on the share of the public good that is to be divided equally among all players, independently of their contributions. The remaining share is returned to the contributors in proportion to their original contribution. The authors report a predominant (and self-serving) preference for proportional returns among voters with high or medium endowments, whereas voters with low endowments more frequently vote for equal returns, which would also benefit these players the most. Observed contribution levels, however, are the higher the more of the public good is reallocated in proportion to contributions, which is consistent with the authors' theoretical predictions.

The study by Dannenberg et al. (2014) involves a collective decision on a binding minimum individual contribution to a public good. This is conducted by simply asking the subjects for contribution pledges and then setting the binding minimum equal to the lowest of these pledges under the assumption that this is the common denominator. Although strategically comparable to a linear public goods game without a contribution constraint, this "minimum contribution mechanism" results in significantly higher average contributions than the unconstrained baseline and even a very unusual increase of contribution levels over time.

Building on this experimental design, the subjects in Gallier et al. (forthcoming) propose minimum total contributions, the lowest of which is again binding for the subsequent contribution decision. In order to derive individual constraints from this goal for total contributions, the authors employ several burden-sharing rules, which are either exogenously imposed on the groups or endogenously chosen by vote. Here, the authors contrast majority and unanimity rules, with the standard (unconstrained) linear public goods game as a fallback outcome if there is no agreement. The burden-sharing rules make use of the player heterogeneity with respect to endowments, so that one rule prescribes contribution in proportion to endowments, while an "equal-payoff scheme" involves contribution shares that result in equal payoffs to all players. A third rule simple divides the total contribution equally among all players, similar to the case studied in Dannenberg et al. (2014). Gallier et al. (forthcoming) again find that unanimous decisions are harder to attain than only a majority agreement, which is particular relevant to this study, because groups that fail to reach agreement consistently contribute less than in the baseline VCM treatment. Accordingly, it seems likely that the subjects react adversely to a failed agreement.

With respect to the choice of burden-sharing rule in groups that reach agreement, the study by Gallier et al. (forthcoming) foreshadows the results of my own voting experiments presented in the following chapters: Almost two-thirds of all groups in the majority treatment and more than half of those in the unanimity treatment agree on an "equal-payoff scheme," which then also leads to the highest average contributions. However, the study leaves unresolved if this result is due to an actual aversion against unequal earnings, as postulated for example by Fehr and Schmidt (1999), or rather caused simply by strategic behavior on behalf of the subjects, given that two of the three player types benefit the most from this "fair" contribution scheme. This problem will be discussed in more detail in the following chapter, which is concerned with similar contribution norms in a ThrPG with heterogeneous players who must either reach a unanimous decision on contribution vectors or coordinate their individual contribution choices by repeatedly interacting in the same group of players.

Chapter 4

Fairness and equilibrium selection in threshold public goods games

4.1 Introduction

The Simplified ThrPG presented in Chapter 2 shows how game parameters affect the selection between one particular threshold equilibrium and the Pareto inferior zero-contributions equilibrium. However, the model leaves unresolved, how this particular threshold equilibrium is selected from an uncountable number of feasible threshold allocations. In other words, we have treated the selection from among two Pareto-ranked equilibria, but still need to discuss the case in which no such ranking exists.

Nevertheless, the experimental literature, both on ThrPGs and coordination games in general, reports that subjects frequently manage to coordinate their behavior in a way that indicates that there is an underlying systematic in this selection process, as well (e.g., Isoni et al., 2013). More specifically, many authors state that the subjects appear to follow a social norm or a principle of distributive fairness. For example, norms applicable to a ThrPG can prescribe equality – of contributions (observed, e.g., by Alberti and Cartwright, 2016) or of payoffs – or proportionality, for example in the sense that contributions are made in proportion to endowments (observed, e.g., by Rapoport and Suleiman, 1993; Bernard et al., Unpublished). In the latter example, the norm only makes sense if there is some kind of difference among the players with respect to endowments, because otherwise this norm would simply prescribe equality of contributions as well. Accordingly, in order to properly discuss a variety of social norms we need to assume player heterogeneity of some kind.

Yet, although it appears reasonable to infer from the experimental data from coordination games that the subjects have other-regarding preferences – i.e., they ascribe a higher utility to outcomes that they deem fairer, even if their individual payoff is the same – this reasoning is actually flawed. All that we can learn from a ThrPG experiment by itself, for example, is that the group has coordinated on a particular threshold equilibrium – which is something of which completely selfish players should be capable, too.[1] In fact, an application of the Simplified ThrPG model to a group of players with Fehr-Schmidt preferences (Fehr and Schmidt, 1999) suggests that other-regarding preferences can actually make the efficient and "fair" outcome *less* likely than in a group of selfish players, because inequality-averse players suffer more strongly if they are the only ones that contribute (see Section 4.A.2).

Selfish players may not care about the payoffs of the other group members, but, being rational, they certainly realize the problem of selecting one from several efficient equilibrium outcomes. Moreover, they may also realize that symmetric outcomes are especially interesting; not because they are "fair", but because they are displayed in a particularly striking manner.[2] I grant that *if* all the players in a ThrPG have similar other-regarding preferences, then this creates a Pareto ranking of the threshold allocations that *may* resolve the equilibrium selection problem.[3] But even in this special case we cannot be certain that this form of preferences is the *only* reason, or even the *main* reason, why a group then actually coordinates on a particular equilibrium. Instead, strategic considerations, of which the tendency to play the risk-dominant strategy is just one component, may have a much larger impact on the final outcome than what the players think is fair. Fairness is then just a side-effect, an epiphenomenon, of what is actually strategic behavior.

In the present chapter, I will do nothing more (and nothing less) than argue that strategic considerations do indeed play a role in selecting one particular threshold equilibrium and that they are possibly even strong enough to overrule individual fairness preferences. I will do this by varying only the decision-making procedure that the groups employ to coordinate their contributions to the underlying ThrPG. The first procedure, the "Repeated game," involves playing the underlying game ten times in a row with the same group composition. The second procedure, the (unanimous) "Vote" discussed previously in Chapter 3, Section 3.2.1, is essentially a one-shot ThrPG in which the group needs to reach unanimous agreement on its vector of contributions, although the players can negotiate repeatedly, for up to ten rounds, if this is necessary to reach agreement.

Both procedures are coordination games, which furthermore implement the same sets of threshold allocations as Pareto-optimal subgame-perfect Nash equilibria.[4] Accordingly, if individual fairness preferences are the only determinant for how allocations are selected from this equilibrium set, we should

[1] Especially given the findings by de Cremer and van Vugt (1999) in whose study prosocial and "pro-self" players make similar average contributions to the public good.

[2] See, for example, Schelling (1980, p. 60ff.) for a series of examples to that effect.

[3] See Section 4.A.1 for an example assuming Fehr-Schmidt preferences, which also shows the limitations of this approach.

[4] This follows from Proposition 3.1 from Chapter 3, Section 3.2.2 in combination with the results from Chapter 1, Section 1.1.2.

expect the same (distribution of) focal point(s) to emerge under both procedures.

However, this turns out not to be the case. Players with heterogeneous endowments predominantly coordinate on equal contributions in the repeated game, but almost exclusively select an allocation that results in equal payoffs under a unanimous vote. Even though homogeneous players, who almost exclusively select equal contributions, and players with heterogeneous marginal contribution costs, who predominantly select equal payoffs, are not significantly influenced by the decision-making procedure, these results show that fairness principles – whether normatively motivated by an ethical theory, like Rawlsian maxi-min (Rawls, 1971) or the equity principle (Adams, 1965), or empirically motivated by results from previous experiments (e.g., Fehr and Schmidt, 1999) – are only unreliable predictors of equilibrium selection.

To be true, procedure effects in connection with distributive fairness are not unknown in experimental economics. However, these studies, like, e.g., Bolton et al. (2005) for ultimatum bargaining and a sequential form of the battle-of-the-sexes game, seem more concerned with violations of a unique behavioral norm, like equality of payoffs, that has been observed consistently before the change in procedure. Yet I am unaware of any studies in which such a procedural difference causes a switch from one behavioral norm to another.

The remainder of this chapter is structured as follows. After briefly relating this work to experiments on committee voting and on heterogeneity in ThrPGs (Section 4.2), equilibrium selection by means of fairness principles is discussed (Section 4.3), followed by a description of the experimental design and procedure (Section 4.4). Section 4.5 presents the results of this experimental investigation, an explanation of which is subsequently attempted in Section 4.6. Section 4.7 compares the results to related studies. Section 4.8 concludes with suggestions for future research.

4.2 Literature review

To a reader familiar with the literature on committee voting experiments (reviewed, e.g., by Palfrey, 2006) it may be no surprise that groups required to come to a unanimous agreement will reach some kind of compromise. In doing so, they give up part of their individual goals, which may also include conformity to fairness principles, in order to achieve an agreement that still serves them better than reaching no agreement at all. While it is therefore unlikely in a ThrPG that any single player will reach his "ideal point," everybody is probably at least closer to this ideal than if the group fails to reach the threshold.

Voting experiments, like those by Eavey and Miller (1984), indicate that we can expect outcomes to reside in or near the core set[5] associated with

[5]In a nutshell, the core set contains every allocation that maximizes group payoffs and is

a particular decision-making rule, although fairness considerations may draw the agreement away from this set. However, in the experiments presented in this chapter, the core set of the two decision-making procedures is identical, because all welfare-maximizing outcomes are threshold allocations.

Most of the experimental studies involving heterogeneity in threshold public goods games, all using the "repeated game" decision procedure, seem to agree that contributions indeed follow a pattern consistent with a small number of fairness principles. Van Dijk et al. (1999) explicitly look for predominant "co-ordination rules" and find a preference for contributions that are proportional to endowments, but do not involve equal payoffs. Rapoport and Suleiman (1993) only state that contributions in their ThrPG are proportional to endowments, but do not report any further details. In more recent experimental studies, Bernard et al. (Unpublished) again report preferences for proportional contributions rather than equal contributions or payoffs, whereas Alberti and Cartwright (2016) predominantly observe outcomes with equal contributions. Other studies involving heterogeneous players in ThrPGs include Croson and Marks (1999, 2001), Marks and Croson (1999), Bagnoli and McKee (1991), and van Dijk and Grodzka (1992).

Yet procedural details may have a larger impact on the outcome than is realized by these authors. For example, the findings by van Dijk and Grodzka (1992) indicate that the amount of information given to the subjects affects the set of allocations that are perceived as focal.[6] Obviously, if the players do not know about the heterogeneity of their group, they cannot condition their actions on this circumstance. Brekke et al. (Unpublished) find that it makes a difference if contributions are framed in absolute or relative amounts.[7] More precisely, in groups with heterogeneous endowments, the contributions of players with low endowments are significantly higher if the players make monetary contributions than if they contribute proportions of their endowment. This difference is also reflected in individual fairness preferences reported in a post-experimental questionnaire, which appear to also be correlated with the contribution decision in the experiment. However, the use of a rebate combined with a non-standard procedure that terminates the experiment as soon as the threshold is reached, makes it impossible to investigate a framing effect on equilibrium selection.

More obvious procedural effects on how the threshold is allocated among the players have been demonstrated by contrasting simultaneous and sequential ThrPGs. For example, Hsu (2008) finds that in the sequential ThrPG equal contributions are less frequent than in the simultaneous game, but this not surprising given that equal contributions is a Nash equilibrium in the latter

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stable in the sense that no coalition that does not include every single player in the group has an incentive to deviate from this allocation. See also Moulin (1988, p. 87ff.).

[6] These and similar results are also discussed in Abele et al. (2010).

[7] Compare Konow (1996), who reports that context can affect self-reported fairness preferences.

case, but not a subgame-perfect equilibrium in the former case. Moreover, I am unaware of any studies involving sequential contributions in which there is also player heterogeneity and accordingly a reason to assume more than one focal threshold allocation.

Studies from the public-choice literature convey the idea that the choice of decision rule may be much more important to the final outcome than the individual player's preferences. A textbook example (e.g., Mueller, 2003, Ch. 4) is the distinction between unanimity and majority rule, which is also prominently discussed by Buchanan and Tullock (1962). Nevertheless, the experimental literature on committee voting appears to have shown little interest (or success) in replicating such a procedure effect. For instance, Margreiter et al. (2005) study the effects of heterogeneous marginal costs in a common-resource problem in which contributions are decided by a majority vote, but do not comment on fairness principles, let alone draw a comparison between these results and their "fallback" procedure (individual contributions) if no agreement is reached. Frohlich et al. (1987a,b) and Frohlich and Oppenheimer (1990) have their subjects vote unanimously to implement one of several distribution principles, finding a preference for maximizing average outcomes (with a constraint for the minimum outcome) over maximizing the minimum outcome, i.e., essentially a preference for utilitarianism over the maxi-min principle (Rawls, 1971). Again, the authors do not vary the decision-making procedure.

There are also mixed results on focal points in bargaining games, starting with Binmore et al. (1993), who are able to condition their subjects on particular focal points in a variant of Nash's bargaining problem (Nash, 1950), only some of which then prove to be stable when the subjects subsequently play the game. Some studies find that the subjects in bargaining games agree on focal points (e.g., Janssen, 2006; Isoni et al., 2013), others report that this need not be the case (e.g., Crawford et al., 2008). Binmore and Samuelson (2006) even give an evolutionary motivation for the prevalence of focal points, although their model is only concerned with the labeling of strategies, not preferences over other players' payoffs.

In summary, while there is abundant theoretical evidence that supports the expectation of a procedure effect in committee voting in general, it is still unclear if this effect applies to ThrPGs or bargaining games as well or if – as the variety of results in previous experiments indicates – individual fairness preferences have a stronger impact on the group's choice in these contexts.

4.3 Equilibrium selection and fairness principles

The underlying model in the subsequently described experiment is a special case of the one described in Chapter 1, Section 1.1. Half of the treatments in this experiment play this game repeatedly, the other half make use of the voting procedure discussed in Chapter 3, Section 3.2.1. All of the treatments assume a damage payment d, which is the same for all players, if the threshold is missed (instead of a reward for reaching the threshold), but grant a full refund of contribution costs in this case. There may be player heterogeneity with respect to endowments, e_i, or marginal costs of contribution, c_i, or not at all so that players are homogeneous. Furthermore, the maximum contribution $\bar{q}$ is the same for all players, so that the set of available actions is the same.[8] In any case, a group contains at most two different player types: a "good" type, G, with a high endowment or low marginal contribution costs, and a "bad" type, B, with a low endowment or high marginal contribution costs. For convenience, I assume that the threshold value can be reached by a coalition of all players of type G.

Accordingly, the decision procedures discussed in the previous chapters do not change the theoretical solutions of this game, because the refund ensures that zero contributions is not implemented as a strict equilibrium under either a unanimous vote or a repeated game with individual voluntary contributions. Considering, moreover, that all of the threshold allocations in this ThrPG differ only in the way in which the contribution burden is distributed among the individual players, we have no reason to assume that strategic considerations favor one particular allocation.

This setup should therefore provide a controlled environment to study the relevance of fairness concepts relating to distributive justice. There are two ways in which these concepts can come into play. In the first scenario, the players adhere to a social norm applicable to real-life interactions of this kind, which then quickly resolves the coordination problem if all players adhere to this norm. In the second scenario, no such social norm exists. It must first develop in the process of the game. In either scenario it is reasonable to assume that differences in individually preferred distribution norms will reflect in an equal variety of equilibrium outcomes. Even if the players in a group do not initially agree on a particular distribution norm, their final choice should still reflect these initial differences and thus depend on individual fairness preferences. This yields the following hypotheses for the experiment:

Hypothesis 4.1. *The decision-making procedure (vote or repeated game) has no significant effect on the threshold allocation(s) selected on average by the groups.*

Hypothesis 4.2. *Individual players with the same individual fairness preferences attempt to coordinate a) on the same threshold allocation independently of the decision rule and b) on a threshold allocation consistent with these preferences under different kinds of player heterogeneity.*

[8]Without this assumption, it may be impossible to implement certain principles, like equality of contributions, if the endowment of some players is too low to contribute an equal share of the threshold.

In order to shed some light on which particular threshold allocations might be preferred by the subjects, I will now draw on several principles of distributive justice that apply to the case at hand:[9] utilitarian welfare maximization (Bentham, 1789), Rawlsian maxi-min (Rawls, 1971), as well as notions of equity (Adams, 1965) and equality (Dworkin, 1981). Even though these principles are normative, specifying which allocation *should* be chosen, the experimental literature cited in the previous section also provides evidence of these principles being employed in collective decision-making. In addition, Loewenstein et al. (1989), Fehr and Schmidt (1999), as well as several others[10] develop empirical models claiming that people prefer equal payoffs under more general circumstances.[11] As discussed in Chapter 2, Section 2.1.1, an experimental study can only challenge descriptive empirical models, not normative moral theories. However, I believe that it is nevertheless interesting to test if (and to what extent) such morally recommended behavior is actually observed in practice.

4.3.1 Utilitarianism

A utilitarian like Bentham (1789) is concerned only with the group's total payoff, which is the same for all threshold allocations, unless marginal contribution costs are heterogeneous. In this case the players with the lowest marginal costs should provide the threshold on their own in order to maximize welfare. Assuming that players of the same type make the same contribution, this reasoning can accordingly reduce the set of "fair" equilibria to a single outcome, namely that in which only player with marginal costs of c_G make contributions, which however involves very asymmetric contributions and payoffs.

In order to calculate this welfare-maximizing (WM) outcome,[12] assume that a group of n players maximize their welfare (or total payoff), given by $\Pi(\mathbf{q}) = \sum_{i=1}^{n} \pi_i(\mathbf{q})$, with a vector of contributions $\mathbf{q^{WM}} = (q_1^{WM}, \ldots, q_n^{WM})$. We call this vector $\mathbf{q^{WM}}$ the social optimum and refer to $Q^{WM} = \sum_{i=1}^{n} q_i^{WM}$ as the socially optimal total contribution. Similarly, $\Pi^{WM} := \Pi(\mathbf{q^{WM}})$ denotes the welfare-maximizing total payoff. In our model we obviously have $Q^{WM} = T$, meaning that it is both socially and individually optimal for the players to reach the threshold value. In order to find $\mathbf{q^{WM}}$, we consider the optimal way of allocating T among the individual players. If the marginal costs of contribution are homogeneous ($c = c_G = c_B$), any allocation of T leads to the same total costs of contribution cT and, consequently, the same total payoff. In contrast, if the marginal costs are heterogeneous, total costs are minimized if only players

[9] These principles as well as a few others are discussed in more detail by Konow (2003).

[10] E.g., Bolton and Ockenfels (2000) or Cappelen et al. (2007).

[11] Fehr and Schmidt (1999, p. 819) even mention the possibility that the "economic environment" can affect equilibrium play, but are more concerned with out-of-equilibrium behavior (like positive contributions in linear public goods games) than the selection from among several Nash equilibria.

[12] This paragraph is adapted from a similar passage in Feige et al. (Unpublished), see also Section 6.3.2 in Chapter 6.

with marginal costs of c_G, the low-cost players, make contributions. The low-cost players should therefore provide T in its entirety, although they can still distribute the contribution burden among themselves in various ways. As for this reason there is rarely a unique welfare-maximizing allocation, it is convenient to let $\mathbf{q^{WM}}$ refer to only the type-symmetric welfare-maximizing threshold allocation, which is indeed unique.

4.3.2 Rawlsian maxi-min

In contrast to utilitarianism, the maxi-min criterion or "difference principle" (Rawls, 1971) focuses on individual payoffs, not just total payoffs, recommending the allocation in which the lowest payoff of any member of the group is maximized.[13] It is easy to see that this is only possible if all group members receive equal payoffs. This in turn requires asymmetric contributions, if the players are heterogeneous,[14] but not to such a strong degree as in the welfare-maximizing outcome.

4.3.3 Equity principle

The equity principle, according to which inputs and outputs should be balanced (e.g., Adams, 1965), leaves some room for interpretation, depending on how "inputs" and "outputs" are defined in this context. If inputs are taken to mean "costs incurred through contribution," while outputs refer to "payoffs gained from reaching the threshold," then endowments are irrelevant to finding the "fair" allocation. All players should then incur the same contribution costs, i.e., $c_i q_i = c_j q_j$ for all i, j,[15] which reduces to the case of equal contributions if marginal costs are homogeneous. Groups with heterogeneous endowments (but homogeneous costs) consequently should select equal contributions, but unequal payoffs, because the payoff differences are not a direct result of the contribution decision. The potential vagueness of the equity principle can be seen in the study by Bernard et al. (Unpublished), who contrast "proportional sacrifice" if the players have heterogeneous endowments with "proportional benefit" if the players have heterogeneous valuations. Both principles can be derived from equity theory by redefining inputs or outputs.

[13] For more information about the motivation of this fairness principle, as well as its merits and demerits, see also Rawls (1974) and Mueller (2003, Ch. 25).

[14] To be true, as the model contains two kinds of heterogeneity, it is conceivably possible, but extremely unlikely, that the two differences cancel each other out, so that equal payoffs coincide with equal contributions. However, because both kinds do not occur at the same time in the experiment, this special case can be ruled out here.

[15] To see this, note that each player i avoids the same damage payment d when reaching the threshold, but incurs differing costs of $c_i q_i$. This leads to a payoff improvement of $d - c_i q_i$ when reaching the threshold, which must be proportional to the invested costs $c_i q_i$ for all players.

4.3.4 Equality principle

Finally, equality (Dworkin, 1981), as probably the most basic notion of fairness, simply stipulates a symmetric outcome of some kind, which in this context can mean either equal contributions or equal payoffs. Although equality's undiscriminating stance in the view of player heterogeneity makes it less appealing as a "fairness" principle, it is nevertheless a good rule of thumb if the differences between the players are difficult to identify (as with van Dijk and Grodzka, 1992). Equality is also often proscribed by anti-discrimination laws, meaning that a moral principle recommends to ignore a dimension of heterogeneity (like gender) in the contribution decision.

4.3.5 Implications for the experiment

In summary, equal contributions (EC) and equal payoffs (EP) are the outcomes most frequently recommended by various fairness principles, although other allocations can certainly be similarly justified under more specific circumstances.[16] Furthermore, the contribution vectors $\mathbf{q}^{\mathbf{EP}}$ and $\mathbf{q}^{\mathbf{EC}}$ associated with these outcomes are both feasible and unique in all the heterogeneity treatments described below, which is why the following experimental investigation focuses on these two distribution norms. The other two predominant fairness principles, namely welfare maximization (WM) and proportionality of contributions to endowments (PC), are less suitable for this particular investigation[17] and are therefore only discussed tangentially in the following, in order to relate to other results from the literature. Accordingly, Hypotheses 4.1 and 4.2 can be rephrased to pinpoint the focus of the following experimental investigation:

Hypothesis 4.3. *The frequency of equal-contribution (EC) and equal-payoff (EP) outcomes is the same a) under both the "Vote" and the "Repeated Game" procedure and b) independently of the kind of heterogeneity, i.e., endowments, marginal costs, or none.*

However, the equilibrium sets of the decision-making procedures investigated here specifically include all the morally recommended allocations, i.e., equal contributions (EC), equal payoffs (EP), proportional contributions (PC), and welfare maximization (WM). As such, the procedures do not favor any particular distribution norm. Note that the Simplified ThrPG from Chapter 2 does not predict any differences either, because a full refund is granted and the model accordingly does not apply.

[16] Schelling (1980, p. 62ff.) gives a nice example of how a "house rule" can be used to basically specify any possible division of a sum of money between two persons A and B, of which A originally lost the money and B now intends to return it minus his finder's fee. Such is the ambiguity of what is morally right.

[17] Welfare maximization does not prescribe a unique allocation of the threshold in the case of homogeneous groups or those with heterogeneous endowments. Proportionality of contributions to endowments is indistinguishable from equal contributions unless there is heterogeneity with respect to endowments.

Table 4.1: Parameter combinations used in the experiment.

	$\mathbf{e_G}$	$\mathbf{e_B}$	$\mathbf{c_B}$	$\mathbf{c_G}$
Homogeneous	30 ExCU	30 ExCU	1.5 ExCU per CU	1.5 ExCU per CU
Heterogeneous marginal costs	30 ExCU	30 ExCU	3 ExCU per CU	1 ExCU per CU
Heterogeneous endowments	33 ExCU	27 ExCU	1.5 ExCU per CU	1.5 ExCU per CU

4.4 Experimental design and procedure

Based on the preceding theoretical sections, the following experimental design is used:

A group consists of four players, each endowed with an amount of "Experimental Currency Units" (ExCU). Every player can convert his endowment into up to $\bar{q} = 10$ "Contribution Units" (CU) at a particular rate of ExCU per CU. These Contribution Units are then collected in a public account (a common project).

Three parameter combinations are considered, each associated with a different kind of heterogeneity (see Table 4.1). In treatments with heterogeneous marginal contribution costs, all four players have the same endowment of 30 ExCU, but two players have low costs of 1 ExCU per CU, whereas the other two players have high costs of 3 ExCU per CU. In treatments with heterogeneous endowments, all four players have the same marginal contribution costs of 1.5 ExCU per CU, but two players have a high endowment of 33 ExCU, whereas the other two players have a low endowment of 27 ExCU. In homogeneous treatments, all four players have the same endowment of 30 ExCU and the same marginal contribution costs of 1.5 ExCU per CU.

In total, this setup results in six treatments which differ with respect to the decision rule (unanimous vote (V) vs. repeated game (R)) and with respect to the kind of heterogeneity (marginal costs of contribution (COST) vs. endowments (END) vs. none (HOM)), as displayed in Table 4.2.[18] Contributions can be made in steps of 0.01 CU, and costs are rounded to 0.01 ExCU. Unless the sum of contributions reaches a threshold value $T = 16$ CU, a penalty of $d = 25$ ExCU is deducted from each player's payoff instead of the contribution costs. This means that for players with costs of 3 ExCU per CU a contribution of at most $^{25}\!/_{3}$ CU ≈ 8.33 CU is individually rational.

Proposals, votes, and individual contributions are all publicly displayed immediately after the choice has been made, together with the IDs of the associated players (e.g., "Player C"). Furthermore, after the first round the subjects

[18]The names used for the individual treatments in the following are simply a combination of these acronyms, for example RHOM for "repeated game, homogeneous players". The two COST treatments are taken from Feige and Ehrhart (Unpublished). The instructions to all treatments are included in Appendix A.1.

Table 4.2: Investigated treatments. For each treatment the number of independent observations (groups) is given in brackets.

	Decision rule	
Heterogeneity	**Vote (V)**	**Repeated Game (R)**
Homogeneous (HOM)	VHOM (n = 8)	RHOM (n = 9)
Het. Endowments (END)	VEND (n = 9)	REND (n = 9)
Het. Costs (COST)	VCOST (n = 9)	RCOST (n = 9)

can call up the results from past rounds whenever they have to make a decision.

During the experiment, the subjects are asked not to talk to each other and to turn off their cell phones. They are seated at computers, which are screened off from the other subjects by plastic dividers. The instructions to the experiment are handed out to the subjects in written form as well as read aloud at the beginning of the experiment. Every subject has to complete a comprehension test consisting of 9 to 12 questions depending on the treatment. The experiment does not start until everybody has answered every question correctly.

Every treatment is followed by a questionnaire containing items on distributive justice (adapted from Konow, 1996, items 1I, 2B, and 5) and procedural justice (partially adapted from Folger and Konovsky, 1989, Table 1) for the purpose of eliciting the subjects' fairness preferences in a more neutral context. This serves as a control for the premise that the subjects do not have ideological differences that could possibly drive preferences for different allocations in different treatments. The questionnaire also includes items related to general personal data (age, gender, experience with experiments).[19]

In line with the theory presented above, all treatments are expected to lead to the same socially optimal total contribution of $Q^{WM} = T = 16$ CU. Table 4.3 contains the numerical predictions for individual contributions by player type (high or low) for the four predominant distribution norms – equal contributions (EC), equal payoffs (EP), contributions in proportion to endowment (PC), and welfare-maximizing contributions (WM) – as well as the associated total group payoffs.[20] Hypothesis 4.1 predicts that the same frequency of EC, EP, PC, and WM outcomes is observed in R and V treatments, which is narrowed down in Hypothesis 4.3a to a prediction that the observed frequencies of EC and EP are the same under both procedures. Hypothesis 4.2 predicts that the players' individual fairness preferences are reflected in the collectively selected allocation, meaning for example that an individual preference for equal-payoff

[19] The complete questionnaire is found in Appendix 4.B. The items concerned with procedural justice and personal data showed no treatment differences and are therefore omitted from the analysis.

[20] Technically, this is an expected value for the repeated game where only a single randomly chosen round is paid, although there is no theoretical reason to assume any variability among choices in different rounds.

Table 4.3: Expected outcomes for individual contributions q_G, q_B in CU and total group payoffs $\Pi(\mathbf{q})$ in ExCU by player type (G or B) and distribution norm (EC, EP, PC, WM). In HOM and END treatments, WM outcomes extend over a range of threshold allocations indicated by a parameter $k \in [0, 8]$.

		HOM (V, R)	**END (V, R)**	**COST (V, R)**
EC	q_G	4 CU	4 CU	4 CU
	q_B	4 CU	4 CU	4 CU
	π_G	24 ExCU	27 ExCU	26 ExCU
	π_B	24 ExCU	21 ExCU	18 ExCU
	$\Pi(\mathbf{q}^{\mathbf{EC}})$	96 ExCU	96 ExCU	88 ExCU
EP	q_G	4 CU	6 CU	6 CU
	q_B	4 CU	2 CU	2 CU
	π_G	24 ExCU	24 ExCU	24 ExCU
	π_B	24 ExCU	24 ExCU	24 ExCU
	$\Pi(\mathbf{q}^{\mathbf{EP}})$	96 ExCU	96 ExCU	96 ExCU
PC	q_G	4 CU	4.4 CU	4 CU
	q_B	4 CU	3.6 CU	4 CU
	π_G	24 ExCU	26.4 ExCU	26 ExCU
	π_B	24 ExCU	21.6 ExCU	18 ExCU
	$\Pi(\mathbf{q}^{\mathbf{PC}})$	96 ExCU	96 ExCU	88 ExCU
WM	q_G	k CU	k CU	8 CU
	q_B	$8 - k$ CU	$8 - k$ CU	0 CU
	π_G	$30 - k \cdot 1.5$ ExCU	$33 - k \cdot 1.5$ ExCU	22 ExCU
	π_B	$18 + k \cdot 1.5$ ExCU	$15 + k \cdot 1.5$ ExCU	30 ExCU
	$\Pi(\mathbf{q}^{\mathbf{WM}})$	96 ExCU	96 ExCU	104 ExCU

outcomes should lead to a collectively selected allocation of $q_G = 6$ CU and $q_B = 2$ CU under heterogeneous endowments or marginal contribution costs, but $q_B = q_G = 4$ CU in homogeneous groups (cf. Hypothesis 4.3b).

4.5 Results

A total of 212 subjects (5 x 9 groups and 1 x 8 groups with four members each) were recruited via ORSEE (Greiner, 2015) from a student pool at the Karlsruhe Institute of Technology. The COST sessions took place in December 2013, the other sessions in June and July 2014. The computerized experiment was conducted with z-Tree (Fischbacher, 2007). Including a show-up fee of €5 (€3 for the COST treatments), the subjects earned on average €15.53 (roughly US$21 at the time of the experiment) in all six treatments. Table 4.4 shows

Table 4.4: Average subject payoffs by investigated treatment in ExCU (exchange rate: 2 ExCU = €1) and cluster-robust standard errors (in brackets) by player type.

	Player type	Vote (V)	Repeated (R) (only rounds paid)	All
HOM		21.63 (2.24)	22.34 (0.91)	22.00 (1.19)
END	both	24.00 (0.00)	23.20 (0.63)	23.60 (0.33)
	$e_G = 33\,\text{ExCU}$	24.17 (0.16)	24.99 (1.14)	24.58 (0.59)
	$e_B = 27\,\text{ExCU}$	23.83 (0.16)	21.41 (0.36)	22.62 (0.35)
COST	both	24.00 (0.00)	19.20 (1.72)	21.60 (1.05)
	$c_G = 1\,\frac{\text{ExCU}}{\text{CU}}$	24.00 (0.00)	19.32 (1.82)	21.66 (1.07)
	$c_B = 3\,\frac{\text{ExCU}}{\text{CU}}$	24.00 (0.00)	19.06 (2.26)	21.53 (1.28)
All		23.27 (0.72)	21.58 (0.76)	22.41 (0.54)

the average payoffs (excluding the show-up fee) by treatment in ExCU (with an exchange rate of 2 ExCU = €1). The subjects spent between one hour and one and a half hours in the laboratory.

The analysis of the experimental results proceeds as follows: First, it is shown that neither total contributions nor success rates, i.e., the frequency with which groups contribute enough to reach the threshold value, differ significantly among treatments, eliminating this dimension as a possible confounding factor for allocation choices. As a next step, treatment differences with respect to this allocation choice are identified on the aggregate and the individual level. Finally, the questionnaire data are evaluated, indicating that there are no significant differences between the subjects' individual fairness preferences in the different treatments that could account for this treatment effect.

4.5.1 Total contributions, allocations, and success rates

The comparison of total contributions is based on the total contribution that the groups have agreed on in the voting treatments. For the groups in the repeated game, the results from the end of the experiment (Round 10) are the most interesting for the analysis, because at this point the groups have had the highest number of interactions, so that it is the most likely that they have selected a particular equilibrium. Accordingly, this round's results are used for the comparison with the voting treatments. Where applicable, data for Round 1 as well as averages over all ten rounds are provided as well.

Figure 4.1 shows the development of average total contributions in the repeated game (R) treatments. Treatment averages are close to the threshold in

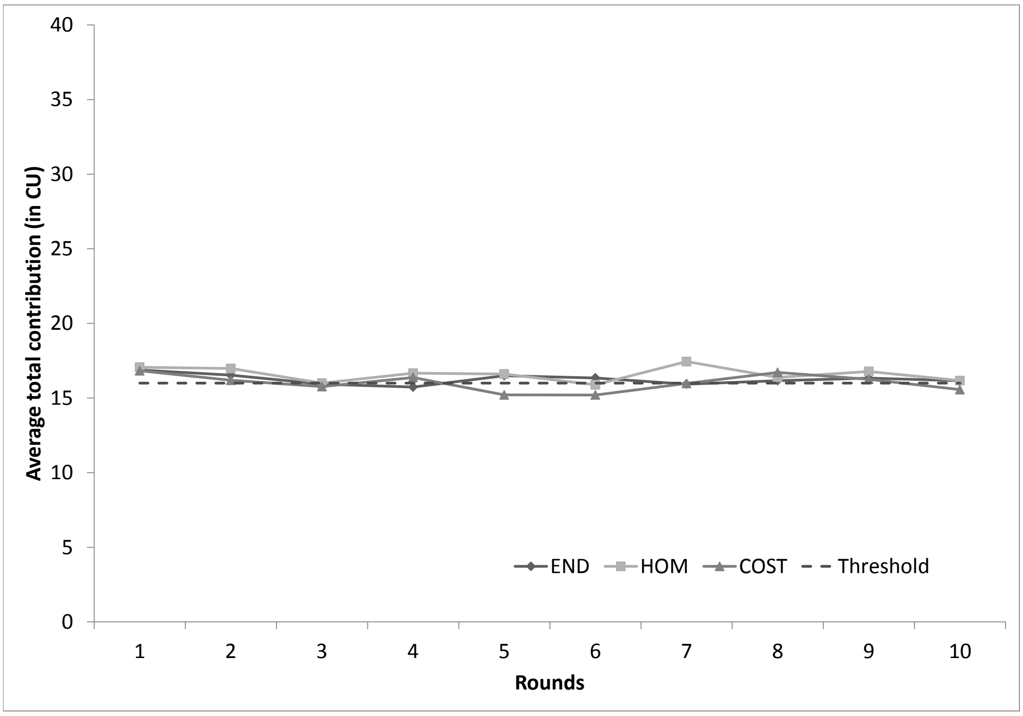


Figure 4.1: Average total contributions of groups in the repeated game treatments (R). The threshold value of 16 CU is included for reference.

all three cases, with no statistical difference between the treatments.[21] When comparing the number of groups that exactly match the threshold value towards the end of the experiment, there appears a clear advantage for voting groups. All but one voting group (which did not come to an agreement) manage to reach the threshold value of 16 CU exactly. Nevertheless, an overall statistical comparison among all treatments (using Round 10 results for the repeated game treatments) finds no significant differences.[22]

When looking at final contribution outcomes (Round 10 contributions for the repeated game, final agreements for the unanimous vote) with respect to the distribution norms that groups employ (as shown in Table 4.5), we observe a strong difference due to the decision rule for both kinds of heterogeneity.[23]

[21] Kruskal-Wallis equality-of-populations ranks test comparing all six treatments with respect to the total contribution of each group:
Round 1 – chi-squared with ties = 0.196 (2 d.f.), $p = 0.9066$
Round 10 – chi-squared with ties = 0.287 (2 d.f.), $p = 0.8665$
Group average over all rounds – chi-squared with ties = 0.291 (2 d.f.), $p = 0.8646$.

[22] Kruskal-Wallis equality-of-populations ranks test comparing all six treatments with respect to the number of groups with a final total contribution of exactly $Q = 16$ CU:
Chi-squared with ties = 3.392 (5 d.f.), $p = 0.6397$.

[23] Fisher's exact test comparing the frequencies of allocation types in each treatment: $p = 0.002$ (VEND vs. REND), $p = 0.009$ (VCOST vs. RCOST), but $p = 1.000$ (VHOM vs. RHOM). The large number of ties in the data makes it necessary to use a categorical

Table 4.5: Absolute frequency of equal contribution (EC) and equal payoff (EP) outcomes, as well as of successful provision of the public good (last column, relative frequencies in brackets). For voting treatments the respective group's final agreement is used.

		EC	**EP**	**EC and EP**	**Other**	**Unsuccessful**	**Success rates**
VHOM		n.a.	n.a.	6	1	1	7 of 8 (87.5%)
VEND		0	8	n.a.	1	0	9 of 9 (100%)
VCOST		0	9	n.a.	0	0	9 of 9 (100%)
	Rd 1	n.a.	n.a.	2	6	1	8 of 9 (88.9%)
RHOM	Rd 10	n.a.	n.a.	7	1	1	8 of 9 (88.9%)
	All Rds	n.a.	n.a.	59	24	7	83 of 90 (92.2%)
	Rd 1	1	0	n.a.	6	2	7 of 9 (77.8%)
REND	Rd 10	5	1	n.a.	3	0	9 of 9 (100%)
	All Rds	40	5	n.a.	35	10	80 of 90 (88.9%)
	Rd 1	0	1	n.a.	6	2	7 of 9 (77.8%)
RCOST	Rd 10	0	3	n.a.	4	2	7 of 9 (77.8%)
	All Rds	0	23	n.a.	49	18	72 of 90 (80.0%)

In the case of heterogeneous costs, this is obviously because of the higher variance of results in the repeated game, as the modal choice is equal payoffs both under a unanimous vote and in the repeated game and (as mentioned above) average total contributions are not significantly different. However, in the case of heterogeneous endowments (END), the groups actually apply different fairness principles, to wit, predominantly equal payoffs when voting and predominantly equal contributions in the repeated game. This allows us to reject Hypothesis 4.3a. Furthermore, groups in the repeated game are equally successful in reaching the threshold as the voting groups at this point of the game (success rates are at 100% in both treatments, see also Table 4.5). This seems to indicate that the groups in the repeated game are indeed satisfied with this outcome and do not try to change it (which would involve coordination failure and thus lower success rates).

4.5.2 Individual contributions and distribution norms

Although the aggregate data from Table 4.5 have already established an impact of the decision rule for the case of heterogeneous endowments, we can learn more about what happened by looking at the individual choices differentiated by player type. By referring to the benchmark values for individual contributions given in Table 4.3, I will first discuss the coordination process in the repeated game treatments, in which all groups play an identical number of rounds.

test for this comparison. An overall test comparing the frequencies in all six treatments also reveals significant differences ($p < 0.05$).

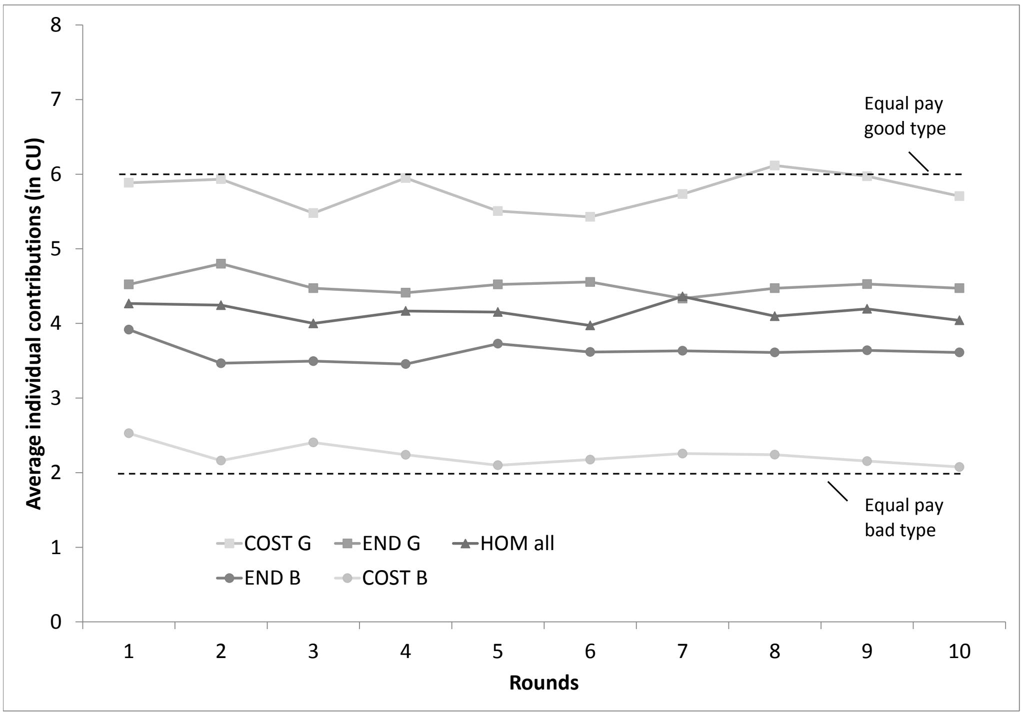


Figure 4.2: Average individual contributions over ten rounds for the repeated-game (RHOM, REND, and RCOST) treatments, differentiated by player type. The "good" player type refers to players with high endowments or low marginal costs, respectively in the REND and RCOST treatments, whereas the "bad" type refers to players with low endowments or high marginal costs, respectively.

Figure 4.2 displays the development of average individual contributions over time in the repeated-game (R) treatments. Individual contributions are close together in the case of heterogeneous endowments (REND), with the "good" type (high endowments) contributing slightly more on average over all ten rounds,[24] but significantly different for heterogeneous marginal costs, where it is also the "good" type (low marginal costs) that contributes more.[25] The graph for the homogeneous treatment, which is located in the middle of the others, conveys the notion that these type-related differences are symmetric around a strict application of the equal-contributions norm. Accordingly, the observed difference is caused merely by the way in which an otherwise efficient total contribution is allocated among the individual players. The differences

[24] 4.51 CU (G) vs. 3.62 CU (B). Two-tailed Wilcoxon signed-rank test comparing for each group the averages of individual contributions (average over all rounds) of players with high endowments (G) and low endowments (B) in REND treatments: $W = 28, n_{s/r} = 8, p > 0.05$.

[25] 5.77 CU (G) vs. 2.23 CU (B). Two-tailed Wilcoxon signed-rank test comparing for each group the averages of individual contributions (average over all rounds) of players with low marginal costs (G) and high marginal costs (B) in RCOST treatments: $W = 45, n_{s/r} = 9, p < 0.05$.

in the statistical results are even more pronounced for Round 10, that is, the final round of the experiment.[26]

In comparing average individual payoffs using only rounds in which a group successfully reaches the threshold,[27] we can establish a similar statistical type-related difference, now for high and low endowments.[28] Groups with heterogeneous marginal costs, in contrast, appear to divide payoffs almost equally between player types, given that the average contributions shown in Figure 4.2 are close to the equal-payoff benchmarks, but the difference in individual payoffs is still statistically significant.[29]

Although this analysis is insufficient to conclude that players with heterogeneous endowments indeed prefer equal contributions or that players with heterogeneous costs prefer equal payoffs, we can at least rule out that the respectively other most focal allocation plays a significant role in the contribution choice. Accordingly, we can reject Hypothesis 4.3b as well. In Section 5.4.3 of the next chapter, I will further demonstrate that the RCOST groups do not coordinate on welfare-maximizing outcomes.

Finally, by examining individual behavior in the first round of the experiment (as shown in Table 4.6), we can see that the distribution norms which prevail in the end seem to be already present before the players start their interactions.[30] Specifically, the difference due to the decision rule for heterogeneous endowments may be related to an initial focus of low-endowment (B) players on equal contributions, which is chosen by 12 of 18 or 66% of these players in the repeated game (REND), but not a single low-endowment (B) player in voting groups (VEND).[31] In contrast, players with high endowments

[26] Two-tailed Wilcoxon signed-rank test comparing for each group the averages of individual contributions (only Round 10) of good (G) and bad (B) player types:
REND: $W = 8, n_{s/r} = 4, p > 0.05$ (average contributions: 4.47 CU (G) vs. 3.61 CU (B))
RCOST: $W = 45, n_{s/r} = 9, p < 0.05$ (average contributions: 5.71 CU (G) vs. 2.08 CU (B)).

[27] Remember that groups that do not reach the threshold in a given round receive a predetermined payoff for this round which therefore does not reflect fairness preferences. However, individual contributions are determined before the group's success or failure is known and are therefore equally meaningful in either case. This is why unsuccessful rounds are excluded from an analysis related to payoffs, but not to contributions.

[28] Two-tailed Wilcoxon signed-rank test comparing for each group the averages of individual payoffs (average over all rounds in which the public good is provided, nine observations each) of players with high endowments (G) and low endowments (B) in REND treatments: $W = 45, n_{s/r} = 9, p < 0.05$ (average payoffs: 26.10 ExCU (G) vs. 21.48 ExCU (B)).

[29] Two-tailed Wilcoxon signed-rank test comparing for each group the averages of individual payoffs (average over all rounds in which the public good is provided, nine observations each) of players with low marginal costs (G) and high marginal costs (B) in RCOST treatments: $W = -39, n_{s/r} = 9, p < 0.05$ (average payoffs: 23.92 ExCU (G) vs. 23.09 ExCU (B)).

[30] An overall comparison of treatments with respect to the frequencies listed in Table 4.6 using a chi-squared test proves highly significant: Pearson Chi-squared = 99.4058 (10 d.f.), $p < 0.001$.

[31] This difference is also statistically highly significant ($p < 0.001$), measured using Fisher's exact test to compare the absolute frequency of type B players in Round 1 of treatment REND ($n = 18$) who contributed 4 CU with the absolute frequency of type B players in

Table 4.6: Absolute frequency by player type (G or B) of own individual contribution choices (actual for repeated game or as part of proposed contribution vector for unanimous vote) in Round 1 that are compatible with a particular distribution norm – equal contribution (EC), equal payoff (EP), both, or neither.

		Equal contributions	**Equal payoffs**	**Both EC and EP**	**Neither EC or EP**
VHOM	all	n.a.	n.a.	26	6
VEND	G	4	5	n.a.	9
	B	0	5	n.a.	13
	all	4	10	n.a.	22
VCOST	B	2	12	n.a.	4
	G	2	7	n.a.	9
	all	4	19	n.a.	13
RHOM	all	n.a.	n.a.	26	10
REND	G	8	5	n.a.	5
	B	12	3	n.a.	3
	all	20	8	n.a.	8
RCOST	B	2	7	n.a.	9
	G	0	8	n.a.	10
	all	2	15	n.a.	19

(G) are not significantly more likely to choose equal contributions in the first round of the repeated game (REND) compared to under a unanimous vote (VEND).[32] The initial choices for players with heterogeneous costs are not significantly different between the decision rules regardless of type.[33]

However, a series of OLS regressions of final individual contributions (voting outcome or contribution in Round 10) with standard errors clustered at the group level (see Tables 4.7, 4.8, and 4.9) suggests that it is the decision rule, not the players' own initial contributions, that drives the results in the heterogeneous treatments. Explanatory variables in each regression model are the players' own individual contributions (actual or proposed) in Round 1 of the experiment, as well as a measure for individual fairness preferences, which is described and discussed in Section 4.6.2 below. In addition, the models con-

Round 1 of treatment VEND ($n = 18$) who propose a contribution vector that assigns themselves a contribution of 4 CU.

[32] 8 of 18 (or 44%) of type G players in repeated game vs. 4 of 18 (or 22%) of type G voting players. Fisher's exact test comparing the absolute frequency of type G players in Round 1 of treatment REND ($n = 18$) who contributed 4 CU with the absolute frequency of type G players in Round 1 of treatment VEND ($n = 18$) who propose a contribution vector that assigns themselves a contribution of 4 CU: $p = 0.321$.

[33] Fisher's exact test comparing the absolute frequencies of EC or EP choices (actual or proposed) for both player types combined under either decision rule (VCOST vs. RCOST, $n = 36$ each): $p = 0.379$.

tain dummy variables for the decision-making procedure as well as the player type (if there is heterogeneity).

Table 4.7: OLS regression for final contributions in END treatments, with and without interaction term, cluster-robust standard errors in brackets (18 groups)

Variable	**Model 1**	**Model 2**
Own contribution (Round 1)	0.205†	0.069
	(0.107)	(0.072)
Vote	-0.041	-1.461**
	(0.055)	(0.272)
Good type	2.042**	0.783
	(0.492)	(0.501)
Good type x Vote		2.900**
		(0.497)
Individual fairness preference (Q1)	-0.259	0.133
	(0.262)	(0.155)
Intercept	2.595**	3.135**
	(0.634)	(0.531)
N	72	72
R^2	0.611	0.801
F	17.07	109.19

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

While the first model for END treatments (Table 4.7) shows that good types (i.e., high endowment) contribute significantly more in general than bad types, introducing an interaction term in a second model makes it clear that this difference only reflects the equal-payoff outcomes in the voting treatment. The fact that the player type does not significantly affect contributions by itself is once again compatible with the idea that voluntary contributions in the repeated game predominantly lead to equal-contribution outcomes.

In the HOM and COST treatments, initial contributions (or proposals) have a higher influence on the final outcome and are in fact the main explanatory factor of the variance of contributions in HOM treatments (Table 4.8). The regression for the COST treatments (Table 4.9), finally, shows that the procedure effect observed for heterogeneous endowments does not appear to apply to heterogeneous marginal costs of contribution. Although the good player type (here this means low marginal costs) contributes significantly more in an overall analysis (Model 1), introducing an interaction term in order to compare individual treatments (Model 2) does not change this result. Quite the opposite: The regression finds no procedural difference between the two COST treatments apart from a tendency of low-cost players in the repeated game to contribute slightly less than an equal-payoff allocation would prescribe. Yet

Table 4.8: OLS regression for final contributions in HOM treatments, cluster-robust standard errors in brackets (17 groups)

Variable	Model 1
Own contribution (Round 1)	0.439**
	(0.123)
Vote	-0.283
	(0.372)
Individual fairness preference (Q1)	0.567
	(0.402)
Intercept	1.175
	(1.031)
N	68
R^2	0.243
F	5.08

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

this is at most an indication for more frequent norm violations in the repeated game (which is consistent with a reduced success rate) and certainly does not suggest a change of focal allocations like in the END treatments.

4.6 Explaining the observed procedure effect

The results show a procedure effect for heterogeneous endowments, in which case the groups favor a different threshold allocation under a unanimous vote than in a repeated game with voluntary contributions. Although this effect becomes the most pronounced towards the end of the experiment, presumably after the subjects have learned to coordinate their behavior, differences appear already in the initial choices which are still unaffected by player interactions.

What is the explanation of this procedure effect? I consider the following three options:

1. Contextual differences between the procedures
2. Differences in the subjects' individual fairness preferences
3. Strategic differences between the procedures

4.6.1 Contextual differences

The first alternative, namely that there are contextual differences between the procedures, suggests that particular expressions used in the experimental instructions have triggered the observed distribution norms. There certainly is

Table 4.9: OLS regression for final contributions in COST treatments, with and without interaction term, cluster-robust standard errors in brackets (18 groups)

Variable	Model 1	Model 2
Own contribution (Round 1)	0.436†	0.446†
	(0.220)	(0.221)
Vote	0.279*	0.017
	(0.114)	(0.162)
Good type	2.448**	2.152*
	(0.787)	(0.879)
Good type x Vote		0.531
		(0.312)
Individual fairness preference (Q1)	-0.118	-0.123
	(0.226)	(0.145)
Intercept	1.030*	1.146*
	(0.473)	(0.457)
N	72	72
R^2	0.839	0.843
F	351.53	306.42

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

a contextual difference between a unanimous vote and a series of individual choices. Speaking of “proposals, votes, and unanimous agreement” may evoke a more cooperative and egalitarian mind-setting than speaking merely of “individual contributions.” So the “procedure effect” could actually be a “framing effect” that then causes the observed procedural differences for heterogeneous endowments.

This conjecture finds some support in the concept of “institutional framing” which is stipulated by Isaac et al. (1991) to cause a similar contextual difference of predominant principles of justice. Elliott et al. (1998) provide experimental evidence for this concept in a public goods game, finding that subjects under a “cooperative” framing contribute more than subjects under an “entrepreneurial” (competitive) framing. A similar framing effect has also been observed by Loewenstein et al. (1989) for stated preferences over outcomes of a distributive dispute, in which a “business” framing leads to more selfish responses. However, all of these studies are primarily concerned with the contrast between free-riders and cooperators, but not between different types of fairness. In my experiment, the more cooperative framing of the voting treatments accordingly should at worst result in higher total contributions, because contributing zero might be considered free-riding, but the aggregate contribution levels are almost the same in all treatments.

The findings by Brekke et al. (Unpublished) are a different matter, however, because here the framing effect is correlated with individual fairness preferences, which in turn might affect equilibrium selection. My REND treatment uses a frame of absolute contributions, which in Brekke et al. (Unpublished) results in the highest contributions for players with low endowments and, thus, *might* be associated with equal contributions. The preference for equal payoffs in my treatment VEND would be consistent with a frame that highlights the payoff domain. The problem is, however, that treatment RCOST also has an absolute-contribution frame, but results in equal payoffs and unequal contributions. Nevertheless, it will be necessary to replicate the results under a more neutral framing for both procedures in order to be sure that contextual differences are sufficiently controlled for.

4.6.2 Self-reported fairness preferences

As the decision rule apparently affects a group's collective preference for a "fair" allocation of contributions, one might wonder what these players' individual fairness preferences are in similar situations. In order to uncover this, the subjects are presented with a number of questionnaire items after the experiment, which were previously used by Konow (1996) to measure fairness preferences of this kind.[34]

Question 1 (Konow, 1996, Item 1I) *Bob and John are identical in terms of physical and mental abilities. They become shipwrecked on an uninhabited island where the only food is bananas. 10 bananas per day fall to their feet on land while others fall into the ocean. They can collect as many bananas as they want by climbing up a tree, picking them before they fall into the ocean and throwing them into a pile. In this way Bob picks 7 bananas per day and John picks 3 per day. Thus, there are a total of 20 bananas per day on the island. If you could decide the distribution of bananas and wanted to be fair, which of the following would you choose?*

A. *Bob gets 10 bananas, the 7 that he picked plus 3 which fell, and John gets 10, the 3 which he picked plus 7 which fell.*

B. *Bob gets 12 bananas, the 7 that he picked plus 5 which fell, and John gets 8, the 3 which he picked plus 5 which fell.*

C. *Bob gets 14 bananas, the 7 that he picked plus 7 which fell, and John gets 6, the 3 which he picked plus 3 which fell.*

The first of these items (Item 1I from Konow, 1996, shown below) entails a direct comparison between different allocations of an output variable (bananas

[34] The use of questionnaire items that are not directly related to the game the subjects have just played controls for the possibility that the subjects choose their answers to be consistent with their contribution choices, and not because this is their actual preference. This may have been less of a problem for Brekke et al. (Unpublished) where in most cases the experiment ended after only one round of contributions.

Table 4.10: Answers to Question 1 by treatment. A: equal sum, B: equal share, C: proportional share

		A	B	C	# observations
Repeated game	RHOM	9 (25%)	27 (75%)	0 (0%)	36
	REND	12 (33%)	23 (64%)	1 (3%)	36
	RCOST	12 (33%)	23 (64%)	1 (3%)	36
Unanimous vote	VHOM	9 (28%)	23 (72%)	0 (0%)	32
	VEND	16 (44%)	20 (56%)	0 (0%)	36
	VCOST	15 (42%)	18 (50%)	3 (8%)	36
Total		73 (34%)	134 (63%)	5 (3%)	212
Konow (1996)		68 (33%)	125 (61%)	12 (6%)	205

received) among two parties that differ in their input variable (bananas picked). Accordingly, this item can distinguish between different instances of the equity principle. Option A refers to equality of overall payoffs, as both parties receive the same total sum of bananas. Option B indicates a different kind of payoff equality, namely one in which only the "free" earnings (bananas which fell) are shared equally. Option C represents proportionality of inputs and outputs, because the share of bananas that fell on the ground is equal to the proportion of previously picked bananas.

Table 4.10 shows how the subjects answered this question in the six treatments, contrasted with the observed frequencies reported by Konow (1996). Strikingly, we do not only *not* see any statistically significant treatment differences,[35] but also no difference to the original Konow (1996) survey.[36] Only the voting treatments reveal a slight tendency towards Option A, possibly as a result of the abundance of equal-payoff outcomes in these treatments.

Question 2 (Konow, 1996, Item 2B)
Smith and Jones work in identical office jobs at a large company and have the same experience, seniority and past performance records. Smith chooses to work 40 hours per week and gets paid \$800 while Jones chooses to work 20 hours per week and gets paid \$400.
1. Very fair 2. Fair 3. Unfair 4. Very unfair

The second and third item are framed in the context of a work environment, where the input-output comparison from equity theory may be even more influential. Not surprisingly, proportional outcomes are perceived as the most

[35]Overall Fisher's exact test comparing the frequencies of answers to Question 1 in all treatments: $p = 0.278$.

[36]Chi-squared test comparing total responses to Question 1 over all treatments with total responses from Konow (1996) sample: Pearson Chi-squared = 3.26 (2 d.f.), $p = 0.196$.

Table 4.11: Answers to Question 2 by treatment.

		Very fair	Fair	Unfair	Very unfair	# observations
Repeated game	RHOM	18 (50%)	14 (39%)	3 (8%)	1 (3%)	36
	REND	15 (42%)	13 (36%)	6 (17%)	2 (6%)	36
	RCOST	15 (42%)	19 (53%)	2 (6%)	0 (0%)	36
Unanimous vote	VHOM	16 (50%)	14 (44%)	1 (3%)	1 (3%)	32
	VEND	21 (58%)	14 (39%)	1 (3%)	0 (0%)	36
	VCOST	19 (53%)	11 (31%)	4 (11%)	2 (6%)	36
Total		104 (49%)	85 (40%)	17 (8%)	6 (3%)	212
Konow (1996)		90 (74%)		31 (26%)		121

fair in this context, meaning that most players choose "Very fair" or "Fair" for Question 2 and Option C for Question 3. Again there is no difference among treatments,[37] nor are the results for Question 3 (Table 4.12) significantly different from the original survey.[38] The responses to Question 2 (Table 4.11) tend more towards "Fair" judgments than in Konow (1996),[39] but this could be explained with the coarser differentiation between answers in the latter case, where subjects could only choose between "Fair" and "Unfair". Overall, we can conclude that the subjects have more or less similar self-reported preferences in all treatments, which in turn more or less correspond to what was observed by Konow (1996) in telephone interviews.

Question 3 (Konow, 1996, Item 5)
Bill and Sam manage a small grocery store at different times and on different days. The manager's duties are always the same and the days and times which each work vary pretty much randomly, but Bill works 40 hours per week while Sam works 20 hours per week. Suppose the manager's salary for a 60 hour week is $1200. Which of the following is the most fair division of this salary?

A. *Bill gets $600 and Sam gets $600.*

B. *Bill gets $700 and Sam gets $500.*

C. *Bill gets $800 and Sam gets $400.*

There seems to be no correlation between the choices in the experiment and the individual fairness preferences stated in the subsequent questionnaire. The

[37] Overall Fisher's exact test comparing the frequencies of answers in all treatments: $p = 0.533$ (Question 2), $p = 0.320$ (Question 3).

[38] Fisher's exact comparing total responses to Question 3 over all treatments with total responses from Konow (1996) sample: $p > 0.1$.

[39] Fisher's exact test comparing total responses to Question 2 (pooling "Very fair" and "Fair" as well as "Unfair" and "Very unfair" options) over all treatments with total responses from Konow (1996) sample: $p = 0.0006$.

Table 4.12: Answers to Question 3 by treatment.

		A (600, 600)	B (700, 500)	C (800, 400)	# observations
Repeated game	RHOM	1 (3%)	4 (11%)	31 (86%)	36
	REND	1 (3%)	6 (17%)	29 (81%)	36
	RCOST	1 (3%)	3 (8%)	32 (89%)	36
Unanimous vote	VHOM	0 (0%)	4 (13%)	28 (88%)	32
	VEND	0 (0%)	4 (11%)	32 (89%)	36
	VCOST	1 (3%)	0 (0%)	35 (97%)	36
Total		4 (2%)	21 (10%)	187 (88%)	212
Konow (1996)		6 (2%)	38 (13%)	281 (85%)	295

regression tables 4.8, 4.7 and 4.9 further indicate that Question 1, which is the closest to exhibiting a treatment effect, does not correlate with the contribution behavior in the experiment. Yet by contrasting Question 1 with Questions 2 and 3, we can see that the subjects indeed react to contextual differences. The social norm for the "work" context apparently does not set as much store in sharing "random earnings" equally as does the one for the "shipwrecked" context.

4.6.3 Strategic differences

The final option of strategic differences between the procedures, has been controlled for to a certain degree by ensuring that all threshold allocations can be implemented as subgame-perfect Nash equilibria under either of the two decision rules. Accordingly, we can say that, if the subjects are assumed to be rational decision-makers, at least standard non-cooperative game theory does not reveal any strategic differences.

However, there are nevertheless certain differences between the two procedures that might turn out to be the cause of the procedure effect. One is the fact that coordination is easier under the voting procedure, because the players can send a multi-dimensional signal, indicating preferences for the total contribution and its allocation among the group members via individual contributions at the same time through different components of their proposals. In contrast, the players in the repeated game only have a one-dimensional signal to convey both preference layers. If these players contribute too little, but according to their individually preferred distribution norm, they risk that the total contribution falls short of the threshold. On the other hand, if they decide to contribute enough to reach the threshold, this may come at the cost of compromising their own understanding of a "fair" allocation. Furthermore, the choices of players in the repeated game potentially affect their payoffs right from the very first round, whereas voting players have less pressure to coordinate their actions, given that only their final agreement counts towards their payoff.

It is also possible that the complexity of the voting rule facilitates coordination on similarly more complex distribution norms, whereas the restricted action set in the repeated game forces the subjects to stick to more easily implemented norms. Strikingly, though, players with heterogeneous costs do not appear to have this problem and predominantly prefer the same distribution norm under both decision rules. It is therefore unlikely that the varying degrees of complexity can explain the outcomes in groups with heterogeneous endowments; or at least they cannot do so entirely. After all, if groups with heterogeneous costs manage to coordinate on a $(2, 2, 6, 6)$ allocation in the repeated game in order to achieve equal payoffs, groups with heterogeneous endowments should be able to do the same thing if they wanted to.

On the other hand, yet another reason to assume a strategic difference between the two decision-making procedures originates from an analysis involving concepts of cooperative game theory (e.g., Moulin, 1988), i.e., addressing the problem from a cooperative perspective. To wit, the characteristic functions for the two decision rules, specifying the total payoffs that various coalitions of (rational) players can attain under their own power (that is, if the remaining players do everything in their power to hamper this coalition's actions), differ in all values except those for the "grand coalition" (all players together) and the singleton coalitions (only individual players). This is because a unanimous vote requires all players to cooperate in said grand coalition in order to implement any outcome other than $\mathbf{q^0}$, whereas a coalition of any two players suffices to reach the threshold (and thereby increase total payoffs significantly) if individual contributions are voluntary. Assuming non-transferable utilities, which makes sense if there are no side-payments among the players, it is then easy to see that all focal points in both decision rules are consistent with the NTU core (e.g., Moulin, 1988, p. 102), basically because they are all Pareto optimal.[40] Although the NTU core is also unable to directly capture the treatment differences, because it is too imprecise, it is likely that other concepts for NTU cooperative games will be more successful.

Finally, the same geometric analysis employed in Chapter 2 can conceivably be used for a pairwise comparison of two threshold allocations, both of which are pure-strategy Nash equilibria in the basic game.[41] Yet if such an approach indeed succeeds in explaining the observed procedure effect, another potential problem arises: Since neither cooperative nor evolutionary game theory assume other-regarding preferences, even a group of selfish players can be expected to coordinate on a "fair" allocation of the threshold, reducing seemingly pro-social behavior to nothing more than a side-effect of what is actually a completely

[40]Bagnoli and Lipman (1989, 1992) derive a similar result for voluntary contributions in a threshold public goods game with a refund of contributions if the threshold is missed, showing that all threshold equilibria are contained in the (TU) core.

[41]Using pairwise comparisons of equilibria for the purpose of equilibrium selection has previously been proposed, e.g., by Harsanyi and Selten (1988).

selfish, but nevertheless strategic choice.

4.7 Discussion

How do these results compare to similar experimental studies?

In the unanimous voting treatments, the subjects almost always agree on a compromise that does not favor individual players or even their varying fairness preferences. With only a few exceptions, the voting players seem to be unerringly drawn towards equal payoff shares. As mentioned above, this outcome is in accordance with the maxi-min criterion (Rawls, 1971), meaning also that these results run contrary to what Frohlich et al. (1987a,b) and Frohlich and Oppenheimer (1990) found in their experiments, where subjects chose utilitarian allocations.[42] On the other hand, the VCOST treatment does in a way corroborate the findings of Eavey and Miller (1984), because the players with heterogeneous marginal costs vote for an outcome that is "fair," namely the equal-payoff allocation, but does not belong to the (TU) core set if costs are heterogeneous (as the outcome is not welfare-maximizing in this case).

Yet also in the repeated game with individual voluntary contributions, the subjects are apparently forced to compromise their individual notions of fairness. Here the reason may be less the equal bargaining power and more the difficulty to coordinate, but still only a few allocations result with a high frequency and rarely those consistent with the individual fairness preferences stated by the subjects afterwards. An alternative interpretation, according to which different fairness norms "evolve" under different procedures that both permit learning through repeated interaction has some roots in the theoretical literature, e.g., by Bester and Güth (1998) who show that other-regarding preferences may originate in an evolutionary process.

Previous studies involving heterogeneous endowments in games with voluntary contributions (van Dijk et al., 1999; Rapoport and Suleiman, 1993; Bernard et al., Unpublished) support the focus on only a small number of salient points, although they almost exclusively report that the better endowed players contribute more, usually in proportion to their endowment share. This study does not seem to corroborate these findings, since most groups end up with equal contributions, which is more similar to the observation by Alberti and Cartwright (2016). However, in the present study, proportional contributions may have simply been dismissed by the subjects as a focal outcome because this allocation involves non-integer contributions. In fact, equal contributions ($q = 4$ CU) are still very close to a proportional allocation of the threshold if endowments are heterogeneous ($q_B = 3.6$ CU, $q_G = 4.4$ CU).

[42]Earlier studies, like the seminal paper by Fiorina and Plott (1978) do not even permit interpersonal comparisons of payoffs that could lead to an agreement on equal-payoff outcomes.

The questionnaire results, finally, are in accordance with Gaertner and Schokkaert who state that questionnaire studies (as part of empirical social choice) "derive information about norms" (Gaertner and Schokkaert, 2012, Ch. 2.2.1, p. 21). In other words, self-reported preferences measure what the subjects think *should be* chosen, i.e., what is socially acceptable, whereas experiments measure what *is* chosen by the subjects, i.e., what maximizes their individual utility. So, if we find that the subjects report a preference for similar norms in all treatments, then this does not mean that they are also able to (or even want to) conform to these norms with their actual behavior in the experiment. Strategic considerations may lead them to ignore what should be done and pragmatically stick to what can be done. Still, establishing that there are no treatment differences with respect to what the subjects think is socially acceptable in a similar context is essential for claiming that the observed treatment differences in actual behavior are indeed caused by the different decision-making procedures.

In summary, there are several possible theoretical explanations of parts of the results reported in this study, but (as yet) no all-encompassing theory that can explain all of these results in a single model.

4.8 Conclusion

This chapter has discussed how principles of distributive fairness are related to equilibrium selection in ThrPGs. An experimental investigation finds that a unanimous binding vote on contributions in a ThrPG results in equal-payoff allocations under several kinds of heterogeneity. In contrast, individual voluntary contributions in a similar scenario result in equal contributions (and unequal payoffs) for players with heterogeneous endowments. Although each result by itself is not very controversial, the combination warrants further investigation of the consistency (or lack thereof) of collective allocation choices under various decision rules.

The experiments presented here indicate that the decision rule employed to bring about a collective choice has an influence on the outcome of this choice. More strikingly, strategic considerations can apparently overrule individual preferences for fair cost allocations. Like politicians in real life, the subjects' choices are governed by what is feasible; they compromise their individual preferences to reach an at least partly favorable agreement, to an extent that the decision rule is a better predictor of the outcome than the subjects' preferences.

Real-world communities will usually have a choice in whether to finance a particular project publicly (e.g., by a vote to increase tax rates) or to leave the funding to the private sector (i.e., voluntary contributions). In the light of the findings of this study, this choice becomes even more difficult, because communal involvement may not merely affect the chances of project being successful, but may also result in a different allocation of the cost burden.

Future research should attempt to reproduce the results reported here in other settings, e.g., in other variants of divide-the-pie games, like the bargaining game described by Harsanyi and Selten (1988, Ch. 8) or ultimatum bargaining (Güth et al., 1982). Some kind of player heterogeneity seems to be required, though, in order to separate the various fairness concepts from each other. This would also complement a strand of the literature (involving, e.g., Bolton et al., 2005) that reports a procedural effect for homogeneous players that reduces the salience of the equality norm, but seemingly without introducing more salient alternatives. There is certainly a difference between the observation of norm violations (as in Bolton et al., 2005) and the origin of altogether different norms as suggested by my experimental results.

Apart from the comparison of cooperative and non-cooperative decision rules, it might also be interesting to compare various voting rules with respect to the fairness concept that they relate to. Majority voting will likely lead to more unequal allocations, but not necessarily so if no player type is in a minority position.

Another extension of this model, transfer payments among the subjects, will be discussed in the following chapter. If a redistribution of payoffs is possible after contributions have been made and the public good has been successfully provided (or not), the contribution decision can be separated from fairness considerations, which are then resolved exclusively via the choice of transfer payments. For heterogeneous marginal costs in particular, this means that welfare maximization and equalization of payoffs (or other principles that depend on a comparison of payoffs among the group members) can be satisfied with the same allocative decision. But players with heterogeneous endowments might also suddenly display a collective preference for equal payoffs if such can be achieved at less risk of coordination failure, i.e., via voluntary ex-post transfer payments.

4.A Inequality aversion in ThrPGs

4.A.1 Equilibrium selection via inequality aversion

I will now argue that the assumption of inequality-averse players by itself is not sufficient to reduce the equilibrium set to a unique threshold allocation, namely one resulting in equal payoffs, but at best shrinks the set of efficient equilibria to allocations close to this outcome. Moreover, zero contributions also remains a Nash equilibrium. As mentioned above, Fehr and Schmidt (1999) give an empirical motivation for a contribution vector that results in equal payoffs to all players.[43] Since subjects are known to be "inequality averse," they can be expected to react to payoff differences between them and other players caused by different threshold allocations. As before, a group is defined by a set of

[43]For a critical discussion of inequality aversion with references to additional literature see, e.g., Bergh (2008).

players $\mathcal{N}$, which contains n individual players. For reasons of simplicity, I will assume that all of these players are identical. Furthermore, corresponding to the experimental investigation in this chapter, the players face a damage payment d if the threshold is not reached, but are granted a full refund of their contribution costs in this case. A player i with Fehr-Schmidt preferences has the following utility function ($\beta \leqslant \alpha, 0 \leqslant \beta < 1$):

$$\begin{aligned} u_i(\pi_1(\mathbf{q}), \dots, \pi_n(\mathbf{q})) = \pi_i(\mathbf{q}) - \alpha \frac{1}{n-1} \sum_{j \in \mathcal{N} \setminus \{i\}} \max\{\pi_j(\mathbf{q}) - \pi_i(\mathbf{q}), 0\} \\ - \beta \frac{1}{n-1} \sum_{j \in \mathcal{N} \setminus \{i\}} \max\{\pi_i(\mathbf{q}) - \pi_j(\mathbf{q}), 0\} \end{aligned} \quad (4.1)$$

This function specifies that player i suffers a disutility for each player j that has a different payoff than himself, although he cares a little less about players that earn less than himself. Obviously, unless the marginal costs of contribution are heterogeneous, a threshold allocation that results in equal payoffs will be the unique welfare-maximizing outcome for players with Fehr-Schmidt preferences with a total utility of

$$U(\pi_1(\mathbf{q^{EP}}), \dots, \pi_n(\mathbf{q^{EP}})) = \sum_{i=1}^{n} u_i(\pi_i(\mathbf{q^{EP}})) = \sum_{i=1}^{n} \pi_i(\mathbf{q^{EP}}) = \Pi^{WM}. \quad (4.2)$$

Any other (feasible) threshold allocation $\hat{\mathbf{q}}$ will result in the same total payoff Π^{WM}, but also create disutilities that lower the total utility, meaning that

$$\forall \hat{\mathbf{q}} \text{ with} \sum_{i=1}^{n} \hat{q}_i = T : U(\pi_1(\mathbf{q^{EP}}), \dots, \pi_n(\mathbf{q^{EP}})) \geqslant U(\pi_1(\hat{\mathbf{q}}), \dots, \pi_n(\hat{\mathbf{q}})). \quad (4.3)$$

Yet, this at best allows the conclusion that the players *should* select this outcome if they feel a moral obligation to maximize the group's total welfare. Even this is not certain, if the players have heterogeneous marginal costs, because the welfare gains from a cost-efficient allocation of contributions may then outweigh the welfare losses from unequal payoffs.

Furthermore, $\mathbf{q^{EP}}$ may still represent only one of many Nash equilibria. To see this, note that, given a threshold allocation $\hat{\mathbf{q}}$, even a marginal reduction of i's contribution will cause the threshold to be missed. But the damages d_i are greater than i's (refunded or saved) contribution costs (or this allocation would not have been a Nash equilibrium for standard preferences). So, the total disutilities from unequal payoffs suffered by i at allocation $\hat{\mathbf{q}}$ must be greater than $d - cq_i$ to warrant the deviation. And this does not yet account for the disutilities that arise from possibly unequal endowments (minus damages) after all players have been refunded their contribution costs.

To prove the point, it is sufficient to show that there are some parameter constellations, under which an inequitable threshold allocation is not eliminated as an equilibrium. Due to the assumption of homogeneous players, equal payoffs result only for the equal contributions outcome. At any other feasible allocation $\hat{\mathbf{q}}$ there are at least two players who make different contributions and therefore earn different payoffs. Without loss of generality, label the player with the highest payoff at $\hat{\mathbf{q}}$ with h (there may be several such players). Similarly, l denotes the player (possibly one of several) with the lowest payoff at $\hat{\mathbf{q}}$. Note that $\pi_h(\hat{\mathbf{q}}) \geqslant \pi_j(\hat{\mathbf{q}})$, for all $j \in \mathcal{N}$, also implies $\hat{q}_h \leqslant \hat{q}_j$, for all $j \in \mathcal{N}$, meaning that player h makes the lowest contribution at this allocation.

Player h could decrease his disutility from unequal payoffs by increasing his contribution which in turn would reduce his payoff. However, this is not individually optimal because $\beta < 1$, meaning that the payoff reduction hurts the player more than he benefits from the inequality reduction. Yet the same player could also decrease his contribution to ensure that the threshold is missed and all players earn the same payoff $e - d$. For this choice to be individually optimal, given that all other players comply with allocation $\hat{\mathbf{q}}$, we must have

$$e - d \geqslant e - c\hat{q}_h - \beta \frac{1}{n-1} \sum_{j \in \mathcal{N} \setminus \{h\}} (e - \hat{q}_h - e + \hat{q}_j) \tag{4.4}$$

or

$$d - c\hat{q}_h \leqslant \beta \frac{1}{n-1} \sum_{j \in \mathcal{N} \setminus \{h\}} (\hat{q}_j - \hat{q}_h) \tag{4.5}$$

A similar inequality is derived for player l who has the lowest payoff at $\hat{\mathbf{q}}$:

$$d - c\hat{q}_l \leqslant \alpha \frac{1}{n-1} \sum_{j \in \mathcal{N} \setminus \{l\}} (\hat{q}_l - \hat{q}_j) \tag{4.6}$$

The remaining players will suffer disutilities from other players' payoffs that are either higher or lower than their own payoff, but otherwise have inequalities of a similar form. The left-hand sides of (4.5) and (4.6) are positive or (at worst) equal to zero, since by assumption $d \geqslant c\hat{q}_i$ for all i. The right-hand sides of (4.5) and (4.6) are strictly positive, as they represent the players' disutilities from unequal payoffs with allocation $\hat{\mathbf{q}}$. Whether or not $\hat{\mathbf{q}}$ is (still) a Nash equilibrium depends mainly on the damage payment d, which can be arbitrarily large. Accordingly, a threshold allocation will be the less likely to be eliminated as an equilibrium under Fehr-Schmidt preferences the higher the damage payments. Furthermore, threshold allocations that are very close to $\mathbf{q}^{\mathbf{EP}}$ are unlikely to be eliminated even if d is low, because the disutilities from payoff differences become infinitesimally small the closer $\hat{\mathbf{q}}$ is to $\mathbf{q}^{\mathbf{EP}}$, while the participation constraint $d \geqslant c\hat{q}_i$, for all i, is less likely to be binding for more equally distributed allocations. Even more problematic for inequality aversion as a selection criterion is the fact that zero contributions remains individually optimal, as individual players are still incapable of providing the public good on their own.

4.A.2 The Simplified ThrPG and inequality aversion

Similar to the case of loss aversion discussed in Section 2.A.2, the Simplified-ThrPG model can be used to compare the predicted success rate for a group consisting entirely of inequality-averse players with a group consisting only of selfish players. Once again, I assume that the inequality-aversion parameters α and β, as well as the payoffs for the different game outcomes, are the same for all players, so that the game is completely symmetric. Furthermore, as opposed to the experimental investigation in this chapter, no refund is granted ($r = 0$). Equal contributions of $q_i = {}^T\!/n$ for all i and zero contributions ($q_i = 0$ for all i) will then be equilibrium strategies of two strict symmetric pure-strategy Nash equilibria that result in equal payoffs to all players.

		Rest of the Group		
		$Q_{-i} = T - \frac{T}{n}$	$0 < Q_{-i} < T - \frac{T}{n}$	$Q_{-i} = 0$
Pl. i	$q_i = \frac{T}{n}$	$e - \frac{T}{n} + v$	$e - \frac{T}{n}(1 + \alpha\frac{n-1-m}{n-1})$	$e - \frac{T}{n}(1 + \alpha)$
	$q_i = 0$	$e - \beta\frac{T}{n}$	$e - \beta\frac{T}{n}\frac{m}{n-1}$	e

Figure 4.3: A simplified threshold public goods game with two pure-strategy Nash equilibria if the players are inequality averse. The game matrix shows the players' utilities based on their other-regarding preferences and the choices of the rest of the group, represented by the total contribution Q_{-i}. Each player can either contribute ${}^T\!/n$ or 0.

Figure 4.3 displays the payoff matrix of this game from the perspective of player i, whereby m ($0 \leqslant m \leqslant n-1$) denotes the number of *other* cooperating players. As becomes apparent from the figure, the utilities in the two pure-strategy equilibria (top-left and bottom-right cell) are equal to the payoffs in the standard game without inequality aversion. But whenever player i chooses a different strategy than at least one other player, the outcome is asymmetric with respect to payoffs and inequality aversion comes into play. If player i contributes $q_i = {}^T\!/n$, but some other players contribute $q_i = 0$, these players will earn comparatively more than i because they incur no contribution costs, causing a disutility for i amounting to the difference in payoffs (i.e., the contribution costs) weighted by the number of players who contribute nothing and i's degree of aversion to earning less than others α. On the other hand, if player i contributes nothing, but several other players contribute, these players will earn comparatively *less* than i because they now incur contribution costs whereas i does not, causing a disutility for i amounting to the difference in payoffs (again the contribution costs) weighted by number of players who contribute and i's degree of aversion to earning *more* than others β.

		Player 2	
		$q_2 = \frac{T}{2}$	$q_2 = 0$
Player 1	$q_1 = \frac{T}{2}$	$e - {}^{T}\!/_{2} + v$, $e - {}^{T}\!/_{2} + v$	$e - {}^{T}\!/_{2} - \alpha{}^{T}\!/_{2}$, $e - \beta{}^{T}\!/_{2}$
	$q_1 = 0$	$e - \beta{}^{T}\!/_{2}$, $e - {}^{T}\!/_{2} - \alpha{}^{T}\!/_{2}$	e, e

Figure 4.4: A simplified two-player threshold public goods game with two pure-strategy Nash equilibria if the players are inequality averse. The game matrix shows the players' utilities based on their other-regarding preferences. Each player can either contribute ${}^{T}\!/_{2}$ or 0.

Instead of calculating the mixed-strategy equilibrium for the more complicated n-player game,[44] I will be satisfied with an analysis of the much simpler case with only two symmetric players displayed in Figure 4.4. Calculating first the mixed-strategy equilibrium and then the success rate for this game yields the following:

$$p_{\frac{1}{2}} = 1 - \sigma = 1 - \sqrt{\frac{1+\alpha}{\frac{2v}{T} + \alpha + \beta}}. \tag{4.7}$$

In a comparison with a group of two selfish players, for whom $\alpha = \beta = 0$, we can see that an aversion to earning *more* than the other players (expressed by $\beta > 0$) increases the success rate. The intuition here is that the fear of earning more than the other players reduces the incentive for a unilateral deviation from the efficient equilibrium $\mathbf{Q}_{1/2}$. However, an aversion to earning *less* than the other players (expressed by $\alpha > 0$) has the opposite effect and *decreases* success rates, because unilateral deviation from zero contributions becomes more costly. Given the assumption that $\alpha \geqslant \beta$, it is reasonable to expect that the latter effect is stronger so that, overall, success rates will be lower in groups consisting of inequality-averse players.

Moreover, a comparison of the theoretical success rate for inequality aversion with that for loss aversion reveals a peculiar similarity of the two concepts, at least for this symmetric example: Both formulas are identical except with

[44]Note that utility values for the different outcomes once again violate the requirements made by Kim (1996), although this need not necessarily mean that the previously discussed selection dynamics cannot be applied. After all, the game still has two strict equilibria in pure strategies, each of which has a basin of attraction of non-zero volume.

respect to the labeling of the parameters, i.e., $\alpha := \eta\lambda$, $\beta := -\eta$. Inequality aversion and loss aversion are *not* one and the same thing, however, because both β and η are supposed to be positive. Still, the structural similarity is striking, because a player that appears to contribute zero because he is averse to losses may instead turn out to be afraid of earning less than the other group members, or vice versa.[45] This equivalence does not hold in larger groups, though, let alone in games with heterogeneous players, because a loss-averse player still cares only about his own payoff relative to a personal reference point. He just happens to act as if he had other-regarding preferences in this particular situation.

4.B Questionnaire

The questionnaire uses for the most part items from English-language sources which are translated into German as literally as possible. Here, however, I reprint the original English version of these items. Question 4 also contains a number of new items or ones that have been rephrased slightly in order to better fit the experimental context.

Please answer the following questions completely. As this is about personal attitudes, there are neither "right" nor "wrong" answers.

Question 1 (Konow, 1996, Item 1I)
Bob and John are identical in terms of physical and mental abilities. They become shipwrecked on an uninhabited island where the only food is bananas. 10 bananas per day fall to their feet on land while others fall into the ocean. They can collect as many bananas as they want by climbing up a tree, picking them before they fall into the ocean and throwing them into a pile. In this way Bob picks 7 bananas per day and John picks 3 per day. Thus, there are a total of 20 bananas per day on the island. If you could decide the distribution of bananas and wanted to be fair, which of the following would you choose?

A. Bob gets 10 bananas, the 7 that he picked plus 3 which fell, and John gets 10, the 3 which he picked plus 7 which fell.

B. Bob gets 12 bananas, the 7 that he picked plus 5 which fell, and John gets 8, the 3 which he picked plus 5 which fell.

C. Bob gets 14 bananas, the 7 that he picked plus 7 which fell, and John gets 6, the 3 which he picked plus 3 which fell.

[45] A similar relation between inequality aversion and individual *risk* aversion has already been suggested by Carlsson et al. (2005).

Question 2 (Konow, 1996, Item 2B)
Smith and Jones work in identical office jobs at a large company and have the same experience, seniority and past performance records. Smith chooses to work 40 hours per week and gets paid $800 while Jones chooses to work 20 hours per week and gets paid $400.
1. Very fair 2. Fair 3. Unfair 4. Very unfair

Question 3 (Konow, 1996, Item 5)
Bill and Sam manage a small grocery store at different times and on different days. The manager's duties are always the same and the days and times which each work vary pretty much randomly, but Bill works 40 hours per week while Sam works 20 hours per week. Suppose the manager's salary for a 60 hour week is $1200. Which of the following is the most fair division of this salary?

A. Bill gets $600 and Sam gets $600.

B. Bill gets $700 and Sam gets $500.

C. Bill gets $800 and Sam gets $400.

Question 4 (adapted from Folger and Konovsky, 1989, Table 1)
Please rate the decision mechanism used in this experiment on the provided scale (strongly agree, agree, disagree, strongly disagree).
The mechanism …

1. … gave you an opportunity to express your side.
2. … used consistent standards in evaluating your behavior.
3. … gave you feedback that led you to reevaluate you decisions.
4. … was honest and ethical in dealing with you.
5. … was designed to achieve a fair result.
6. … led to a result with which you were not satisfied. (own item)
7. … allowed personal motives to influence the result.
8. … gave you the opportunity to significantly influence the other players' payoff. (own item)

Socio-demographic questions:

- Age:
- Gender (female, male):
- How often did you participate in an economic experiment? (never, once, two to five times, more than five times)

Chapter 5

Transfer payments in threshold public goods games

5.1 Introduction

The experiments in the previous chapter have shown among other things that players in a ThrPG with heterogeneous marginal costs are either unwilling or unable to coordinate on a threshold allocation that maximizes their group's total payoff. Instead, the players favor an allocation that results in equal payoffs for all player types. Leaving aside possible explanations of this outcome – be they fairness considerations or merely strategic decision-making of selfish players – I will now simply take it as an empirical fact that the game as it is leads to inefficient outcomes, whether or not each player chooses his contribution individually or the group votes unanimously on a contribution vector. Based on this premise of inefficiency, it is then worthwhile to consider variations of the game, mechanisms by which the group's total payoff, and thus efficiency, can be increased. This chapter discusses one such mechanism, namely the optional redistribution of payoffs via transfer payments after the contributions have been made.[1]

Ever since Fehr and Gächter (2000) showed that punishment can increase contributions in a public goods game, experiments involving sanctioning mechanisms, which also include beneficial "sanctions" in the form of rewards of which transfer payments (as "zero-sum rewards") are a subgroup, seem to have focused only on contribution increases induced by reciprocal action:[2] Low contributions are punished at a cost to both the offending player and the punishing player, and consequently the group's total payoff. High contributions may be reciprocated in a similar fashion by a reward paid to the exemplary player. In a recent experimental study, Andreoni and Gee (2015) show that institutional

[1]Most of this chapter is taken from a joint paper with Karl-Martin Ehrhart under the title "Voting and transfer payments in a threshold public goods game" (Feige and Ehrhart, Unpublished).

[2]See Chauduri (2011) for a review of the literature on sanctions in public goods games.

punishment can also increase efficiency in ThrPGs, although results from an earlier study by Guillen et al. (2006) indicate that their "hired-gun mechanism" is likely to be abolished in a collective decision by all group members. However, the literature has so far kept mostly silent on a possibly just as interesting second aspect of sanctioning mechanisms: the redistribution of payoffs to achieve a "fair" (as in "socially acceptable") outcome.

Admittedly, redistribution can play only a minor role in public goods games if punishment is the only available means of sanctioning, because this option decreases the payoffs of both sides. For this reason I primarily focus on studies that allow reward payments, which only reduce the giver's payoff in favor of the receiver. In order to make sure that the sanctioning mechanism cannot be exploited by shifting rewards back and forth among all players, these payments are restricted to zero-sum rewards (i.e., transfer payments) in most studies (e.g., Walker and Halloran, 2004; Gürerk et al., 2006; Sefton et al., 2007; Sutter et al., 2010). Others (e.g., treatment L3 in Sutter et al., 2010) multiply the initial reward by a given factor similar to the design of a trust game (Berg et al., 1995), making a maximum reward payment socially (but not individually) optimal independently of the preceding choice of contributions. The fact that such a sanctioning mechanism can lead to welfare increases which are then shared among the players by redistribution has already been briefly discussed by Andreoni et al. (2003), albeit in the context of a proposer-responder game.

In the present chapter, I therefore investigate the use of transfer payments (i.e., reward payments) in a public goods context, not as a means of reciprocating fair individual choices by possibly reducing social welfare, but as a mechanism that can actually implement welfare-maximizing outcomes if the players have heterogeneous productivity. As this type of heterogeneity already provides a certain leverage to achieve efficiency gains, namely by shifting contributions to more productive players, transfers in the experiment are strictly zero-sum, an assumption which makes it possible to better separate redistribution from reciprocity as a motive for making such payments.

As discussed before, the heterogeneity among the players opens up a variety of potential distribution norms – among others welfare maximization, equal payoffs, and equal contributions – that all manifest in distinct allocations of the threshold value (the socially and individually optimal outcome). Without transfer payments, all of these allocations are unique and distinct from each other. Most importantly, an allocation can be either welfare-maximizing or result in equal payoffs, but not both at the same time. However, if transfer payments are possible after the contributions have been provided, payoffs from implementing a welfare-maximizing allocation can be redistributed to achieve equal payoffs as well, possibly increasing this allocation's attractiveness in the process.

The experiment simulates two different scenarios in which transfer payments can occur: First, if the ThrPG is played repeatedly, an incentive to pay transfers can be created by threatening to play an inefficient equilibrium strategy in subsequent rounds. Benoit and Krishna (1985) show that equilibria involving such trigger strategies are subgame perfect in finitely repeated games. Second, if transfer payments are negotiated at the same time as individual contributions, specifically in a binding unanimous vote, a redistribution of payoffs can be implemented even in a one-shot situation.

In practice, the first scenario with voluntary contributions and reciprocal transfer payments resembles reward-based crowdfunding. Here, the initiator of the crowdfunding campaign represents a (group of) player(s) with an idea for an interesting project, but high opportunity costs for risking their own money. Involving other contributors in the project spreads the risk over many people. With a fixed minimum amount of funding to realize the project, this is already a typical case of a ThrPG. However, most crowdfunding campaigns go a step further and promise rewards proportional to the contribution if the project is successful. This is common practice at internet platforms.[3] These platforms usually collect contribution pledges which are only redeemed if the specified funding goal is reached. In other words, these ThrPGs grant a full refund of contribution costs ($r = 1$). The second scenario, a combined negotiation of contributions and transfer payments, can be observed in the ongoing climate negotiations, where emissions trading is employed as a transfer mechanism between industries that can cheaply reduce greenhouse gas emissions and those capable only of costly abatement.[4]

There also exists a few other experimental studies that deserve mentioning in this context. Tyran and Sausgruber (2006) find that voting behavior to redistribute payoffs from “rich” to “poor” subjects is consistent with Fehr and Schmidt (1999) preferences of inequality aversion. Cabrales et al. (2012) study a coordination game in which the players can first choose between a costly high effort and a costless low effort to earn payoffs and then vote on a redistribution of their earnings. Interestingly, the authors observe redistribution mostly in groups that predominantly choose low efforts, indicating that this device is unable to increase efficiency levels in this experiment.

The remainder of this chapter is structured as follows. The theoretical model and its solutions are described in Section 5.2, followed by the experimental design and procedure in Section 5.3. Section 5.4 presents the results of the experimental investigation, which are further discussed in Section 5.5. Section 5.6 concludes with suggestions for future research and possible practical implications of this work.

[3] See Mollick (2014) for an empirical study on crowdfunding platforms.

[4] Fuentes-Albero and Rubio (2010) show theoretically that transfer payments can increase the size of stable coalitions of countries reaching international environmental agreements. However, they find the largest potential increase in efficiency not in the case of heterogeneous abatement costs, but heterogeneous damages from global warming.

5.2 Theoretical Model

5.2.1 Transfer payments in the underlying game

The basic version of a ThrPG introduced in Chapter 1, Section 1.1 is now extended to a two-stage decision process as follows:

1. As before, the players simultaneously choose their individual contributions.
2. If the threshold is reached, the players now also simultaneously choose individual transfer payments to bestow upon their fellow players.

Just as in the previous chapter, I assume that a group of four players choose their contributions to a public goods game with a threshold T. Each player $i = 1, \ldots, 4$ has the same endowment e and suffers the same damages d if the threshold is missed, but the players have heterogeneous marginal costs. There are two player types – one with high marginal contribution costs, $c_i = c_H$, and the other with low marginal costs, $c_i = c_L$. Each group contains two players of each type. I assume $c_H \geqslant c_L > 0$ and $4d > c_H T$. So far, this is the same parameter setting as in the COST treatments discussed before.

In addition, if the total contribution reaches the threshold, each individual player i can now use his remaining endowment, i.e., $e - c_i q_i$, to make bilateral transfer payments t_{ij} to each and every other player j, who then increases his final payoff by the transferred amount. Although individual players i can make (or receive) "net" transfer payments $t_i := \sum_{j \in \mathcal{N} \setminus \{i\}} [t_{ji} - t_{ij}]$ that are different from zero, all net transfer payments sum to zero, i.e., $\sum_{i=1}^{4} t_i = 0$. This means that (unlike in punishment games) no welfare is lost in the process.

Player i's payoff $\pi_i(\mathbf{q}, t_i)$ is therefore given by:

$$\pi_i(\mathbf{q}, t_i) = \begin{cases} e - c_i q_i + t_i & \text{if} \quad Q \geqslant T \\ e - d & \text{if} \quad Q < T \end{cases} \tag{5.1}$$

Since, in this variant of the basic (one-shot) game, transfer payments to other players just decrease one's own payoff, all subgame-perfect Nash equilibria of this game have $t_{ij} = 0$ for all i and j. Apart from that, any feasible vector of individual contributions $\mathbf{q}$ that exactly reaches a total contribution of $Q = T$ in the first stage can obviously still be implemented as a subgame-perfect Nash equilibrium if it is the result of a strategy that makes zero transfer payments in the second stage. In fact, the set of allocations that can be implemented as equilibria is identical to that in the game without transfers.

Similar to the approach in Chapter 4, I consider three distribution norms in order to significantly reduce the number of equilibria to the presumably most focal ones: welfare maximization (WM), equal payoffs (EP), and equal contributions (EC). As explained in Section 4.3.1 of that chapter, low-cost players must provide T in its entirety in order to maximize welfare. They will only do so if this is individually rational, i.e., if $c_L q_i < d$ for each contributing player i.

The previously motivated EP and EC outcomes, with associated contribution vectors $\mathbf{q^{EP}}$ and $\mathbf{q^{EC}}$, are both feasible and unique in this experiment. Furthermore, note that, due to the heterogeneity of marginal costs, all three distribution norms result in distinct contribution vectors, meaning that $\mathbf{q^{WM}} \neq \mathbf{q^{EP}} \neq \mathbf{q^{EC}}$. So, in this set-up there is in particular a conflict between maximizing welfare (WM) and distributing the earned payoff equally (EP).

5.2.2 Transfer payments in a repeated game with individual contributions

What about a potential redistribution by means of transfer payments, though? If high-cost players were able to make a credible promise to share their earnings from the WM outcome, welfare maximization and equality of payoffs could be achieved at the same time. Such a credible promise can be made, for example, if the basic game is played repeatedly with the same group of players.

Transfer payments can give low-cost players an additional incentive to contribute according to $\mathbf{q^{WM}}$, if they expect high-cost players to reciprocate their high contributions with generous transfers. However, as mentioned above, if the basic game is played only once, it is not individually optimal to pay a positive ex-post transfer, because there are no repercussions for not doing so. Such payments just reduce the transferring players' payoffs.

Yet matters are different if the players interact repeatedly. Using the RCOST treatment from the previous chapter as a benchmark, an "RTRANS" treatment therefore adds the option of ex-post transfers, which are paid voluntarily as described above, but only if the threshold has been reached in that particular round.[5] The optional transfer payments create additional equilibria to those arising by simply playing the game repeatedly, in which transfer payments are used to redistribute payoffs. Assuming that the goal of redistribution is to achieve equality of payoffs, the following subset of equilibria is of particular interest:

Proposition 5.1. *In a finitely repeated threshold public goods game with transfer payments, all feasible threshold allocations can be implemented as subgame-perfect Nash equilibria that assign equal payoffs to all players if the damage payment d is sufficiently large.*

Proof: In order to equalize the payoffs which the players earn from contributing an arbitrary threshold allocation, it is usually[6] necessary to redistribute

[5] This is not a critical assumption for the theoretical result. It is only intended to reduce the complexity of the subsequent experiment.

[6] The only exception is the unique equal-payoff allocation.

payoffs by means of transfer payments. Using backward induction and starting in the final round, we notice that transfer payments are not individually optimal in this round (just like in the one-shot game). However, there are multiple equilibria in this round and therefore multiple outcomes to which this subgame may be reduced in the subsequent analysis of the preceding round, making it possible to condition this final choice on the actions taken in earlier rounds (cf. Benoit and Krishna, 1985).[7]

Payoff-equalizing transfer payments can accordingly be implemented by using $\mathbf{q^0}$ (zero contributions) as a threat point in a trigger strategy. This requires that, for every player i who has to make a positive transfer payment in order to balance payoffs, this player's cumulative transfer payment is less than the payoff reduction suffered if $\mathbf{q^0}$ is triggered. It is sufficient to consider the last two rounds of the game and any feasible threshold allocation $\hat{\mathbf{q}}$ to find a condition for d which satisfies the proposition: Player i faces the choice between paying the transfer payment in the second-to-last round, which results in the same threshold allocation $\hat{\mathbf{q}}$ in the final round without this transfer payment, or not paying the transfer payment, which triggers the status quo in the final round. Player i chooses to pay the transfer if

$$\sum_{j \in \mathcal{N} \setminus \{i\}} t_{ij} < \pi_i(\hat{\mathbf{q}}) - \pi_i(\mathbf{q^0}) = d - c_i \hat{q}_i, \tag{5.2}$$

which is fulfilled for all players i if the damage payment d is sufficiently large. □

This immediately gives us the following result for the special case of a welfare-maximizing (WM) threshold allocation.

Corollary 5.1. *In a finitely repeated threshold public goods game with transfer payments, any welfare-maximizing threshold allocation can be implemented as a subgame-perfect Nash equilibrium that assigns equal payoffs to all players if the damage payment d is sufficiently large.*

Admittedly, it is a rather harsh threat to contribute nothing at all, because the low-cost players may be worse off under $\mathbf{q^0}$ than if WM were played without transfers. But equal contributions or even equal payoffs may be plausible alternative threats, with their credibility depending on the actual choice of parameters. If payoff-equalizing transfers in a "WM & EP" outcome (an equal-payoff version of WM)[8] satisfy $n_L t_{HL} < \pi_H(\mathbf{q^{WM}}) - \pi_H(\mathbf{q^{EP}})$, where n_L is the number of low-cost players in the group, then even a single round with $\mathbf{q^{EP}}$ and zero transfer payments as a threat-point equilibrium is a sufficient deterrent to withholding transfer payments after socially optimal contributions have been made.

[7] Compare also the equilibrium analysis in Chapter 1, Section 1.1.

[8] There are actually many possible outcomes that are both welfare-maximizing and involve equal payoffs after transfers, but only a single one in which all low-cost players make the same contribution and (as a consequence) receive the same transfer payment.

With respect to the experiment, these results yield the following hypothesis:

Hypothesis 5.1. *Transfer payments will be used in the repeated game to implement a welfare-maximizing allocation with equalized payoffs.*

5.2.3 Transfer payments under a unanimous vote

A second approach to incentivize transfer payments takes into account the fact that public good provision is often decided cooperatively, e.g., by a joint decision of the members of a committee representing the involved stakeholders. This committee may negotiate contributions and transfer payments at the same time, fixing the outcome in a binding contract. As long as compliance with this contract is ensured (a standard assumption in cooperative game theory), positive transfer payments and the associated redistribution of payoffs are now an optimal outcome.

The binding unanimous vote described in Section 3.2.1 of Chapter 3 can be extended so that the group negotiates a vector of net transfer payments $\mathbf{t} = (t_1, \ldots, t_4)$, which must be zero-sum, i.e., $\sum_{i=1}^{4} t_i = 0$, at the same time as the vector of individual contributions $\mathbf{q} = (q_1, \ldots, q_4)$. In every voting round, each player then makes a proposal $(\mathbf{q}, \mathbf{t})$ for a contribution vector $\mathbf{q}$ and (if these contributions exceed the threshold) a transfer vector $\mathbf{t}$. Following the same reasoning as in the equilibrium analysis in Section 3.2.2 of Chapter 3, we realize that all threshold allocations can still be implemented as subgame-perfect Nash equilibria. However, there are now also equilibria in which the payoffs that result from these allocations are redistributed among the players, so that, in addition to the previously motivated focal points – i.e., WM, EP, and EC – “WM & EP”, a welfare-maximizing outcome with equal payoffs can be attained as well. Accordingly, I postulate a hypothesis similar to that for the repeated game:

Hypothesis 5.2. *Transfer payments will be used in the voting game to implement a welfare-maximizing allocation with equalized payoffs.*

5.3 Experimental design and procedure

The two new treatments, RTRANS and VTRANS, use the same parameter setting as the benchmark treatments RCOST and VCOST, that is $e = 30$ ExCU, $\bar{q} = 10$ CU, $T = 16$ CU, $c_H = 3\,{}^{\text{ExCU}}\!/\!_{\text{CU}}$ and $c_L = 1\,{}^{\text{ExCU}}\!/\!_{\text{CU}}$, $d = 25$ ExCU. Table 5.1 displays the relevant treatments for this analysis (RCOST and VCOST are reprinted to facilitate the comparison).[9]

In order to simplify matters for the subjects, transfer payments are possible only from high-cost to low-cost players. This reduces complexity mostly in the repeated game, where high-cost players can now directly determine their

[9] The participant instructions to all treatments are included in Appendix A.1.

Table 5.1: Investigated treatments. For each treatment the number of independent observations (groups) is given in brackets.

	Decision rule	
	Vote (V)	**Repeated Game (R)**
No Transfer (COST)	VCOST (n = 9)	RCOST (n = 9)
Transfer (TRANS)	VTRANS (n = 9)	RTRANS (n = 9)

Table 5.2: Expected outcomes for individual contributions q_H, q_L in CU and total group payoffs $\Pi(\mathbf{q})$ in ExCU by player type (H or L) and focal point (WM, EP, EC).

	$\mathbf{q_H}$	$\mathbf{q_L}$	$\boldsymbol{\Pi}(\mathbf{q})$
Welfare maximization (WM)	0 CU	8 CU	104 ExCU
Equal payoffs (EP)	2 CU	6 CU	96 ExCU
Equal contributions (EC)	4 CU	4 CU	88 ExCU

net transfer and accordingly their final payoff for a given round. In the voting treatment with transfers, proposals with a total contribution of 16 CU or more, i.e., those that reach the threshold, can be extended by four additional numbers (one for each player) indicating the net transfer this player is to receive. This number is a deduction for high-cost players (who pay the transfer) and an addition for low-cost players (who receive the transfer). In the repeated game, the two high-cost players in each group wait until after the individual contributions have been made and can then transfer part of their earnings to each of the low-cost players separately, but again only if the threshold is reached.

Similar to the procedure described in Chapter 4, Section 4.4, proposals, votes, individual contributions, and transfer payments are all publicly displayed immediately after the choice has been made, together with the IDs of the associated players (e.g., “Player C”). Furthermore, after the first round the subjects can again call up the results from past rounds whenever they have to make a decision.

In line with the theory presented above, all treatments are expected to lead to the same (optimal) total contribution of $Q^{WM} = 16$ CU. For all three focal points in terms of contributions – welfare maximization (WM), equal payoffs (EP), and equal contributions (EC) – Table 5.2 contains the numerical predictions for individual contributions by cost-type as well as the associated total group payoffs.[10] Hypotheses 5.1 and 5.2 then imply that allocation WM is chosen if transfers are available and that the resulting total payoff of 104 ExCU

[10]This is an expected value for the repeated game where only a single randomly chosen round is paid.

Table 5.3: Average subject payoffs in investigated treatments in ExCU (exchange rate: 2 ExCU = €1) and cluster-robust standard errors (in brackets) by player type.

	Player type	**Vote (V)**	**Repeated (R) (only rounds paid)**	**All**
COST	both	24.00 (0.00)	19.20 (1.72)	21.60 (1.04)
	$c_L = 1$	24.00 (0.00)	19.33 (1.79)	21.66 (1.07)
	$c_H = 3$	24.00 (0.00)	19.06 (2.22)	21.53 (1.28)
TRANS	both	25.67 (0.23)	21.62 (1.36)	23.64 (0.84)
	$c_L = 1$	25.67 (0.23)	23.46 (1.08)	24.56 (0.62)
	$c_H = 3$	25.67 (0.23)	19.78 (2.25)	22.73 (1.35)
All		24.83 (0.23)	20.41 (1.14)	22.62 (0.69)

is redistributed equally among all players for individual payoffs of 26 ExCU.

5.4 Results

A total of 144 subjects (4 x 9 groups with four members each) were recruited via ORSEE (Greiner, 2015) from a student pool at the Karlsruhe Institute of Technology. All sessions took place in December 2014. The computerized experiment, which used essentially the same procedures as those described in Chapter 4, Section 4.4, including the post-experimental questionnaire, was conducted with z-Tree (Fischbacher, 2007). Together with a show-up fee of €3, the subjects earned on average €14.32 (roughly US$19.5 at the time of the experiment) in all four treatments. Table 5.3 shows the average payoffs by treatment in ExCU. The subjects spent between one hour and one and a half hours in the laboratory.

5.4.1 Total contributions, total payoffs, and success rates

A first step in this analysis will be to show that transfer payments do not significantly affect total contributions or success rates compared to the COST benchmarks. Nevertheless, there is a significant difference compared to the no-transfer benchmark with respect to total payoffs. This allows the conclusion that transfers are not (or at least not primarily) used as a means of sanctioning, that is, to reciprocate contribution behavior in earlier rounds.

Just like in Chapter 4, Section 4.5.1, the comparison of total contributions is based on the agreed-upon total contribution in the voting treatments. For the groups in the repeated game, we use either average values over all rounds or the results from Round 1 and Round 10, as these represent the start and end points of the coordination process, respectively. Because of the large number of

Table 5.4: Absolute frequency of equal-contribution (EC), equal-payoff (EP), and welfare-maximizing (WM) outcomes (with associated total payoffs in ExCU), as well as "Other" threshold allocations in groups that successfully reach the threshold value. For voting treatments the respective group's final agreement is used.

		EC (88 ExCU)	EP (96 ExCU)	WM (104 ExCU)	Other	Unsuccessful	Success rates
VCOST		0	9	0	0	0	9 of 9 (100%)
VTRANS		0	1	7	1	0	9 of 9 (100%)
	Rd 1	0	1	0	6	2	7 of 9 (77.8%)
RCOST	Rd 10	0	3	0	4	2	7 of 9 (77.8%)
	All Rds	0	23	0	49	18	72 of 90 (80.0%)
	Rd 1	0	0	0	7	2	7 of 9 (77.8%)
RTRANS	Rd 10	0	1	4	4	0	9 of 9 (100%)
	All Rds	0	6	14	58	12	78 of 90 (86.7%)

ties in our data, we again mostly perform a categorical analysis using Fisher's exact test for pairwise comparisons of treatments.[11]

When comparing the number of groups that exactly match the threshold value towards the end of the experiment, we find a clear advantage for voting groups, but no significant effect due to transfer payments. All voting groups (with and without transfers) manage to reach the threshold value of 16 CU exactly, resulting in success rates of 100%. Subjects in Round 10 of the repeated game exactly reach the threshold in only four out of nine groups without transfers (RCOST) and in six out of nine groups with transfers (RTRANS).[12] Overall, average success rates are also only slightly higher in RTRANS than in RCOST (86.7% and 80.0%), see Table 5.4. In the following analysis of total payoffs, we restrict our sample to these successful groups, because transfer payments to redistribute these payoffs are only possible if the threshold value has been reached.

Figure 5.1 shows average total payoffs for successful groups on a round-by-round basis. For voting groups, the data are average proposals in early rounds until agreement is reached. Afterwards the agreed-upon contribution vectors are used instead where possible. Groups that use transfer payments clearly earn higher total payoffs in voting treatments. In the repeated game this difference takes a few rounds to develop. In any case, we observe the predicted efficiency increase. Statistically, this effect is supported by the OLS regression of average total payoffs given in Table 5.5, according to which the transfer treatments result in significantly higher total payoffs both in the repeated game with voluntary contributions (dummy variable "Transfer") and under a

[11]In each case, we have first checked for differences among all treatments with the same test, which proved significant (Fisher's exact: $p < 0.05$), unless stated otherwise.

[12]Fisher's exact test comparing the number of groups in RCOST and RTRANS treatments ($n = 9$ in each case) for which the final contribution is equal to $Q = 16$ CU: $p = 0.637$.

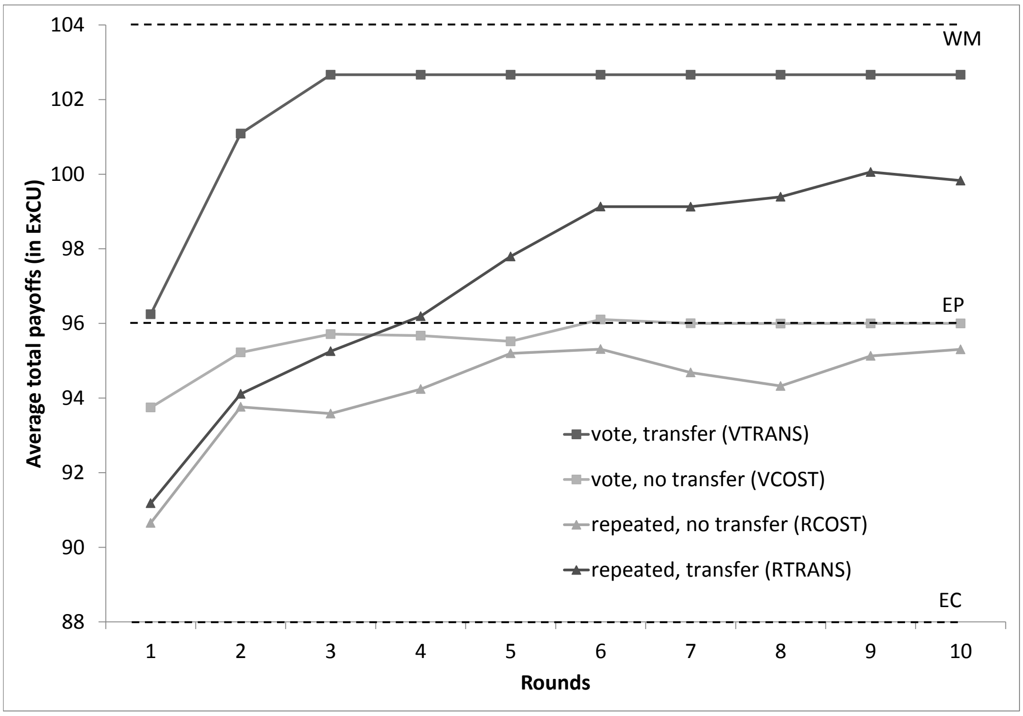


Figure 5.1: Average total payoffs of groups who successfully reach the threshold value. Welfare-maximizing (WM), equal payoff (EP), and equal contribution (EC) benchmarks are included as reference points. Data for voting treatments are average proposed contributions in early rounds, replaced with final contributions in later rounds once a group reaches agreement.

binding unanimous vote (dummy variable "Vote x Transfer"). The highest total payoffs are in fact achieved by a combination of voting and transfer payments.

5.4.2 Collectively preferred threshold allocations

Since total contributions do not vary among treatments with and without transfer payments, the observed differences in total payoffs must reflect in the choice of individual contributions and thus the threshold allocation on which the players (at least tacitly) agree. Table 5.4 shows the absolute frequency of equal-contribution (EC), equal-payoff (EP), and welfare-maximizing (WM) allocations as defined in Table 5.2. Note that, for the sake of this comparison, we ignore any redistribution by means of transfer payments, focusing only on the choice of contributions. Remember that, without any redistribution via transfer payments, a threshold allocation achieves equal payoffs (EP) if and only if both high-cost players contribute 2 CU and both low-cost players contribute 6 CU. This momentarily disregards the possibility of ex-post achieving outcomes with identical payoffs by means of payoff redistribution, which is discussed in Section 5.4.4.

Table 5.5: OLS regression for total payoffs. The regression is based on round averages in the repeated game (R) treatments, counting only rounds in which the threshold is reached successfully.

Variable	**Coefficient**	**Std. Err.**
Vote	1.983†	1.039
Transfer	3.636**	1.039
Vote x Transfer	3.031*	1.469
Intercept	94.017**	0.735
N	36	
R^2	0.704	
F	25.36	

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%

Looking again to the end of the coordination process (i.e., Round 10 in the repeated game and the final choice in the unanimous vote), we can now more clearly identify the effect of transfer payments on total payoffs that has already become apparent from the average values displayed in Figure 5.1. While voting groups without transfers (VCOST) all agree on the equal-payoff outcome EP with a total payoff of 96 ExCU, voting groups with transfer payments (VTRANS) predominantly maximize social welfare by choosing WM outcomes (104 ExCU).[13] This supports the prediction of Hypothesis 5.2.

Similarly, while three out of seven successful groups in the repeated game without transfer payments (RCOST) coordinate on the equal-payoff outcome by Round 10, only one of the groups with transfers (RTRANS) does so, whereas four others instead manage to maximize welfare. Although this difference is not significant in this categorical analysis,[14] mainly due to the large number of "Other" results, a coarser, but exhaustive, categorization by payoff intervals does the trick: All seven successful groups in the RCOST treatment earned a total payoff of at most 96 ExCU, while seven out of nine groups in the RTRANS treatment made use of the transfer mechanism and earned *more* than 96 ExCU.[15] These results corroborate Hypothesis 5.1.

[13]Fisher's exact test comparing the frequency distribution of chosen allocations by distribution norm in successful groups of VCOST and VTRANS treatments ($n = 9$ for each treatment): $p < 0.001$.

[14]Fisher's exact test comparing the frequency distribution of chosen allocations by distribution norm in Round 10 in successful groups of RCOST ($n = 7$) and RTRANS ($n = 9$) treatments: $p = 0.119$.

[15]Fisher's exact test comparing the number of outcomes with a total payoff higher than 96 ExCU in Round 10 in successful groups of RCOST ($n = 7$) and RTRANS ($n = 9$) treatments: $p = 0.0032$.

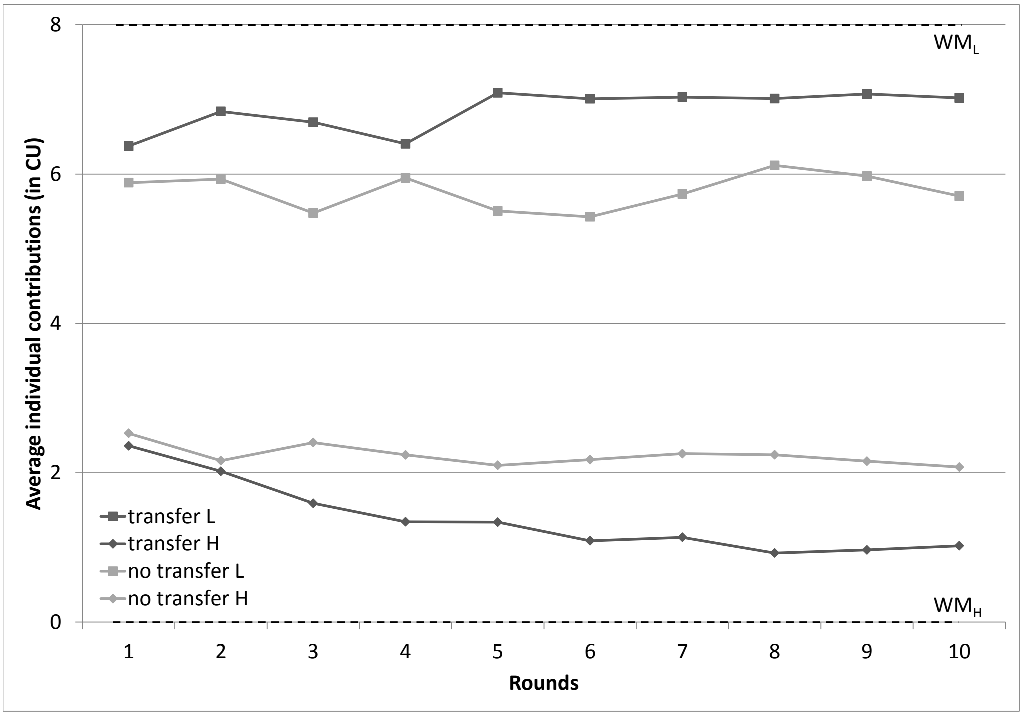


Figure 5.2: Average individual contributions over ten rounds for the repeated-game (R) treatments, differentiated by player type (high (H) or low (L) marginal contribution costs). Welfare-maximizing benchmarks (WM_H, WM_L) are included as reference points.

5.4.3 Individually preferred threshold allocations

Although Table 5.4 also includes the results from the repeated-game treatments, preferences for equality of payoffs and welfare maximization are obviously more difficult to reveal in these treatments, as we can only observe individual contribution choices directly. In the following statistical analysis,[16] we always use a Wilcoxon signed-rank test (two-tailed, unless stated otherwise) for within-treatment comparisons and refer to Table 5.2 for the individual contribution benchmarks.

Average individual contributions of 8 CU by low-cost players can be taken to indicate a preference for welfare maximization (WM). In contrast, welfare-maximizing high-cost players will contribute nothing at all (0 CU). Both benchmarks are also displayed in Figure 5.2 which shows the development of average individual contributions by player type (high-cost vs. low-cost) over all ten rounds of the repeated game.

First note from the differences in contributions between player types in Figure 5.2 that groups in neither treatment display a preference for equal contributions (EC), which would entail individual contributions of 4 CU for both

[16] The sample for this analysis again includes only successful groups.

player types. In both treatments, average contributions in the final Round 10 are significantly higher for low-cost players.[17] The OLS regression for individual contributions in Round 10 given in Table 5.6 gives additional support for this result. Model 1 shows that players with low marginal contribution costs contribute significantly more on average in the final round of the experiment (dummy variable "Low-cost player"), ruling out equal contributions as a focal outcome. In addition, the regression demonstrates that the transfer option does not affect average individual contributions if both player types are considered jointly (dummy variable "Transfer"), again corroborating the result that total contributions, as well as the resulting success rates, are not significantly affected by transfer payments in this game. Introducing an interaction term into the regression (Model 2) reveals an effect of transfer payments on individual contributions, however. We can now see that high-cost players contribute significantly less if transfer payments are possible (dummy variable "Transfer"), whereas low-cost players contribute significantly more (dummy variable "Low-cost player x Transfer").

Another non-parametric comparison using Wilcoxon's rank-sum test, this time of individual contribution costs, shows that low-cost players also face significantly higher average contribution costs in Round 10 of the treatment with transfers,[18] but not in the same round of the treatment without transfers.[19] As individual contribution costs in successful groups can be viewed as a proxy for payoffs (before transfer payments),[20] we can rule out a preference for the equal-payoff allocation in the treatment with transfer payments, but not in the one without.

Tests against the respective welfare-maximizing benchmarks show that by Round 10 contributions in groups without the transfer option (RCOST) are significantly different from these values.[21] In contrast, groups in the transfer treatment do not differ that clearly from the WM benchmarks towards the end of the experiment, as four groups exactly match these values by this point, leaving us unable to reject the claim that contributions are equal to this

[17] Wilcoxon signed-rank test comparing for each group the average contributions by player type in Round 10:
RCOST: $W = 28, n_{s/r} = 7, p < 0.05$; average contributions: 5.86 CU (L) vs. 2.16 CU (H).
RTRANS: $W = 45, n_{s/r} = 9, p < 0.05$; average contributions: 7.02 CU (L) vs. 1.02 CU (H).

[18] Wilcoxon signed-rank test comparing for each group the average contribution costs by player type in Round 10 of RTRANS treatment (9 successful groups):
$W = 34, n_{s/r} = 8, p < 0.05$; average contribution costs: 7.02 ExCU (L) vs. 3.07 ExCU (H).

[19] Wilcoxon signed-rank test comparing for each group the average contribution costs by player type in Round 10 of RCOST treatment (7 successful groups):
$W = -10, n_{s/r} = 4, p > 0.05$; average contribution costs: 5.86 ExCU (L) vs. 6.49 ExCU (H).

[20] Compare also Figure 5.3, a) below.

[21] Wilcoxon signed-rank test comparing for each group the average contribution of one player type (low-cost or high-cost) in Round 10 of RCOST treatment against the respective welfare-maximizing contribution ($q_H = 0$ CU, $q_L = 8$ CU): $W = 45, n_{s/r} = 9, p < 0.05$ in both cases.

Table 5.6: OLS regression for final contributions in successful groups, with and without interaction term. Standard errors are cluster robust (34 groups).

Variable	**Model 1**	**Model 2**
Own contribution (Round 1)	0.317*	0.223
	(0.123)	(0.136)
Vote	0.210*	0.086
	(0.079)	(0.052)
Transfer	0.043	-1.333**
	(0.064)	(0.223)
Vote x Transfer		0.120
		(0.140)
Low-cost player	4.185**	3.144**
	(0.590)	(0.500)
Low-cost player x Transfer		2.600**
		(0.425)
Individual fairness preference (Q1)	0.062	0.095
	(0.137)	(0.109)
Intercept	0.423	1.335**
	(0.347)	(0.347)
N	136	136
R^2	0.873	0.921
F	68.24	678.78

Significance levels : † : 10% $*$: 5% $**$: 1%

benchmark in a statistical test.[22]

The above statistical analysis allows us to rule out two of the three candidates for a focal allocation in each of the two repeated-game treatments. Remarkably, the availability of transfer payments creates a difference between the two treatments here, because in groups with transfer payments welfare maximization is the only remaining focal allocation, whereas players in groups without transfer payments predominantly choose contributions in accordance with the equal-payoff allocation.

[22] Wilcoxon signed-rank test comparing for each group the average contribution of one player type (low-cost or high-cost) in Round 10 of RTRANS treatment against the respective welfare-maximizing contribution ($q_H = 0$ CU, $q_L = 8$ CU):
Low-cost players (two-tailed): $W = -15, n_{s/r} = 5, p > 0.05$
High-cost players (one-tailed): $W = 15, n_{s/r} = 5, p = 0.05$.

5.4.4 Individual payoffs, transfer payments, and payoff redistribution

In this section, we compare the payoffs of the two player types on an individual level in order to investigate the extent of payoff redistribution. In the voting treatment with transfer payments, a preference for redistribution is rather obvious. All groups that agree on an outcome with a total payoff higher than 96 ExCU (the social optimum without transfers) also agree on a redistribution of this outcome by means of transfer payments that achieves equal payoffs. Seven of the nine groups in the voting treatment with transfers (VTRANS) choose a WM & EP outcome. Compared to the voting treatment without transfers (VCOST), where all groups vote for an EP allocation, individual payoffs are at least as high in all cases for both player types (and usually strictly higher).

In the repeated game with transfers (RTRANS), the greater variance of outcomes makes it slightly more difficult to discover a redistribution effect. Figure 5.3 shows average individual payoffs by player type in successful groups in the repeated-game treatments, before and after transfer payments in transferring groups. In a comparison of payoffs that is only based on contributions (Subfigure a)), we first note the difference in payoffs between high-cost and low-cost players in the transfer treatment (RTRANS), which is statistically different when comparing group averages of successful groups.[23] This is consistent with the difference in contribution costs established in the previous section. Including transfer payments (Subfigure b)), however, the payoff differences between high-cost and low-cost players disappear.[24]

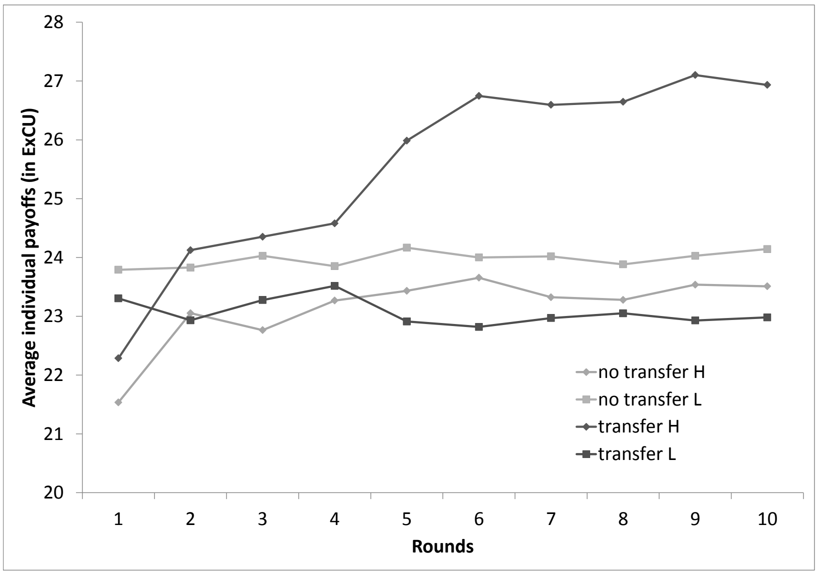
The high-cost players in treatment RTRANS start out on a payoff level similar to their RCOST counterparts, but quickly achieve a relative improvement of their average payoffs. The average individual payoff over all rounds of 24.29 ExCU for high-cost players in treatment RTRANS is accordingly significantly higher than the 23.09 ExCU earned by the same player type in the treatment without transfer payments.[25] The average improvement of individual payoffs due to transfer payments is less pronounced for low-cost players, with averages of 23.92 ExCU (RCOST) and 24.53 ExCU (RTRANS), but still statistically significant.[26]

[23]Wilcoxon signed-rank test comparing average individual payoffs before redistribution (on average over all ten rounds, using only successful rounds) of high-cost (H) and low-cost (L) players in the same group in treatment RTRANS: $z = 2.192$, $p = 0.0284$. Average payoffs (excluding transfers) over all rounds: 25.82 ExCU (H), 23.00 ExCU (L).

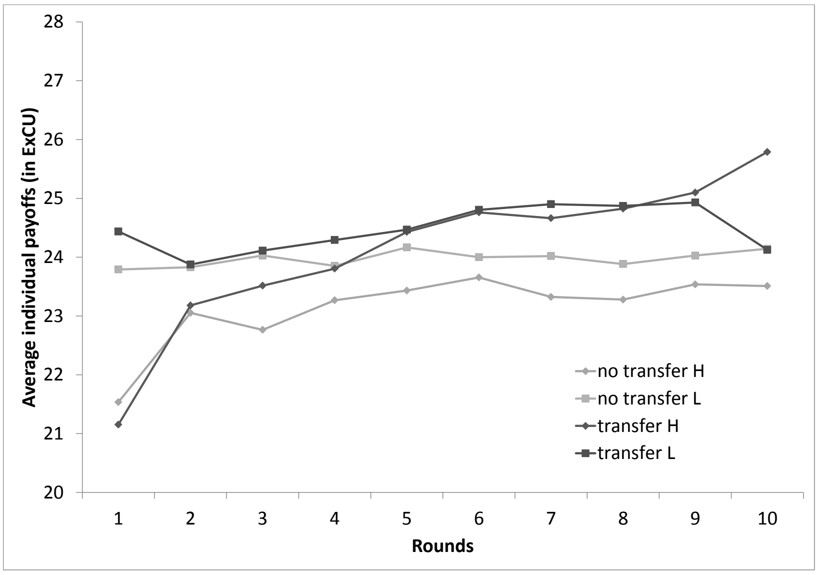
[24]Wilcoxon signed-rank test comparing average individual payoffs after redistribution (on average over all ten rounds, using only successful rounds) of high-cost (H) and low-cost (L) players in the same group in treatment RTRANS: z = -1.362, $p = 0.1731$. Average payoffs (including transfers) over all rounds: 24.29 ExCU (H) vs. 24.54 ExCU (L).

[25]Wilcoxon rank-sum test comparing the individual payoffs of high-cost (H) players (group averages over all successful rounds) in RTRANS and RCOST treatments: $z = 2.693$, $p = 0.0071$.

[26]Wilcoxon rank-sum test comparing the individual payoffs of low-cost (L) players (group



(a) before transfer payments



(b) after transfer payments

Figure 5.3: Average individual payoffs before and after transfer payments over ten rounds for the repeated-game (R) treatments, differentiated by cost type (H and L) and using only successful groups.

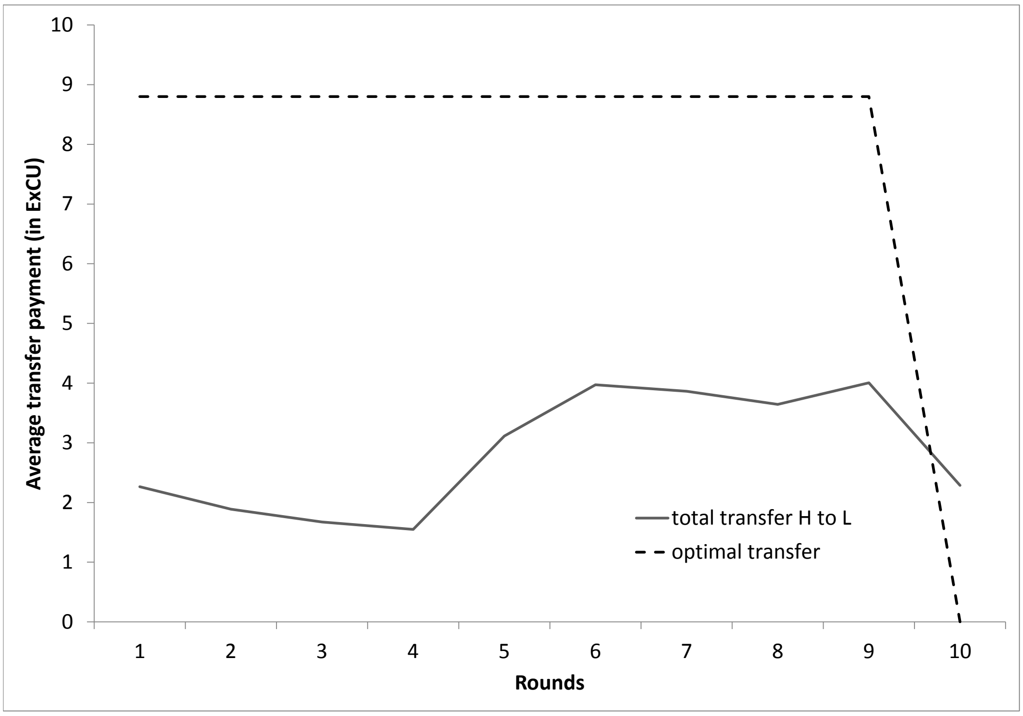


Figure 5.4: Total transfer payments from high-cost to low-cost players over ten rounds (averaged over all groups in each round) in the RTRANS treatment. The benchmark assumes that a group coordinates on a WM outcome in each round and transfers a total of 8.8 ExCU each round in Rounds 1 to 9 to achieve equality of payoffs only in regard to the expected payoff over all ten rounds.

Finally, Figure 5.4 displays the average amount of transfer payments over time in the RTRANS treatments. Although positive, transfers are on average clearly below the benchmark specified by a subgame-perfect Nash equilibrium which leads to equal expected payoffs for all players. Interestingly, transfers are paid by several subjects even in the final round of the game, though the payments experience decrease at this point (from an average of about 4.00 ExCU in Round 9 to only 2.28 ExCU in Round 10). It is unclear, however, if these high-cost players want to reciprocate the (from their perspective) beneficial actions of low-cost players, who carried the major contribution burden, or if these players are motivated by inequality aversion and feel the need to equalize payoffs even in this final round.

averages over all successful rounds) in RTRANS and RCOST treatments: $z = 2.075$, $p = 0.0380$.

5.5 Discussion

How do these results relate to other experimental studies? As voluntary sanctions have so far only been investigated in the context of linear public goods games, in which the unique Nash equilibrium involves contributing nothing,[27] a comparison to these studies based on total or individual contributions, even if only comparing relative changes, is meaningless. Instead, I therefore use relative changes in total and individual *payoffs* as a measure of comparison.

Voluntary reward payments in linear public goods games also appear to increase total payoffs (e.g., Figure 3 in Sefton et al., 2007). Whereas in the RTRANS treatment, transfer payments increase in later rounds, however, rewards are used less frequently over time in the treatments studied by Sefton et al. (2007), indicating that this instrument is used myopically, for reasons of reciprocity instead of redistribution and wears out its use as an incentive after some time. Sutter et al. (2010) furthermore do not find an increase of total payoffs due to rewards in their zero-sum treatment (L1), unless this rule is chosen endogenously. Walker and Halloran (2004) do not find any effect at all on average earnings in their one-shot setting.

As none of these studies report payoff distributions to indicate relative payoff differences on the group level, incidences of possible redistribution can at best be inferred from cases in which a particular player makes a lower than average contribution and follows this with a reward payment directed at players who have contributed more than average before. This occurs, for example, in the study by Sutter et al. (2010) who observe a higher likelihood of being rewarded if the rewarding player has contributed relatively little (cf. Sutter et al., 2010, the two rightmost columns in Figure 3). Due to their lower-than-average contributions, the rewarding players face higher than average earnings, which they are apparently willing to share with the rest of the group.

In order to observe redistribution more clearly, we must turn to trust games (Berg et al., 1995) and similar set-ups. Andreoni et al. (2003), for example, report a large share of equal payoff outcomes, if the initial payment is matched with a positive return payment (reward). In their opinion this is a remarkable result, because the original trust game does not usually result in equal splits. In the view of the experiments described in this chapter we can interpret transfers or rewards that equalize payoffs as an indicator of redistribution (from rich to poor). Unequal payoffs in the trust game may in turn indicate that reciprocity, not redistribution, is the primary motivation behind the responder payments. Accordingly, the players in these games do not primarily care about how much the other player earns, only that he deserves a reward. And without the necessity of using reciprocating transfers as a coordination device, the responding players can make deviations from equal payoffs that are to their own advantage without having to fear a breakdown of cooperation.

[27] At least I am unaware of studies on sanctioning in public goods in which this is not the case.

In summary, although increases of efficiency due to sanctioning mechanisms are a well-known phenomenon in the experimental literature, redistribution effects are rarely as obviously discerned as in this experiment.

5.6 Conclusion

This chapter shows that ex-post transfer payments are able to increase efficiency in a ThrPG with heterogeneous marginal contribution costs by merging two formerly conflicting principles of distributive fairness, to wit, welfare maximization and equalization of payoffs. Furthermore, this result holds for both tested decision rules, unanimous voting and voluntary contributions in a repeated game, although groups in the latter setting have more difficulties employing transfer payments efficiently.

I should, however, also point out a few possible limitations of this work. In order to attain comparability between voting and repeated-game groups, we have restricted the experiment to (up to) ten rounds of interactions. While this may have already been too long for some of the voting groups, ten rounds is rather short to achieve coordination just by repeated interaction. Consequently, some players in the repeated-game treatment with transfer payments may not have been able to understand this mechanism well enough to employ transfers efficiently. Nevertheless, the results at least provide proof of concept, since most groups indeed increase their total payoffs.

Moreover, the results in the voting treatments are driven by the decision process, which requires the agreement of all group members and therefore favors equal-payoff outcomes because all players have the same bargaining power. However, using a variation of a unanimity rule is rather common in international negotiations, because this (or rather the "consensus" rule) is the default procedure until other rules can be agreed upon (Buchanan and Tullock, 1962). Furthermore, because the welfare-maximizing outcomes with and without transfers are individually optimal under this voting rule, we do not face the problems of Bös and Kolmar (2003), in whose model an agreement between the players to share their earnings must be exogenously enforced by a "Constitution." Of course, an attempt to reproduce these results under different voting rules may be worthwhile. If anything, one might criticize the choice of the non-agreement outcome or "status quo." A different choice of this fallback outcome than $\mathbf{q^0}$ (i.e., zero contributions) may make agreement much harder, if not impossible, if a former equilibrium outcome is now no longer Pareto superior to the status quo.

Additional experiments might attempt to better separate intentions of reciprocity and redistribution in the use of reward payments in linear public goods games with heterogeneous players. An example for such an experiment is Dekel et al. (Unpublished), in whose case a minority of players, who is actually harmed by the provision of the public good, can be compensated through redistribution. However, in their case the players receive an additional endowment just for transfer payments, which may be a reason why the authors report that minority players do not contribute more if they are compensated.

In regard to practical implications of this investigation, I have already mentioned that a threshold public goods game with transfer payments appears to have some similarities to a crowdfunding campaign. Crowdfunded projects require a certain amount of seed money (a threshold sum) which the initiators of the campaign cannot provide on their own. However, they are able to attract other investors by promising them part of the earnings (or some other reward) if the project is successful, creating a win-win situation for all participants. Although crowdfunding is mostly used to finance commercial products (see, e.g., Mollick, 2014, for a recent empirical study), the same principle can also be employed to support communal undertakings, like funding a public library, which create positive externalities and can therefore be considered public goods.

Crowdfunding campaigns usually address much larger groups than can be brought together under laboratory conditions, most projects having thousands of backers. It seems likely, though, that with an increasingly larger variety of players (as a side-effect of larger group size) finding an allocation that equalizes payoffs will become increasingly more difficult. Let alone the fact that evaluating the exact payoff or utility that results from a provision of the public good for each player is an all but impossible task in itself.

As a consequence, transfer payments in real life will usually not result in a redistribution with completely equal payoffs, but even small transfers may be enough to improve the efficiency of public good provision and raise efficiency in doing so. While there is no doubt that transfer payments are observed in real life, field studies in cooperation with crowdfunding platforms may be necessary to measure the actual amount of redistribution in real-life situations by investigating, for example, if higher transfer payments (per contributed dollar or euro) indeed make a project's success more probable.

Finally, the Ocean Cleanup, a current project to remove plastic garbage from the Pacific Ocean, is an example for crowdfunding on an international level.[28] At this level, political negotiations among the affected countries are another way to bring about such projects of public interest, whereby individual contributions and transfer payments can be negotiated at the same time. For example, international negotiations to prevent climate change use emissions trading as a transfer mechanism, aiming to reward industrial companies for producing fewer greenhouse-gas emissions. An attempt to model climate negotiations in a controlled laboratory experiment is presented in the next chapter.

[28]See www.theoceancleanup.com, last accessed on June 15, 2015.

Chapter 6

Modeling climate negotiations: top-down voting and threshold uncertainty

6.1 Introduction

This chapter is concerned with a practical application of the findings discussed in the rest of this thesis to the ongoing international negotiations to prevent global warming.[1] Here, the 2009 Copenhagen Accord specifies a threshold value of an acceptable temperature increase of 2°C. This value is said to constitute a "tipping point" beyond which any damages to the climate will be irreversible.[2] A particular challenge for the negotiations is, however, that the global abatement quantity of greenhouse gas emissions that is necessary to reach this threshold cannot be precisely determined due to the complexity of the system. Accordingly, the exact threshold value is uncertain. In contrast with the model used in Chapters 4 and 5, there is also no refund of contributions, meaning here the costs for emission reductions, if the global abatement quantity does not reach the target. This significantly increases the risk involved in the contribution decision compared to the models analyzed in the preceding chapters.

Furthermore, the collective contribution decision in the negotiations is split into two parts: The total (global) contribution has more or less already been determined by setting the 2°C target, leaving only the decision on how this total is allocated among the individual contributors, i.e., the countries. In order to find out if this "top-down" procedure is indeed the best course of action, this chapter presents an experimental comparison of this procedure with two other ways of determining contributions to a threshold public good, to wit, the deci-

[1] Most of these results stem from a joint paper with Karl-Martin Ehrhart and Jan Krämer under the title "Voting on contributions to a threshold public goods game – an experimental analysis" (Feige et al., Unpublished).

[2] See the 2007 IPCC report (Meehl et al., 2007, p. 775) and Hansen et al. (2008).

sion rules discussed in previous chapters. The unanimous voting rule described in Chapter 3, Section 3.2.1 corresponds to a "bottom-up" procedure, by which only national abatement efforts are negotiated and then simply aggregated to a total abatement quantity. Individual voluntary contributions, the standard decision rule for public goods games, instead represents the "worst-case scenario" of failed negotiations and uncoordinated abatement efforts.

Modeling climate negotiations in a computer-based laboratory experiment requires a number of simplifying assumptions. Most importantly, the vague consensus rule[3] employed in the free-form negotiations of the COP meetings[4], which in any case leads to an outcome that cannot be legally enforced due to the lack of an international authority to do so,[5] is approximated by a binding unanimous voting procedure in which the communication between the subjects is restricted to making proposals and casting votes. However, we can justify the unanimity rule as a representation of consensus agreement with arguments in favor of the similarity of these procedures by Buchanan and Tullock (1962, particularly Ch. 7) and Törnudd (1982). In addition, due to the theoretical properties of ThrPGs, in which all Pareto-optimal outcomes can be implemented as Nash equilibria (see in particular Section 6.3.3 below), a lack of compliance with collective decisions should not be a problem.

Apart from the decision rule, the model is quite realistic for several reasons: In addition to a randomly distributed threshold value, the players face a negative payment for missing this target, comparable to the environmental damages associated with climate change. Moreover, having different marginal contribution costs for two player types, similar to the COST treatments discussed in the preceding chapters, accounts for the technological differences in marginal abatement costs in the real world. For example, emerging economies like China and India can conceivable reduce their greenhouse gas emissions at much lower marginal costs than industrialized countries like the U.S. or Germany. The findings presented in this chapter should therefore also be relevant to the real climate negotiations.

The rest of this chapter begins with a literature review in Section 6.2, followed by Section 6.3 which describes the theoretical model. The subsequent sections are concerned with the experimental design and procedure (Section 6.4), as well as the experimental results (Section 6.5) and their discussion (Section 6.6). Section 6.7 concludes the chapter with a number of implications

[3]"Consensus" has been found to mean anything from a unanimous decision with or without abstention to absolute or only simple majority (D'Amato, 1970, p. 106), extending occasionally even to simple judgment calls like the one made by Mohamed Nasser al Ghanim, acting as chairman for the 2012 ITU conference in Dubai, who only asked for an informal vote (and apparently even emphasized later that "no, it was not a vote") in order to get "a feel for the room" and then declared a decision based on this feeling (see e.g., https://www.techdirt.com/blog/?tag=mohamed+nasser+al+ghanim, last accessed on January 15, 2015).

[4]"COP" is an abbreviation of "Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC)."

[5]This problem is discussed in more detail, e.g., by Finus (2001).

of these results and those presented in earlier chapters for policy-makers in this context.

6.2 Literature review

Barrett and Dannenberg (2012) suggest that the lack of success of climate negotiations so far is actually a failure to coordinate (and not to cooperate), precisely because there is already a global consensus on reaching the threshold, i.e., the 2°C target. In two recent experimental studies, Barrett and Dannenberg (2012, 2014) therefore investigate individual contributions to a ThrPG for the purpose of modeling international efforts to prevent global warming.[6] The authors report that, by making coordination on the threshold value more difficult, "threshold uncertainty" (or more precisely: a randomly distributed threshold value) reduces total contributions substantially, despite the possibility of pre-play communication via contribution pledges. A similar negative effect of a randomly distributed threshold value on success rates has also been observed by Suleiman et al. (2001) and McBride (2010), the latter being concerned with binary contributions. Our experimental design complements these studies by using a binding unanimous vote on the one hand, and voluntary individual contributions in a repeated game on the other. Moreover, we also run treatments with heterogeneous marginal contributions costs, thereby extending the previous focus on symmetrical players to a more general case.

Preferences for fairness principles also play a rule in climate negotiations, where they appear in the form of burden-sharing principles. For instance, Gampfer (2014) discusses principles of "causal responsibility" (according to which the most severely polluting countries should carry the heaviest burden of emissions reduction), "ability to pay" (the richest countries contribute the most), and "vulnerability" (the most vulnerable countries are granted relief from their cost burden).[7] In a subsequent experimental analysis using a variant of an ultimatum game, Gampfer (2014) then observes that only the first two principles are reflected in the proposed allocations, meaning that a difference in damages (incurred if a proposal is rejected) is less relevant to the subjects' choices. Our own experimental design is insensitive to distinctions of responsibility for, or vulnerability towards, damages. And although we also do not assume that some players are richer than others (all have the same endowment), it could be said that the more productive players (with lower marginal costs of contribution) are able to carry a larger share of the contribution burden.

[6] The studies by Milinski et al. (2008), Tavoni et al. (2011), and Dannenberg et al. (2015) are also concerned with this topic but, unlike our approach, employ sequential and not simultaneous contributions. Another study (Bosetti et al., Unpublished) has simultaneous contributions, but the uncertainty refers to whether or not the remaining endowment is lost if the threshold is missed.

[7] See also Gallier et al. (forthcoming).

The distinction between top-down and bottom-up decision rules originally stems from budget negotiations. In this context, there is a widespread belief (see Ehrhart et al., 2007, for more details) that a top-down procedure, which determines the size of the total budget first and the allocation of this total to individual projects only afterwards, is more efficient than simply negotiating the budgets for the individual projects in sequence, i.e., with a bottom-up procedure. Ehrhart et al. (2007) simulate top-down and bottom-up budget negotiations in a laboratory experiment, finding that, depending on the parameter setting, either procedure can result in higher budgets and thus be less efficient than the other. This also conforms to the theoretical work by Ferejohn and Krehbiel (1987). Consequently, if the total abatement quantity is to be treated as the "total budget" for climate negotiations, there is no reason to believe that the current top-down process with a 2°C target is superior to the alternative of negotiating national abatement efforts without such a global target. Following the reasoning in Chapter 2, Section 2.A.2, the fact that in our model (just like in climate negotiations) the players face a negative (damage) payment if they fail to reach the threshold (instead of a positive reward if they succeed) should not matter in the players' contribution decisions, even if they are loss averse.

6.3 Theoretical Model

6.3.1 Basic game

The basic game is by and large the same as that used in previous chapters: It assumes that the players have homogeneous endowments and damage payments, but have heterogeneous marginal costs in some treatments, in which case there are then again only two player types with costs $c_H \geqslant c_L > 0$. However, no refund of contribution costs is granted, if the threshold is missed ($r = 0$). A second new element is that the threshold T is randomly distributed over all natural numbers between (and including) $T_{min} < T_{max}$. Each of these numbers can result with an equal probability of $1/(T_{max}-T_{min}+1)$.[8] We set $\bar{q} < T_{min}$ and $T_{max} < n\bar{q}$, so that it is always possible to reach the actual threshold value, but only if multiple players make contributions. Furthermore, we assume $nd > c_H T_{max}$ to make sure that reaching the threshold is collectively profitable.

Similar to before, player i's payoff $\pi_i(\mathbf{q})$ is given by:

$$\pi_i(\mathbf{q}) = \begin{cases} e - c_i q_i & \text{if } \; Q \geqslant T \\ e - c_i q_i - d & \text{if } \; Q < T \end{cases} \tag{6.1}$$

[8] This corresponds to the assumptions made in the experimental investigation by Suleiman et al. (2001), although their theoretical investigation assumes a continuous probability distribution.

6.3.2 Ex ante social optimum

With our choice of parameters, the (ex ante) social optimum of this game is reached with a total contribution of $Q^* = T_{max}$,[9] which is the highest possible threshold level. A vector $\mathbf{q}^* = (q_1^*, \ldots, q_n^*)$ that maximizes the expected total payoff $\mathrm{E}[\Pi(\mathbf{q})] = \mathrm{E}\left[\sum_{i=1}^n \pi_i(\mathbf{q})\right]$ is called the (ex ante) social optimum. We refer to $Q^* = \sum_{i=1}^n q_i^*$ as the socially optimal total contribution. In order to find $\mathbf{q}^*$, we first need to know Q^*. However, please note that, if marginal contribution costs are heterogeneous, there are contribution vectors that sum to Q^* without maximizing the expected total payoff. This is because the same total contribution may lead to different contribution costs, depending on how the contributions are allocated among the player types (see below).

Proposition 6.1. *The (ex ante) socially optimal total contribution Q^* of the considered public goods game with n players and a threshold value T that is distributed uniformly over the natural numbers between (and including) $T_{min} < T_{max}$ is equal to the maximum threshold level, i.e., $Q^* = T_{max}$.*

Proof: Following a similar proof by Suleiman et al. (2001), we realize that for $T_{min} - 1 \leqslant Q < T_{max}$ an increase of the total contribution by 1 leads to a similar increase of the probability of reaching the threshold, $Prob(T \leqslant Q)$, by $^1/_{(T_{max}-T_{min}+1)}$. Accordingly, in this interval, an increase of the total contribution that is large enough to increase the probability of reaching the threshold can also lead to an increase of the expected total payoff, if the marginal costs of contribution c are sufficiently small or if the damage payment d for missing the threshold is sufficiently large. Formally, this is the case if $c < {}^{nd}/_{(T_{max}-T_{min}+1)}$, or equivalently, if $c(T_{max} - T_{min} + 1) < nd$ for $c \in \{c_L, c_H\}$. Since by assumption $nd > c_H T_{max}$ and $T_{min} > \bar{q}$, this condition is satisfied,[10] resulting in $Q^* = T_{max}$. $\square$

Note, however, that an ex ante socially optimal contribution vector is not necessarily welfare-maximizing. Next, we therefore consider the optimal way of allocating Q^* among the individual players, i.e., the welfare-maximizing contribution vector $\mathbf{q}^*$.

If the marginal costs of contribution are homogeneous ($c = c_H = c_L$), any allocation of Q^* leads to the same total costs of contribution cQ^* and, consequently, the same expected total payoff. So $\mathbf{q}^* \in \{\mathbf{q} | \sum_{i=1}^n q_i = Q^*\}$. But if the marginal costs of contribution are heterogeneous ($c_H > c_L$), the total costs decrease if the low-cost players provide a larger share of the total contribution. Thus, low-cost players should provide either Q^* in its entirety, or

[9] There is slight conceptual difference to the welfare-maximizing total contribution Q^{WM} used in the preceding chapters that warrants this changed notation. Since the value of T is now uncertain, Q^* refers to the best choice of total contribution that the group can make in this uncertain condition if the players are risk-neutral. Once the group learns the true value of the threshold, it may realize ex post that the actual welfare-maximizing total contribution would have been lower, so that $Q^{WM} \leqslant Q^*$.

[10] Technically, we also need to assume $\bar{q} > 1$.

$n_L\bar{q}$ if this is smaller than Q^*. Moreover, $c_i q_i \leqslant d$ has to be satisfied for each individual player i to make this contribution individually rational. Assume that $\mathcal{N}_L \subset \mathcal{N}$ and $\mathcal{N}_H \subset \mathcal{N}$ refer to the subgroups of low-cost and high-cost players, respectively. Then the following characterization of $\mathbf{q}^*$ results:

$$\mathbf{q}^* \in \left\{ \mathbf{q} \,\middle|\, \sum_{i \in \mathcal{N}_L} q_i = min\{Q^*, n_L\bar{q}\} \wedge (\forall i \in \mathcal{N}_L : c_L q_i \leqslant d) \right. \\ \left. \wedge \sum_{j \in \mathcal{N}_H} q_j = Q^* - \sum_{i \in \mathcal{N}_L} q_i \wedge (\forall j \in \mathcal{N}_H : c_H q_j \leqslant d) \right\} \quad (6.2)$$

According to (6.2), in order to find $\mathbf{q}^*$, we first assign a share of Q^* to the low-cost players (top line). This share must be technologically possible ($\sum_{i \in \mathcal{N}_L} q_i \leqslant n_L\bar{q}$), but otherwise should be as large as possible. Furthermore, each individual low-cost player may not be assigned contribution costs higher than the damage payment, i.e., $\forall i \in \mathcal{N}_L : c_L q_i \leqslant d$. Any remaining share of Q^* is then allocated among the high-cost players (bottom line) in an individually rational manner, i.e., $\forall j \in \mathcal{N}_H : c_H q_j \leqslant d$. All ex ante social optima are also Nash equilibria in expected payoffs of the basic game, if $c_H(T_{max} - T_{min} + 1) < d$, i.e., if the damage payment is high enough to prevent even individual players from reducing their contributions if this entails reducing the total contribution below the socially optimal value of $Q^* = T_{max}$.

For the purpose of treatment comparison, we also define an efficiency measure $\eta(\mathbf{q})$[11] as follows:

$$\eta(\mathbf{q}) := \frac{\mathrm{E}[\Pi(\mathbf{q})]}{\mathrm{E}[\Pi(\mathbf{q}^*)]} \quad (6.3)$$

As derived above, maximizing the expected total payoff $\mathrm{E}[\Pi(\mathbf{q})]$ requires a total contribution of Q^*. However, the ex ante socially optimal total payoff $\mathrm{E}[\Pi(\mathbf{q}^*)]$ also depends on the allocation of this total contribution among the individual players, so that the groups with heterogeneous marginal costs achieve the highest expected total payoff – for which $\eta(\mathbf{q}^*) = 1$ (or 100%) – if the low-cost players contribute as much as possible. The measure is therefore normalized by $\mathrm{E}[\Pi(\mathbf{q}^*)]$ to account for this advantage over homogeneous groups, which receive the same expected total payoff for every allocation of the total contribution. Since $\mathbf{q}^*$ is a Nash equilibrium in expected payoffs whether the players have heterogeneous costs or not, we also should not see a difference in normalized efficiency levels due to player heterogeneity.

[11] Margreiter et al. (2005) use a similar measure.

These theoretical results provide the following hypothesis for our experiment:

Hypothesis 6.1. *Player heterogeneity in regard to marginal contribution costs does not affect the levels of a) total contributions and b) relative efficiency compared to groups with homogeneous players.*

6.3.3 Voting treatments

In our experiment, we compare two voting rules to the case of a non-cooperative game without voting. In the voting treatments, the group needs to reach a unanimous agreement on a vector of individual contributions $\mathbf{q} = (q_1, \ldots, q_n)$ as before. However, instead of the "bottom-up" voting rule employed in previous chapters, in which the total contribution results automatically as an aggregate of the accepted contribution vector, some of the treatments will follow a top-down voting procedure, in which the total contribution is negotiated first and the proposals in the subsequent vote on individual contributions are then restricted to contribution vectors that result in the same total.

These top-down treatments consist of two parts of up to five rounds each, ten rounds in total, just as with bottom-up voting. In the first part the players vote on their group's total contribution Q. In the second part another vote is used to divide this total contribution among the players. If there is no agreement among the players in either the first or the second part, the zero-contribution vector $\mathbf{q^0}$ is used as the group's choice. The second part does not take place unless a positive total contribution ($Q > 0$) is chosen in the first part.

From the analysis in Chapter 3, Section 3.2.2, we know that any feasible threshold allocation is a socially optimal equilibrium under the bottom-up procedure if the threshold is known with certainty. But if the threshold is distributed uniformly as in the treatments investigated here, the ex ante socially optimal choice of contributions, namely $Q^* = T_{max}$, also leads to a certain payoff. Accordingly, the reasoning from that section can be applied to feasible allocations of T_{max}, which here constitute a set of socially optimal subgame-perfect Nash equilibria in expected payoffs.

It follows immediately that both voting rules can be expected to lead to comparable contribution vectors, although the strategic characterizations of the corresponding subgame-perfect Nash equilibria are, of course, slightly different. For top-down voting, a proposal of $\hat{\mathbf{q}}$ in the second part will be tied to a particular total contribution $\hat{Q} = \sum_{i=1}^{n} \hat{q}_i$ determined in the first part. Otherwise, the reasoning is the same: If $\hat{Q}$ results in allocations $\hat{\mathbf{q}}$ that are Pareto improvements to $\mathbf{q^0}$, any feasible combination $(\hat{Q}, \hat{\mathbf{q}})$ is implemented in a voting equilibrium, whereby $\hat{Q}$ is chosen in the first round of the first part and $\hat{\mathbf{q}}$ in the first round of the second part. Again, proposing or voting for $\mathbf{q^0}$ is an equilibrium, but not a strict equilibrium. In addition, note that the socially optimal set of feasible threshold allocations is a subset of these voting equilibria and in fact constitutes this game's NTU core (Moulin, 1988, p. 102) (see also Chapter 4, Section 4.6.3). These results are summarized in the following proposition:

Proposition 6.2. *In both voting games, i.e., top-down and bottom-up procedure, the set of feasible ex-ante socially optimal contribution vectors characterized by $Q^* = T_{max}$ can be implemented as subgame-perfect Nash equilibria with respect to expected payoffs.*

Accordingly, the equilibrium analysis gives no reason to expect differences in contribution behavior between the two voting procedures. Noting further that $\mathbf{q^0}$ is not likely to result in the experiment, because it is not a strict equilibrium, we postulate the following hypothesis:

Hypothesis 6.2. *Both top-down and bottom-up voting will lead to a) ex-ante socially optimal total contributions and, subsequently, b) to the same relative efficiency.*

6.3.4 Repeated game treatments

By assuming a binding vote and a predetermined fallback outcome in the case of no agreement, we have made two necessary simplifications to keep the game's complexity within the bounds suitable for an experimental investigation. It would be more realistic, of course, to allow the players to renege on their agreements and contribute as they want. And this is also likely to happen instead of a predetermined fallback outcome: If there is no agreement, each country will decide individually about only its national abatement efforts.

Instead of trying to incorporate these elements in a single, and accordingly complex, treatment, we present additional groups of test subjects with something like a "worst-case scenario" for climate negotiations, which at the same time relates to the more traditional decision procedure in ThrPGs. The players are only able to make individual contributions to the public good, and cannot propose contribution vectors, let alone vote on their fellow players' contributions. Moreover, accounting for the possibility of learning from past contribution choices in similar situations, the players will be required to play the basic game repeatedly, i.e., in several separate rounds with new endowments and new (randomly drawn) contribution thresholds.

At a first glance, learning from repetition may present the players with an opportunity to cooperate by coordinating their contributions efficiently, but in the light of the decreasing contributions over time commonly observed in linear public goods games (e.g., Kroll et al., 2007) and also occasionally in ThrPGs (e.g., Isaac et al., 1989) the opposite is even more likely: In later rounds, the players may come to realize that they are better off accepting the damage payment and contributing nothing than being once more disappointed by the lack of contribution efforts of their fellow players and paying the damage payment in addition to their wasted contribution costs.

We conduct two repeated-game treatments (homogeneous and heterogeneous costs) in which the basic game is played ten times in a row with the same group of players (partner setting). This provides the subjects with the same number of interactions as the maximum in the voting treatments. In each round a new threshold value is randomly determined. At the end of the experiment, a single randomly selected round is paid to each player. In both treatments, the participants are given complete information on past decisions (contributions and threshold values). Provided that $c_H(T_{max} - T_{min} + 1) < d$, which is a stricter assumption on the size of the damage payment than for the collective solution, we can also derive the following proposition:

Proposition 6.3. *In the repeated-game treatments the set of feasible ex ante socially optimal contribution vectors characterized by $Q^* = T_{max}$ can be implemented as subgame-perfect Nash equilibria with respect to expected payoffs.*

Similar to the reasoning in Chapter 5, Section 5.2.2, the set of subgame-perfect Nash equilibria with respect to expected payoffs can be determined via backward induction, i.e., by solving the final round of this game first. The Nash equilibria with respect to expected payoffs of this final round can be calculated in a similar fashion as the ex ante socially optimal total contribution, but maximizing individual (not total) expected payoffs. In addition, contributing nothing in the final round (i.e., $\mathbf{q^0}$) is a strict equilibrium in both repeated-game treatments, which serves as an indicator that this contribution vector is more likely in the repeated game than under a unanimous vote. Since the final subgame contains multiple equilibria, the least preferable one of these, to wit $\mathbf{q^0}$, can again be used as a threat in a trigger strategy which can implement any one of a large set of contribution outcomes in earlier rounds. Similar to the unanimous voting rule, these outcomes must be Pareto improvements to the status quo $\mathbf{q^0}$. Again, all feasible threshold allocations, meaning all feasible ex ante socially optimal contribution vectors, can be implemented as equilibria.

Once more, the equilibrium analysis gives no reason to assume different contribution behavior compared to the voting treatments. Accordingly, we postulate the following hypothesis:

Hypothesis 6.3. *The repeated-game treatments will lead to a) ex ante socially optimal total contributions and, subsequently, b) to the same relative efficiency as the voting treatments.*

6.4 Experimental design and procedure

Based on the preceding theoretical sections, we use the following experimental design:

A group consists of $n = 5$ players, each endowed with $e = 25$ ExCU ("Experimental Currency Units"). Every player can convert his endowment into up to $\bar{q} = 10$ CU ("Contribution Units") which are then collected in a public account (a common project).

In total, we consider six treatments which differ with respect to the voting rule (top-down, bottom-up, repeated game) and with respect to the marginal costs of contribution (homogeneous vs. heterogeneous), as displayed in Table 6.1.[12] In the case of homogeneous marginal contribution costs, all players have the same costs $c_H = c_L = 1\,{}^{\text{ExCU}}\!/_{\text{CU}}$. In the case of heterogeneous marginal costs, three of the five players have high costs, $c_H = 1.25\,{}^{\text{ExCU}}\!/_{\text{CU}}$, and the remaining two players have low costs, $c_L = 0.77\,{}^{\text{ExCU}}\!/_{\text{CU}}$. Contributions can be made in steps of 0.01 CU,[13] and costs are rounded to 0.01 ExCU.

Unless the sum of contributions reaches the threshold value T, a damage payment of $d = 10$ ExCU is deducted from each player's payoff at the end of the experiment. This means that high-cost players should rationally contribute at most $q_H = {}^{10}\!/_{1.25}$ CU $= 8$ CU. The threshold value takes on a whole number between (and including) $T_{min} = 16$ CU and $T_{max} = 24$ CU, each with equal probability, yielding $k = 9$ possible outcomes, each occurring with a probability of ${}^{1}\!/_{9}$.

In line with the theory presented above, all treatments are expected to lead to the same (ex ante) socially optimal contribution of $Q^* = 24$ CU (the maximum possible threshold value). Table 6.1 also contains the maximum total payoff, $\Pi(\mathbf{q}^*)$, that can be achieved in the different treatments. For homogeneous treatments, this is 101 ExCU which results from any allocation of $Q^* = 24$ CU, involving total costs of 24 ExCU deducted from the total endowment of 125 ExCU. In the heterogeneous treatments, a higher total payoff of 104.6 ExCU can be reached if the two low-cost players contribute their maximum of 10 CU each, with the remaining 4 CU split among the high-cost players.

The parameter choice for heterogeneous marginal costs ensures that any one of the nine possible threshold values can be allocated as individual contributions among the five players in such a way that an equal-payoff contribution vector can be attained, which is identical in terms of individual payoffs to that of the homogeneous counterpart. For example, in all treatments a total contribution of 21 CU can be allocated among players so that every player receives 20.6 ExCU if the threshold is reached, or 10.6 ExCU if not. This also makes sure that the optimal contribution vector does not stand out among the other choices, just because it "looks nice". However, with these cost parameters it is not individually optimal for high-cost players in the heterogeneous repeated-game treatment to reach the threshold value,[14] leaving only $\mathbf{q^0}$ as a subgame-perfect Nash equilibrium in expected payoffs. In contrast, in all other treatments, i.e., the four voting treatments and the homogeneous

[12] The participant instructions to all treatments are included in Appendix A.2.

[13] The three homogeneous treatments were conducted earlier and allowed contributions only in steps of 0.1 CU.

[14] Here, this would only be the case for $c_H \leqslant {}^{10}\!/_{9} \approx 1.11$.

Table 6.1: Investigated treatments as well as (ex ante) socially optimal total payoffs $E[\Pi(\mathbf{q}^*)]$ and resulting individual payoffs $E[\pi_i(\mathbf{q}^*)]$ for (type-) symmetric allocations. For each treatment the number of independent observations (groups) is given in brackets.

Decision rule	**Marginal contribution costs** **Homogeneous (HOM)** $c_L = c_H = 1$	**Heterogeneous (HET)** $c_L = 0.77$, $c_H = 1.25$
Top-down (TD)	TDHOM (n = 8)	TDHET (n = 8)
$E[\Pi(\mathbf{q}^*)]$	101.0 ExCU	104.60 ExCU
$E[\pi_L(\mathbf{q}^*)]$	20.2 ExCU	17.30 ExCU
$E[\pi_H(\mathbf{q}^*)]$		23.33 ExCU
Bottom-up (BU)	BUHOM (n = 8)	BUHET (n = 8)
$E[\Pi(\mathbf{q}^*)]$	101.0 ExCU	104.60 ExCU
$E[\pi_L(\mathbf{q}^*)]$	20.2 ExCU	17.30 ExCU
$E[\pi_H(\mathbf{q}^*)]$		23.33 ExCU
Repeated game (RG)	RGHOM (n = 8)	RGHET (n = 8)
$E[\Pi(\mathbf{q}^*)]$	101.0 ExCU	104.60 ExCU
$E[\pi_L(\mathbf{q}^*)]$	20.2 ExCU	17.30 ExCU
$E[\pi_H(\mathbf{q}^*)]$		23.33 ExCU

repeated-game treatment, every ex ante socially optimal contribution vector can be implemented as a subgame perfect Nash equilibrium with respect to expected payoffs, i.e., as an individually optimal choice.

The experimental procedure is the same as that used in the preceding chapters with the following exceptions. In order to rule out variations in the results due to varying individual risk preferences, every treatment is followed by a Holt and Laury (2002) decision task,[15] for which the subjects are given separate instructions including a decision sheet for them to fill in.[16] The subjects are asked to copy their decisions into another questionnaire running on their computer, which also includes questions related to general personal data (age, gender, experience with experiments) as well as strategies used in the main part of the experiment.[17]

[15]One might argue that this test is not a good measure for "collective risk preferences". However, Harrison et al. (2013) find a high correlation between individual and group risk aversion, which supports our decision for a non-interactive risk measure that is unbiased by the outcomes in the preceding experiment.

[16]These instructions are not included here as they are a rather common procedure in experimental economics.

[17]The results from both the decision task and the accompanying questionnaire show no treatment differences and are therefore omitted.

Table 6.2: Average payoffs in ExCU, cluster-robust standard errors (groups) in brackets (exchange rate: 2 ExCU = €1)

	cost	**TD**	**BU**	**RG**	**All**
HOM	$c = 1$	19.10 (1.19)	20.20 (0.00)	16.27 (0.94)	18.52 (0.59)
	both types	18.50 (1.32)	19.55 (0.65)	17.90 (1.02)	18.65 (0.59)
HET	$c_L = 0.77$	18.50 (1.32)	19.55 (0.65)	17.54 (1.63)	18.53 (0.72)
	$c_H = 1.25$	18.50 (1.31)	19.55 (0.65)	18.13 (1.29)	18.73 (0.63)
All		18.80 (0.86)	19.88 (0.32)	17.08 (0.70)	18.59 (0.41)

6.5 Results

A total of 240 subjects (6x8 groups with five members each) were recruited via ORSEE (Greiner, 2015) from a student pool at the Karlsruhe Institute of Technology. The sessions took place between December 2012 and August 2013. The computer-based experiment was conducted with z-Tree (Fischbacher, 2007). Including a show-up fee of €3 and the payoff from the Holt and Laury (2002) decision task, the subjects earned on average €14.74 (roughly US$19 at the time of the experiment) in all six treatments. Table 6.2 shows the average payoffs by treatment in ExCU. In the case of the repeated-game treatments, this is the actual payment to the subjects, i.e., the payoff from the randomly selected round. The subjects spent between one hour and one and a half hours in the laboratory.

6.5.1 Total contributions and success rates

Our main goal in this section is to show that the voting treatments lead to allocations that are approximately optimal with respect to reaching the threshold, while the repeated game usually does not. This corresponds to corroborating Hypothesis 6.2a, but rejecting Hypothesis 6.3a. The analysis is best accomplished via a comparison of total contributions and expected success rates in the various treatments. The expected success rate refers to the probability with which a given total contribution is expected to reach the threshold.[18] The comparison of total contributions is based on the total contribution on which the groups agree in the voting treatments, which in the top-down treatments is the result of the first part of the voting procedure. For the repeated game, we use Round 10, because by this point the groups will have had the highest number of interactions and opportunities for tacit coordination.

Because of the large number of ties in our data, we categorize total contributions as "optimal" ($Q \geqslant 24$ CU),[19] "risky" (16 CU $\leqslant Q < 24$ CU), or

[18] This accounts for the randomness of the threshold value which may positively or negatively affect the actual average success rate of a particular group.

[19] Since in the repeated game pin-point coordination is much harder, we also count con-

Table 6.3: Total contributions by category, as well as on average by treatment (standard errors in brackets). The last column shows the average probability of reaching the threshold given these total contributions.

		Inferior (0-15.99 CU)	**Risky** (16-23.99 CU)	**Optimal** (24-50 CU)	**Average**	**Prob. success**
TD	All	0	6	10	23.06 CU (0.3 CU)	89.58%
	HOM	0	2	6	23.25 CU (0.5 CU)	91.67%
	HET	0	4	4	22.88 CU (0.5 CU)	87.50%
BU	All	1	0	15	22.50 CU (1.5 CU)	93.75%
	HOM	0	0	8	24.00 CU (0 CU)	100.00%
	HET	1	0	7	21.00 CU (3 CU)	87.50%
RG (Rd 1)	All	3	9	4	19.27 CU (1.2 CU)	45.83%
	HOM	3	3	2	17.93 CU (2.1 CU)	36.11%
	HET	0	6	2	20.61 CU (1.1 CU)	55.56%
RG (Rd 10)	All	8	7	1	11.37 CU (2.6 CU)	32.64%
	HOM	6	2	0	5.20 CU (3.2 CU)	12.50%
	HET	2	5	1	17.54 CU (2.9 CU)	52.78%

"inferior" ($Q < 16$ CU), as displayed in Table 6.3. This table also shows average total contributions as well as the expected success rates given the range of total contributions in the respective treatment. The data for Round 1 in the repeated-game treatments are included as well for an additional analysis below.

There is no appreciable difference among the two voting rules in terms of optimal behavior, which is also corroborated by a statistical analysis.[20] The similarities with respect to expected success rates reflect this outcome.[21] In addition to Hypothesis 6.2a, these results also support Hypothesis 6.1a for the voting treatments.

However, we observe a higher frequency of "inferior" or at least "risky" choices in the repeated-game treatments, especially in homogeneous groups (RGHOM), which is also apparent in the reduced probability of success. By Round 10 half of the groups in the repeated game (and six of eight homogeneous groups) make "inferior" contributions, compared to just one in all voting groups combined, leading to average expected success rates of only 32.64% (12.5% in homogeneous groups) in the repeated game, compared to 89.58% combined in the two top-down treatments and 93.75% combined in the two bottom-up treatments. This difference is also statistically significant for both homogeneous and heterogeneous groups.[22] These results refute Hypothesis 6.3a.

tributions greater than 24 CU as "optimal".

[20]Fisher's exact test comparing absolute frequencies by treatment: $p > 0.05$ for the overall comparison as well as the pairwise treatment comparisons of categorized groups in the four voting treatments.

[21]This is not tested statistically due to the large number of ties in the data.

[22]Fisher's exact test comparing the number of successful groups: $p = 0.001$ for TDHOM

In the repeated game, most groups display lower than optimal total contributions already in Round 1 (see Table 6.3). As a consequence, after a few rounds many groups prefer not contributing at all to risking the loss of their invested contributions in addition to the damage payment for missing the threshold. Interestingly though, while six out of eight homogeneous groups converge to zero contributions in this manner over the course the experiment, only two out of eight heterogeneous groups exhibit a similar decline (see Figure 6.1). By the end of the experiment, total contributions are accordingly significantly higher in treatment RGHET than in treatment RGHOM (also Table 6.3),[23] thus allowing us to reject Hypothesis 6.1a for the repeated game.

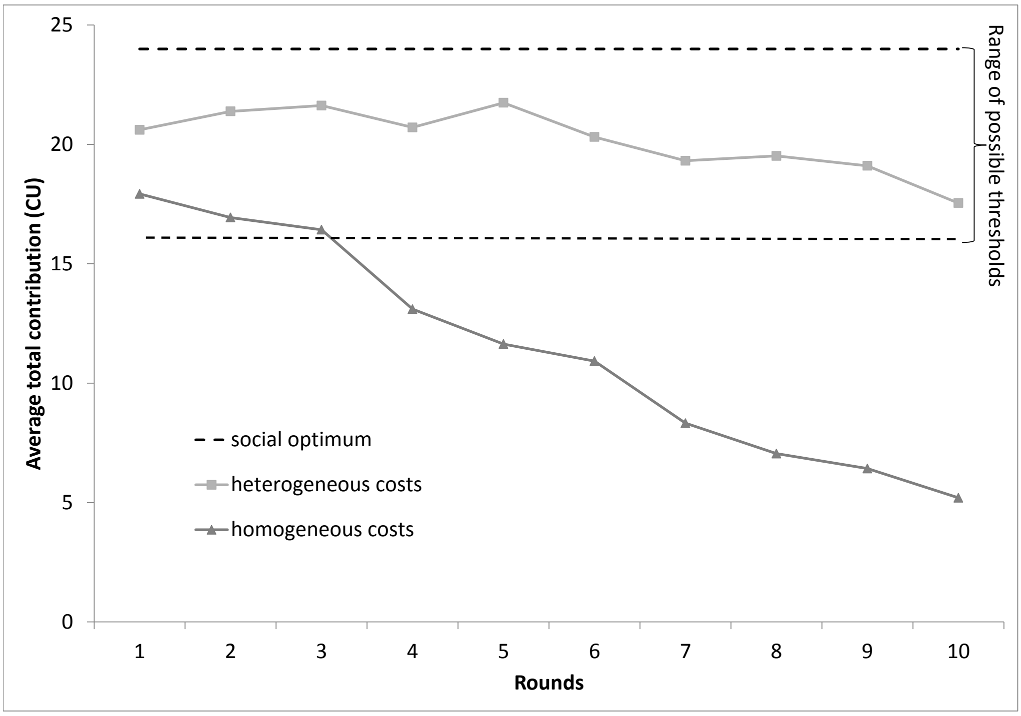


Figure 6.1: Average total contributions repeated-game (RGHOM, RGHET) treatments on a round-by-round basis.

vs. RGHOM, $p = 0.152$ for TDHET vs. RGHET, $p < 0.001$ for BUHOM vs. RGHOM, $p = 0.004$ for BUHET vs. RGHET. An overall comparison with the same test involving all six treatments also shows a significant difference among these treatments ($p < 0.001$).

[23]Two-tailed Mann-Whitney-U-test: $z = 2.318, p = 0.0204$. The test compares the total contribution in Round 10 in each group of treatment RGHET with those in treatment RGHOM.

Table 6.4: Detailed experimental results for voting treatments. Selected allocations (in CU) and rounds required to reach agreement by group in the four voting treatments.

Treatment	Group #	Rounds voted	Part I (total c.)	Part II (ind. c.)	Threshold value	Total contribution	Allocation (LL/HHH)
	1	3	2	1	17	24	(4.8/4.8/4.8/4.8/4.8)
	2	3	2	1	17	21	(4.2/4.2/4.2/4.2/4.2)
	3	7	3	4	20	24	(4.8/4.8/4.8/4.8/4.8)
	4	6	2	4	20	24	(4.8/4.8/4.8/4.8/4.8)
TDHOM	5	7	2	5	22	24	(4.8/4.8/4.8/4.8/4.8)
	6	5	4	1	22	21	(4.2/4.2/4.2/4.2/4.2)
	7	3	2	1	23	24	(4.8/4.8/4.8/4.8/4.8)
	8	4	2	2	23	24	(4.8/4.8/4.8/4.8/4.8)
	avg	4.75	2.375	2.375		23.25	
	1	4	3	1	19	24	(6.3/6.3/3.8/3.8/3.8)
	2	3	2	1	19	24	(6.15/6.15/3.9/3.9/3.9)
	3	4	1	3	22	22	(5.72/5.72/3.52/3.52/3.52)
	4	10	5	5	22	[23]	no agreement (0/0/0/0/0)
TDHET	5	4	2	2	18	24	(6.24/6.24/3.84/3.84/3.84)
	6	4	2	2	18	20	(5.2/5.2/3.2/3.2/3.2)
	7	3	1	1	16	24	(6.24/6.24/3.84/3.84/3.84)
	8	7	3	4	16	22	(5.72/5.72/3.52/3.52/3.52)
	avg	4.875	2.375	2.5		22.88	
	1	1			18	24	(4.8/4.8/4.8/4.8/4.8)
	2	2			18	24	(4.8/4.8/4.8/4.8/4.8)
	3	10			17	24	(4.8/4.8/4.8/4.8/4.8)
	4	1			17	24	(4.8/4.8/4.8/4.8/4.8)
BUHOM	5	2			22	24	(4.8/4.8/4.8/4.8/4.8)
	6	1			22	24	(4.8/4.8/4.8/4.8/4.8)
	7	7			24	24	(4.8/4.8/4.8/4.8/4.8)
	8	1			24	24	(4.8/4.8/4.8/4.8/4.8)
	avg	3.125				24	
	1	2			17	24	(6.24/6.24/3.84/3.84/3.84)
	2	6			17	24	(6.24/6.24/3.84/3.84/3.84)
	3	4			23	24	(6.24/6.24/3.84/3.84/3.84)
	4	10			23	no agreement (0)	no agreement (0/0/0/0/0)
BUHET	5	3			18	24	(6.24/6.24/3.84/3.84/3.84)
	6	8			18	24	(6.24/6.24/3.84/3.84/3.84)
	7	3			22	24	(6.24/6.24/3.84/3.84/3.84)
	8	10			22	24	(6.24/6.24/3.84/3.84/3.84)
	avg	5.75				21	

Table 6.5: Average efficiency levels in percentage of socially optimal expected payoffs, standard errors in brackets.

	TD	**BU**	**RG**	**TD & BU**	**All**
HOM	96.62 (2.22)	100 (0)	75.30 (1.63)	98.31 (1.16)	90.64 (2.44)
HET	89.09 (3.35)	93.45 (3.11)	79.97 (4.46)	91.27 (2.27)	87.50 (2.34)
All	92.85 (2.17)	96.73 (1.73)	77.63 (2.37)	94.79 (1.41)	89.07 (1.69)

The higher average number of voting rounds in HET treatments – 4.75 vs. 4.875 rounds for TDHOM vs. TDHET and even 3.125 vs. 5.75 rounds for BUHOM vs. BUHET (see Table 6.4) – suggests that the negotiation was more difficult for heterogeneous voting groups than for their homogeneous counterparts, but this difference cannot be statistically confirmed in this small sample. However, as the top-down procedure lasted only marginally longer on average in treatment TDHET, there is no reason to assume that more data would prove any different. After all, by splitting the negotiation into two separate dimensions, top-down voting is designed to lower decision costs (i.e., number of rounds) in more complex situations. Bottom-up voting, on the other hand, is quicker than top-down in the less complex situation with homogeneous players who can all contribute the same, but slower when negotiating an asymmetric allocation in the case of heterogeneity.

6.5.2 Total payoffs and efficiency

After having established that both voting procedures lead to approximately optimal total contributions, while voluntary contributions in the repeated game usually do not, we now show that heterogeneous voting groups nevertheless contribute inefficiently with respect to how the contribution is allocated among the group members. The following analysis makes use of the efficiency measure $\eta(\mathbf{q})$ defined in Section 6.3.2. The reference values for (ex ante) socially optimal total payoffs that are used to normalize this measure are displayed in Table 6.1.

While the average efficiency levels by treatment shown in Table 6.5 already indicate the presence of differences among the decision rules, an additional analysis is necessary to verify their statistical significance. For this purpose, Table 6.6 shows OLS regressions of the efficiency levels, which are based on the total contribution that the groups agreed on in the voting treatments and the total contributions of Round 10 in the repeated game. Model 1 contains all six treatments and shows that heterogeneous groups are less efficient than homogeneous groups. Furthermore, the groups in the repeated-game treatments achieve lower levels of efficiency than those under either of the voting rules, thus rejecting Hypothesis 6.3b. When restricting the sample to only the four voting treatments (Model 2), we still observe the same heterogeneity effect. It should be pointed out, though, that in this experiment this effect does not result from actual differences in total costs or payoffs, but is due to the unused potential in heterogeneous groups to increase welfare levels beyond those achievable under homogeneity. The subjects place more weight on equalizing individual payoffs than on maximizing their total gains. Moreover, we find that bottom-up voting leads to more efficient results than the top-down procedure, even though the total contributions in both treatments are not significantly different. This rejects Hypothesis 6.2b.

Table 6.6: OLS regressions for efficiency based on expected total payoffs given actual choices of total contributions. For the repeated game treatments the efficiency values are calculated based on the expected total payoffs for Round 10 contributions. The values are normalized with respect to the socially optimal expected total payoff. Whereas Model 1 applies to all six treatments, Model 2 uses only data from the voting treatments. Standard errors in brackets.

Variable	**Model 1**	**Model 2**
Heterogeneous Costs	-5.589**	-5.059**
	(1.868)	(1.797)
Repeated Game	-7.703**	
	(2.485)	
Total Contribution	0.821**	1.172**
	(0.137)	(0.213)
Bottom Up Rule		4.531*
		(1.765)
Intercept	71.09**	68.36**
	(2.269)	(5.318)
N	48	32
R^2	0.728	0.646
F	39.25	17.01

Significance levels : † : 10% $*$: 5% $**$: 1%

A non-parametric analysis of the relative efficiency of each group along the treatment dimensions using two-tailed Mann-Whitney-U tests also supports these results.[24] Furthermore, we can also establish the heterogeneity

[24] Voting ($n = 32$) vs. RG ($n = 16$): $z = 4.403$, $p < 0.001$; HOM vs. HET (all rules, $n = 24$ each): $z = 2.201$, $p = 0.028$; HOM vs. HET (only voting, $n = 16$ each): $z = 4.066$, $p < 0.001$.

Table 6.7: Summary of hypothesis tests

Hypothesis	Verdict
6.1a (no heterogeneity effect on total contributions)	supported (BU, TD), rejected (RG)
6.1b (no heterogeneity effect on relative efficiency)	rejected (BU, TD), supported (RG)
6.2a (same total contribution in TD and BU)	supported
6.2b (same relative efficiency in TD and BU)	inconclusive
6.3a (same total contribution in RG and voting)	rejected
6.3b (same relative efficiency in RG and voting)	rejected

effect in a pairwise comparison for each voting rule,[25] but not for the repeated game,[26] where the heterogeneous groups are actually more efficient on average. However, a non-parametric comparison of the two voting rules (excluding the repeated-game treatments) does not lead to significant differences,[27] meaning that the final verdict for Hypothesis 6.2b is inconclusive.

Table 6.7 summarizes our verdict for the tested hypotheses.

6.6 Discussion

In the study by Margreiter et al. (2005), which involves extractions from a common-pool-resource game, an analogous heterogeneity to ours, namely of marginal extraction costs, can be exploited to increase efficiency levels as well. Yet, while the authors also report lower efficiency for groups with heterogeneous players, this is due to a lack of agreement, and not due to an inefficient allocation. In fact, almost all adopted proposals appear to be socially optimal (cf. Margreiter et al., 2005, Table V). While we cannot confirm the findings of Margreiter et al. (2005) that heterogeneous groups are less likely to reach an agreement, we nevertheless observe a significantly higher number of voting rounds in heterogeneous treatments, which equally indicates that negotiations in these groups are more difficult. Walker et al. (2000) in their unanimity treatment (part of Design II) with homogeneous players also observe a high percentage of efficient symmetric proposals, but a significantly lower proportion of actual agreement implementing such a proposal (only 60% adoption rate). Having only a single paid round instead of twenty separate chances of earning money as well as being able to negotiate several rounds before the choice is implemented compared to only one round are probably the two reasons for the higher adoption rates in our voting treatments.

The predominance of equal-payoff outcomes we observe again contrasts with other experimental studies that involve committee voting.[28] Equal-payoff out-

[25] BUHOM vs. BUHET: $z = 3.771$, $p < 0.001$; TDHOM vs. TDHET: $z = 2.162$, $p = 0.031$.

[26] RGHOM vs. RGHET: $z = -0.853$, $p = 0.394$.

[27] TD vs. BU ($n = 16$ each): $z = -1.295$, $p = 0.1952$.

[28] See the discussion in Chapter 4, Section 4.7.

comes also do not seem to play a role in the study by Margreiter et al. (2005), likely due to the accumulated payoff from multiple paid rounds. The proposers in the study by Gampfer (2014) do not try to equalize payoffs as well, although here the reason may be that this would have required a very asymmetric allocation.

In terms of total contributions and (expected) success rates, our homogeneous treatments are most closely related to the studies by Barrett and Dannenberg (2012, 2014). Of the four treatments with threshold uncertainty that these authors report, three almost exclusively result in coordination failure with total contributions below or at best at the bottom end of possible threshold values. Only the “145/155” treatment has comparable results to ours, with 40% choices that we would classify as “optimal” and the remaining 60% in the “risky” range. Since all of these treatments are one-shot voluntary contribution games with homogeneous players, these results can best be compared to Round 1 of the RGHOM treatment, which has only slightly worse results (25% optimal, 37.5% risky, 37.5% inferior; cf. Table 6.3). Of course, our homogeneous voting treatments, which are essentially also one-shot, perform much better in terms of optimality (BUHOM: 100% optimal, TDHOM: 75% optimal, 25% risky; cf. Table 6.3), but do not involve voluntary contributions. Remarkably, although Barrett and Dannenberg (2012, 2014) use larger groups of ten players, this does not seem to impede successful contribution in the “145/155” treatment.

The decrease of contribution levels in the homogeneous repeated-game treatment can be directly attributed to the fact that contribution costs are lost if the threshold is missed (no refund). Isaac et al. (1989) observe a similar decline in contributions over time. Strikingly, we observe higher contribution levels in non-voting groups with heterogeneous marginal contribution costs, despite the fact that reaching the threshold is not individually optimal for high-cost players. Unlike homogeneous groups, most heterogeneous groups manage to keep total contributions on a level that is almost comparable to that of voting groups.

A possible explanation for this result is the presence of multiple and conflicting behavioral norms in the RGHET treatment (as suggested also by the experiments discussed in Chapter 4). Whereas in the homogeneous treatment reducing one’s contribution is a clear signal of an unwillingness to reach the threshold, the same reduction of contributions in the heterogeneous treatment, if caused by a high-cost player, may equally be an attempt to move to a more efficient allocation of the current total, benefiting all players in the long run. Furthermore, as it is initially unclear what particular allocation rule the group should follow, which could involve maximizing expected welfare just as well as equalizing payoffs, the players in the heterogeneous treatment may just have been more tolerant towards violations of this allocation rule. In contrast, those players who contribute less than average in the homogeneous treatment are likely to provoke other players into lowering their contributions as well. On the other hand, ten rounds of voting may have just been too little for a clear verdict on convergence patterns.

6.7 Conclusion

We show that the top-down procedure currently in use in the international negotiations to prevent global warming has a good chance of reaching this goal. However, given that the countries involved in these negotiations are heterogeneous with respect to the marginal abatement costs of green-house gas emissions, any agreement is unlikely to be cost-efficient. In the light of the efficiency-increasing effect of transfer payments reported in Chapter 5, promoting emissions trading may be a logical political step.

The procedure effect that was established in Chapter 4 is also very relevant to climate negotiations. What if some countries deliberately sabotage an agreement reached under the consensus rule, hoping that subsequent attempts to prevent global warming via strictly national abatement efforts or at best regional agreements will be no less successful? It is very unlikely then, that exactly the same allocation of the abatement burden results under both procedures, meaning that some countries will indeed profit from a procedural change under these circumstances. On the other hand, there is still the possibility that a failure of negotiations leads to the collapse of abatement efforts stipulated in this experiment's choice of no-agreement outcome. I should point out, though, that reaching an agreement of any kind would be more difficult, if not impossible, if said no-agreement outcome did not allow Pareto improvements to occur in the negotiations. Considering that the Middle East (as oil-producing countries) and Russia (with its large areas of currently still frozen soil) may have little, if anything, to gain from successful negotiations, a collective effort to prevent global warming may not be feasible in any case.

6.A The Simplified ThrPG and adaptation measures

In this section, I will extend the Simplified ThrPG from Chapter 2 in a way that is applicable in the context of climate change, with which the present chapter has been concerned. More precisely, I will use the model to contrast the trade-off between investing in emissions reductions (mitigation) and investing in measures to decrease only the national damages a country expects to suffer due to global warming (adaptation). This topic has been of interest to environmental economists for at least fifteen years (e.g., Kane and Shogren, 2000) and has recently also been investigated experimentally (e.g., by Blanco et al., Unpublished). By including adaptation in the model, I will derive the (to my knowledge) novel prediction that the mere anticipation of adaptation efforts already reduces the probability that climate change will be prevented.

The readiness to prepare for impending damages may therefore create a self-fulfilling prophecy, because other players may take this expectation as a signal for mistrust in the attempted cooperation.

In order to show this result, it is unnecessary to assume a randomly distributed threshold value or heterogeneous players, which is why I focus again on the game with homogeneous players, no refund, and contribution costs of $c = 1$ that was also used in the previous model extensions. The new element in this variant is that, in addition to investing their endowment in contributions, the players can now also invest in preventive adaptation measures at a cost of $a < e$, which decreases damages d by a fraction of a/e, but does not affect the probability of taking damages in the first place. In other words, mitigation to prevent climate change and adaptation to reduce individual climate-change-related damages are independent investments. I will assume that adaptation is a binary choice, meaning that the players can choose between no adaptation ($a = 0$) and adaptation at a specific positive level of $0 < a$.[29] With the additional assumption of $a \leqslant e - \bar{q}$, I furthermore rule out that the decision between mitigation and adaptation is governed by restricted resources, meaning that a player can only afford either to contribute or to reduce damages, but not both at the same time. This is not a critical assumption, however. A player's strategy now takes the form (q_i, a), where q_i is player i's contribution and a is the player's adaptation effort.

This modifies player i's payoff $\pi_i(\mathbf{q}, a)$ as follows:

$$\pi_i(\mathbf{q}, a) = \begin{cases} e - q_i - a & \text{if} \quad Q \geqslant T \\ e - q_i - a - (1 - \frac{a}{e})d & \text{if} \quad Q < T \end{cases} \tag{6.4}$$

If the threshold value T is reached, adaptation is unnecessary and therefore optimally set equal to zero. In all other cases, adaptation at a level of $a > 0$ increases player i's payoff if and only if

$$e - q_i - a - (1 - \frac{a}{e})d > e - q_i - d \tag{6.5}$$

or equivalently

$$d > e. \tag{6.6}$$

This inequality is true if damages d are sufficiently large, meaning that a player will usually prefer adaptation to no adaptation if the threshold is not reached. This also means that contributing nothing, but spending money on adaptation, i.e., strategy $(0, a)$, is a best response if all other players also do not contribute. In theory, adaptation could work so well that it turns $(0, a)$ into a strictly dominant strategy, to be preferred, for example, even if all other players contribute a fair share of the threshold. This means that a player rather

[29] This is a simplification of the approach by Blanco et al. (Unpublished) who model the interaction of mitigation and a range of possible adaptation choices in a linear public goods game.

spends his money on a cheap adaptation measure instead of a costly reduction of his emissions. This would be the case if

$$e - \frac{T}{n} < e - a - (1 - \frac{a}{e})d \tag{6.7}$$

or equivalently

$$d < \frac{\frac{T}{n} - a}{1 - \frac{a}{e}}. \tag{6.8}$$

However, for this condition to be satisfied, damages would have to be smaller than endowments ($d < e$) which contradicts condition (6.6). We can conclude from this that adaptation does not affect the game's pure strategy equilibria with respect to contributions. Furthermore, only the zero-contributions equilibrium will entail positive adaptation levels, meaning that the players substitute mitigation (contributions) for adaptation. Figure 6.2 shows the subsequently simplified game – with strategies $q_{i,1/n}(0) := (T/n, 0)$ and $q_{i,0}(a) := (0, a)$ – from the perspective of player i playing against the rest of the group (again assuming only equal contributions as a focal threshold allocation).

		Rest of the Group	
		$Q_{-i} = T - \frac{T}{n}$	$Q_{-i} < T - \frac{T}{n}$
a) Player i	$q_{i,1/n}(0)$	$e - \frac{T}{n}$	$e - \frac{T}{n} - d$
	$q_{i,0}(a)$	$e - a - (1 - \frac{a}{e})d$	$e - a - (1 - \frac{a}{e})d$

Figure 6.2: A simplified threshold public goods game with two pure-strategy Nash equilibria if the players can invest their endowment in adaptation in addition to contributions. The matrix shows the payoffs of player i playing against the rest of the group, whose decisions are represented by the total contribution Q_{-i}.

The theoretical success rate resulting from this game is equal to

$$p_{\frac{1}{n}}(a) = 1 - \sqrt[n-1]{\frac{T}{nd} + a(\frac{1}{e} - \frac{1}{d})}. \tag{6.9}$$

It is then easy to see that $p_{1/n}(a) < p_{1/n}(0)$ if

$$d > e, \tag{6.10}$$

that is to say, whenever a positive level of adaptation is individually optimal under the expectation that the threshold is not reached. These findings are consistent with the theoretical analysis by Kane and Shogren (2000), who also predict that mitigation efforts are adversely affected by adaptation efforts.

However, in contrast with their model, the Simplified ThrPG can yield this prediction even if there is no conflict of resources that forces a government to decide between *either* reducing their emissions *or* preparing for a potential climate catastrophe.

Given these results, let us imagine now that the same group of players meets twice to discuss their individual contribution strategies (in an informal manner that does not lead to a binding agreement, but allows the group to single out a specific threshold allocation as a focal point). In the first meeting the groups talks only about emission reductions and basically analyzes the game in the case of $a = 0$. The group realizes the potential benefit of an equal split of T, but also recognizes zero contributions as a safe choice, as well as also a threat point against non-compliance in a possible cooperative solution to the problem. When the group meets for the second time, however, some players declare that they have considered adaptation measures to reduce any individual damages that they could suffer if climate change is not prevented. These players assure their fellow group members that they can still contribute their assigned share of T, but that they would rather be safe than sorry should reaching the threshold prove unlikely. As a result, the aforementioned threat of zero contributions looses much of its teeth, because adaptation severely reduces the damages suffered by non-contributors in this event. So, any players that have not yet considered adaptation will likely do so after the second meeting in order to maximize their payoffs when the game is finally played.

This example shows that, even though not a single contribution has yet been made, the mere anticipation of failing to reach the threshold, of suffering damages due to climate change, can already lower the chances of reaching this goal. Just by considering adaptation measures, the group creates a self-fulfilling prophecy which makes it all the more likely that these measures will actually have to be implemented. What is particularly insidious here is that a player's adaptation plans have no direct impact on his mitigation efforts (assuming no conflict of resources), but instead affect his contribution choice only indirectly through an adjusted reaction to the *other* players' (expected) mitigation efforts.

Chapter 7

Summary and outlook

Most of the results presented in this thesis are still work in progress, meaning that this is ultimately only a snapshot of my current research. This concluding section of the thesis therefore serves as much as an outlook on future research possibilities as it summarizes the main findings from the preceding chapters.

The theoretical model of success rates in ThrPGs discussed in Chapter 2 appears to fit rather well with the existing experimental literature. However, it still needs to prove its predictive power in a direct empirical test. One way to do this is to conduct a new meta-analysis similar to Croson and Marks (2000), testing the model on a general level. At this time, I have collected most of the necessary data, but am still looking for the best methodological approach for using this data to test my model against competing predictions, e.g., those by impulse balance theory (Alberti et al., Unpublished). Another approach is to derive predictions for specific parameters, e.g., that success rates decrease in groups with more players, and conduct a series of experimental tests.

Aside from the empirical corroboration of the model, additional theoretical work is necessary to extend the model beyond the "primary dimension" of choosing between one focal threshold equilibrium and zero contributions to the "secondary dimension" of choosing between multiple focal equilibria. I am quite optimistic that a geometric analysis of the *entire* ThrPG can succeed here. However, doing so will likely require expressing the total number of Nash equilibria of this game as an explicit function of parameters like the proportion of the threshold value to total endowments as well as the number of players.

The apparent effect that different decision rules have on the selection of focal equilibria in ThrPGs described in Chapter 4 needs to be reproduced in an additional experimental analysis. For this purpose, it may be sufficient to conduct a one-shot ThrPG with different decision rules, possibly including the variations employed by Alberti and Cartwright (2016), and to analyze only the difference of individual contribution behavior (by player type). A more refined method of measuring stated fairness preferences, possibly based on social value orientation (e.g. Murphy et al., 2011), should complement these additional experiments. A very simple test (at least based on what has already been discussed in this thesis) of the hypothesis that the subjects (individually) prefer equal payoffs also in the repeated game with heterogeneous endowments, but find this too difficult to implement, is to give these players the option to redistribute the resulting payoffs via transfers, similar to the experiment with heterogeneous marginal costs that Karl-Martin Ehrhart and I have already conducted.

On the other hand, having established the usefulness of transfer payments for efficiency increases in a controlled setting in Chapter 5, future research could focus more on the application of this idea in practice, e.g., in the context of reward-based crowdfunding. Here, an initial step is to extend the model to sequential contributions in "large" groups (in the sense that individual players are rarely pivotal to reaching the threshold). Transfer payments (or rewards) then become more of an incentive to contribute instead of a means of redistribution. In this scenario, the collective value of reaching the threshold may fall behind the personal interests of the contributors, leading to excessive overcontribution, which here means that contributions are made even after the threshold has already been reached.

Modeling international negotiations, as has been done in Chapter 6, will obviously continue to be a meaningful undertaking in the future. The fact that the outcome of these negotiations depends so strongly on the status quo scenario, to the extent that real-life climate negotiations may very well fail on a global scale, because some countries stand to benefit from global warming, gives rise to the question whether this threat point can be manipulated by the negotiating parties or by a higher authority (if such exists). Given that unanimous agreement requires a Pareto improvement over this status quo situation, decreasing a competitor's reference payoff, for example through economic sanctions or even a military attack, may be seem like a good idea if the negotiations are stuck. On the other hand, such a hostile behavior may be just as likely to provoke countermeasures instead of facilitating agreement.

All in all, threshold public goods games still offer many opportunities for future research. My thesis will hopefully provide an additional impulse in that respect.

Afterword

"The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!', but 'That's funny ...'" – Isaac Asimov

Contrary to the structure presented in the following introductory section, my thesis actually started with an attempt to model the ongoing climate negotiations in a laboratory environment. This was meant as a contribution to the project "Cooperative Regimes for a Future Climate Policy" (CORE), funded by the German Federal Ministry for Research, which provided the means to conducting the (relatively expensive) experiments that form the backbone of this work.

The results of this initial research, which have been summarized in the final chapter of this thesis, were on the one hand surprisingly consistent with what we (that is, Karl-Martin Ehrhart, Jan Krämer, and me) had theoretically predicted. In fact, in the first two series of experiments (a top-down vs. bottom-up comparison with uniform vs. truncated normal threshold distributions) we did not find any statistically significant effects at all, even though the results were very consistent. Only by adding first individual voluntary contributions and then player heterogeneity did we finally obtain some testable results. These results were surprising in another sense, because now we could not explain them at all with our theoretical model: Why should groups with heterogeneous marginal contributions costs focus so much on equal-payoff outcomes, and not so much on welfare maximization? And why is it that the same heterogeneous groups, when employing only individual contributions to coordinate their behavior, are so much more successful than their homogeneous counterparts – at least if the threshold is uncertain and/or the contributions are not refunded if the threshold is missed?

The earlier chapters in this thesis came about in response to these "funny" outcomes. First was the idea (originally brought forward by Karl-Martin Ehrhart) of using transfers payments as a means for redistribution, which, at least in theory, should make welfare-maximizing outcomes more attractive, because the welfare can now be shared equally. This worked quite well, actually, both theoretically and experimentally. Second was the idea (now entirely my own) to introduce a different kind of heterogeneity in order to possibly replicate our previous results and to better contrast them with the rest of the experimental literature. Although the results for each of the two decision rules were by themselves again pretty much in concordance with previous experiments, in combination they created another of those "that's funny" moments that Isaac Asimov was apparently talking about: Why should a group negotiating under a unanimity rule focus on equal payoffs (and unequal contributions), but a similar group relying on individual voluntary contribution focus on equal contributions (and unequal payoffs)? Although the theoretical work presented at the very beginning of this thesis helped me understand some of the connections between unanimous voting and voluntary contributions (for example, both are essentially coordination games), everything written down here is still pretty much work in progress. I'm not sure if this research will actually amount to something worth calling a "new discovery", but the initial funny feeling has definitely inspired me to do additional studies in this field.

Appendix A

Experimental instructions

The following experimental instructions were translated from German. Please note that the instructions are only translations for information; they are not intended to be used in the lab. The instructions in the original language were carefully polished in grammar, style, comprehensibility, and avoidance of strategic guidance.

A.1 Instructions to Chapters 4 and 5

A.1.1 Treatment VEND

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €5 Over the course of the experiment you can earn an additional amount of up to €16.50. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment.

THE PROJECT Your task in this experiment is to choose your and your fellow players' contributions to a project. Your decision consists in a **vote on the individual contributions of all players in a group**. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players vote on the **individual contributions of all group players to a project.** This happens in **up to ten voting rounds** and proceeds as follows:

1. Proposals for contributions to the project
2. Unanimous vote on the proposals
3. Result: project successful?

If there is **no unanimous agreement**, Steps 1. and 2. are repeated, i.e., **new proposals** are made and **new votes** are cast. After the tenth unsuccessful voting round, the **status quo** is implemented, which means that nobody contributes anything.

DETAILS OF THE PROCEDURE

1. Proposals for contributions to the project

   At the beginning of the experiment, each player has an **endowment which is measure in Experimental Currency Units (ExCU). The exact amount of this endowment differs among the players:**

Players A and B	Endowment of **27 ExCU**
Players C and D	Endowment of **33 ExCU**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   Each player's contribution is measured in Contribution Units (CU). Each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution can therefore amount to up to 40 Contribution Units.

The costs per provided Contribution Unit are the same for all players:

Players A, B, C, D	1 Contribution Unit costs 1.5 Experimental Currency Units **(1 CU = 1.5 ExCU)**

Each player makes a proposal for the contribution of every single player. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). **The individual contributions from each proposal are automatically summed up to a total contribution.**

By clicking on **"Calculate values"** you can make the program display the total contribution, as well as each player's contribution costs and earnings in Experimental Currency Units.

The proposals (that is, contribution costs, total contribution, and resulting earnings) are shown to all players in a list (see Table A.1). Among these is also a proposal called **"status quo"**. This proposal means that each player makes a contribution of 0 Contribution Units (total contribution 0 CU). Next to each proposal there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Including the status quo, there can accordingly be up to five different contribution proposals.

2. Unanimous vote on the proposals

   At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal please click on "Accept" in the column directly to the right of the proposal. Each player then learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative.

   (a) **Unanimous decision** (all four players vote for the same proposal):
   The experiment ends with the calculation of earnings and payoffs.

   (b) **No unanimous decision:**
   Rounds 1 to 9: New proposals are made (see above, 1.), on which new votes are then cast.
   Round 10: The **status quo** (each player makes a contribution of 0 Contribution Units, total contribution of 0 Contribution Units, individual earnings of 2 or 8 Experimental Currency Units) is used for the calculation of payoffs.

3. Result: project successful?

   In the experiment the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached, each player must make a **payment in Experimental Currency Units**, which is deducted from his endowment. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

Table A.1: Reproduction of screenshot for voting decision in treatment VEND.

Voting round 2 of up to 10
You are Player A
Please accept one of the following proposals!
If the total contribution is smaller than 16.00 CU, every player must make a payment of 25 ExCU **instead** of the contributed amount.
Results Round 1 | Back to decision

Proposal	**Endowment (ExCU)**	**Player A 27 ExCU**	**Player B 27 ExCU**	**Player C 33 ExCU**	**Player D 33 ExCU**	**Total Contribution (CU)**	
Player A (your	Contribution (CU)	1	3	4	2	10	Accept
proposal)	Payment (ExCU)	-25	-25	-25	-25		
Player C	Earnings (ExCU)	2	2	8	8		
Player B	Contribution (CU)	8	3	4	2	17	Accept
	Contribution Costs (ExCU)	-12	-4.5	-6	-3		
	Earnings (ExCU)	15	22.5	27	30		
Player D	Contribution (CU)	9	5	6	3	23	Accept
	Contribution Costs (ExCU)	-13.5	-7.5	-9	-4.5		
	Earnings (ExCU)	13.5	19.5	24	28.5		
Status quo	Contribution (CU)	0	0	0	0	0	Accept
	Payment (ExCU)	-25	-25	-25	-25		
	Earnings (ExCU)	2	2	8	8		

The payment if the minimum contribution is not reached is the same for all players:

Players A, B, C, D Payment of **25 ExCU**

(a) Total contribution **greater than or equal to** 16 CU
Every player pays his contribution costs.
Earnings = your endowment (in ExCU) − your contribution costs (in ExCU)

(b) Total contribution **less than** 16 CU
Every player pays 25 ExCU
Earnings = your endowment (in ExCU) − 25 ExCU

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, the obtained earnings are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€5).

Example for the procedure of a voting round:
A total of five proposals for the group players' individual contributions:

(See Table A.1)

The proposal "1 CU, 3 CU, 4 CU, 2 CU" with a total contribution of 10 CU has been made twice, but only counts as a single alternative. As the minimum contribution is missed with this proposal, each player must make a payment of 25 ExCU instead of contribution costs.

The proposal "8 CU, 3 CU, 4 CU, 2 CU" with a total contribution of 17 CU exceeds the minimum contribution of 16 CU. Each player must therefore pay his contribution costs.

All four players vote for "B". The other three different proposals ("Status quo", "A, C", "D") do not receive any votes this time.

The voting procedure ends in this example with the selection of proposal "B" and a total contribution of 17 CU.

Examples for the calculation of earnings:
Example 1:
The players in a group provide the following individual contributions which add up to a **total contribution of 10 CU:**

- Player A: 1 CU with costs of 1.5 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU. Accordingly, Players A and B (endowment 27 ExCU) receive earnings of 2 ExCU, whereas Players C and D (endowment of 33 ExCU) receive earnings of 8 ExCU.

Example 2:

The players in a group provide the following individual contributions which add up to a **total contribution of 17 CU:**

- Player A: 8 CU with costs of 12 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **reached** in this case. Accordingly, Player A for example receives earnings of 30 ExCU − 12 ExCU = 18 ExCU. In contrast, Player C receives earnings of 30 ExCU − 6 ExCU = 24 ExCU. Accordingly, Player A (endowment 27 ExCU) for example receives earnings of 27 ExCU − 12 ExCU = 15 ExCU. In contrast, Player C (endowment 33 ExCU) receives earnings of 33 ExCU − 6 ExCU = 27 ExCU.

Please note that, with the beginning of the second voting round, you may recall the **results from preceding rounds** during each decision by clicking on the button "Result Round X" for the respective Round X. By clicking on the button "Back to Decision" you can return to the current voting round.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

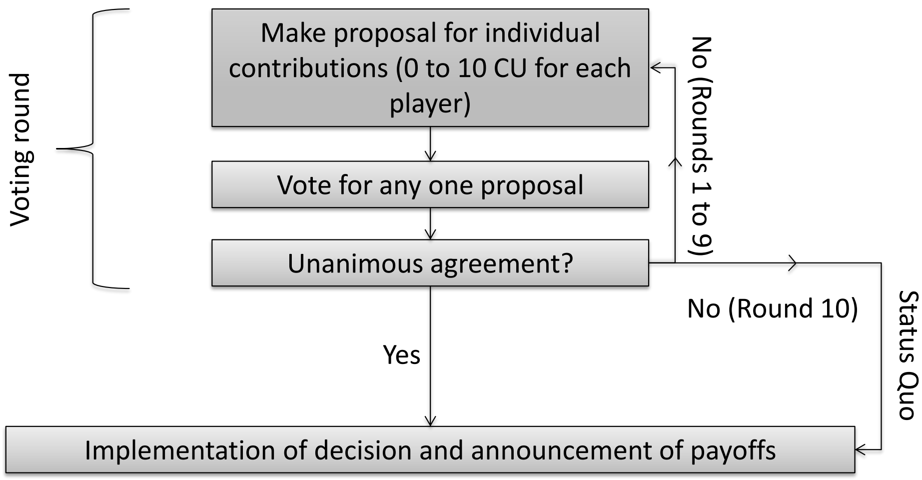


Figure A.1: Experimental procedure of treatment VEND.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.1.2 Treatment REND

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €5 Over the course of the experiment you can earn an additional amount of up to €16.50. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment, that is, in all **ten rounds**.

THE PROJECT Your task in each of the ten rounds is to choose your contribution to a project. At the same time, all other players in your group also choose their own contributions to this project. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players each choose **your own contribution to a project.** This occurs repeatedly in a total of **ten decision rounds**, which all proceed as follows:

1. Choice of contributions to the project
2. Result: project successful?

The experiment consists of a **total of ten such independent decisions** in a total of ten rounds. **Only one of these rounds is relevant for your payoff, however.** Which of these rounds is paid will be determined at the end of the experiment, individually for each player. In doing so, each of the ten rounds has the same probability of being chosen.

DETAILS OF THE PROCEDURE

1. <u>Choice of contributions to the project</u>

   At the beginning of each round, each player has an **endowment which is measure in Experimental Currency Units (ExCU). The exact amount of this endowment differs among the players:**

   Players A and B Endowment of **27 ExCU**
   Players C and D Endowment of **33 ExCU**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   Each player's contribution is measured in Contribution Units (CU). In every single round, each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution in each round can therefore amount to up to 40 Contribution Units.

The costs per provided Contribution Unit are the same for all players:

Players A, B, C, D	1 Contribution Unit costs 1.5 Experimental Currency Units **(1 CU = 1.5 ExCU)**

At the same time as all of the other players in his group, each player chooses his own contribution to the project. In order to do so, he chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on **"Calculate values"** you can make the program display the corresponding amount in Experimental Currency Units, as well. **The individual contributions of all players are automatically summed up to a total contribution.**

2. Result: project successful?

   In each round the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached in a particular round, each player must make a **payment in Experimental Currency Units**, which is deducted from his earnings in the respective round. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

   The payment if the minimum contribution is not reached is the same for all players:

Players A, B, C, D	Payment of **25 ExCU**

   (a) Total contribution **greater than or equal to** 16 CU

   Every player pays his **individual contribution costs**.

   Earnings = your endowment (in ExCU) − your contribution costs (in ExCU)

   (b) Total contribution **less than** 16 CU

   Every player pays 25 ExCU

   Earnings = your endowment (in ExCU) − 25 ExCU

   After all players in your group have made their contribution choice, all players are shown the total contribution of their group as well as the resulting earnings of all players. The contributions and contribution costs of the other players in the group are displayed, too.

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, one of the ten rounds is selected at random. All rounds have the same probability of being selected. **This means that you receive only the final earnings of a single round.** The results of the remaining rounds are no longer relevant for your payoff, no matter whether or not the minimum contribution was reached in these rounds. The earnings obtained in the randomly selected round are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€5).

Example for the procedure of a round:
Example 1:
The players in a group provide the following individual contributions in this round which add up to a **total contribution of 10 CU:**

- Player A: 1 CU with costs of 1.5 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, Players A and B (endowment 27 ExCU) receive earnings of 2 ExCU, whereas Players C and D (endowment of 33 ExCU) receive earnings of 8 ExCU in this round.

Example 2:
The players in a group provide the following individual contributions in this round which add up to a **total contribution of 17 CU:**

- Player A: 8 CU with costs of 12 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **reached** in this case. Accordingly, Player A (endowment 27 ExCU) for example receives earnings of 27 ExCU − 12 ExCU = 15 ExCU. In contrast, Player C (endowment 33 ExCU) receives earnings of 33 ExCU − 6 ExCU = 27 ExCU.

Please note that, with the beginning of the second round, you may recall the **results from preceding rounds** during each decision by clicking on the button "Result Round X" for the respective Round X. By clicking on the button "Back to Decision" you can return to the current round. After choosing your contribution (Button "Confirm Choice") you have one additional opportunity to correct this choice if necessary. As soon as you click the button "Confirm Choice and Continue", your choice is final.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right

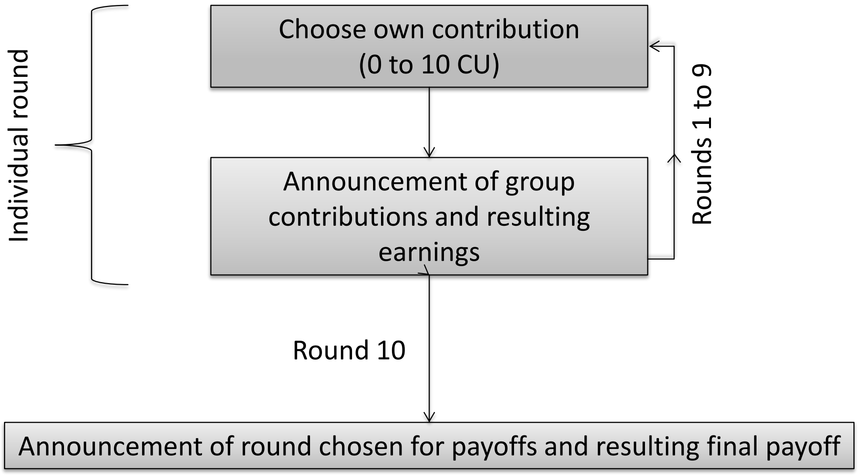


Figure A.2: Experimental procedure of treatment REND.

side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.1.3 Treatment VHOM

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €5 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment.

THE PROJECT Your task in this experiment is to choose your and your fellow players' contributions to a project. Your decision consists in a **vote on the individual contributions of all players in a group**. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players vote on the **individual contributions of all group players to a project.** This happens in **up to ten voting rounds** and proceeds as follows:

1. Proposals for contributions to the project
2. Unanimous vote on the proposals
3. Result: project successful?

If there is **no unanimous agreement**, Steps 1. and 2. are repeated, i.e., **new proposals** are made and **new votes** are cast. After the tenth unsuccessful voting round, the **status quo** is implemented, which means that nobody contributes anything.

DETAILS OF THE PROCEDURE

1. Proposals for contributions to the project

   At the beginning of the experiment, each player has an **endowment which is measure in Experimental Currency Units (ExCU). The exact amount of this endowment is the same for all players:**

Players A, B, C, D	Endowment of **30 ExCU**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   Each player's contribution is measured in Contribution Units (CU). Each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution can therefore amount to up to 40 Contribution Units.

   The costs per provided Contribution Unit are the same for all players:

Players A, B, C, D	1 Contribution Unit costs 1.5 Experimental Currency Units **(1 CU = 1.5 ExCU)**

   Each player makes a proposal for the contribution of every single player. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). **The individual contributions from each proposal are automatically summed up to a total contribution.**

   By clicking on **"Calculate values"** you can make the program display the total contribution, as well as each player's contribution costs and earnings in Experimental Currency Units.

   The proposals (that is, contribution costs, total contribution, and resulting earnings) are shown to all players in a list (see Table A.2). Among these is also a proposal called **"status quo"**. This proposal means that each player makes a contribution of 0 Contribution Units (total contribution 0 CU). Next to each proposal there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Including the status quo, there can accordingly be up to five different contribution proposals.

2. Unanimous vote on the proposals

   At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal please click on "Accept" in the column directly to the right of the proposal. Each player then learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative.

   (a) **Unanimous decision** (all four players vote for the same proposal):

   The experiment ends with the calculation of earnings and payoffs.

(b) **No unanimous decision:**

Rounds 1 to 9: New proposals are made (see above, 1.), on which new votes are then cast.

Round 10: The **status quo** (each player makes a contribution of 0 Contribution Units, total contribution of 0 Contribution Units, individual earnings of 5 Experimental Currency Units) is used for the calculation of payoffs.

3. Result: project successful?

In the experiment the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is not reached, each player must make a **payment in Experimental Currency Units**, which is deducted from his endowment. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

The payment if the minimum contribution is not reached is the same for all players:

Players A, B, C, D Payment of **25 ExCU**

(a) Total contribution **greater than or equal to** 16 CU

Every player pays his contribution costs.

Earnings = your endowment (in ExCU) − your contribution costs (in ExCU)

(b) Total contribution **less than** 16 CU

Every player pays 25 ExCU

Earnings = your endowment (in ExCU) − 25 ExCU

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, the obtained earnings are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€5).

Example for the procedure of a voting round:

A total of five proposals for the group players' individual contributions:

(See Table A.2)

The proposal "1 CU, 3 CU, 4 CU, 2 CU" with a total contribution of 10 CU has been made twice, but only counts as a single alternative. As the minimum contribution is missed with this proposal, each player must make a payment of 25 ExCU instead of contribution costs.

The proposal "8 CU, 3 CU, 4 CU, 2 CU" with a total contribution of 17 CU exceeds the minimum contribution of 16 CU. Each player must therefore pay his contribution costs.

All four players vote for "B". The other three different proposals ("Status quo", "A, C", "D") do not receive any votes this time.

The voting procedure ends in this example with the selection of proposal "B" and a total contribution of 17 CU.

Table A.2: Reproduction of screenshot for voting decision in treatment VHOM.

Voting round 2 of up to 10

You are Player A

Please accept one of the following proposals!

If the total contribution is smaller than 16.00 CU, every player must make a payment of 25 ExCU **instead** of the contributed amount.

Results Round 1 Back to decision

Proposal	**Endowment (ExCU)**	**Player A 30 ExCU**	**Player B 30 ExCU**	**Player C 30 ExCU**	**Player D 30 ExCU**	**Total Contribution (CU)**	
Player A (your proposal)	Contribution (CU)	1	3	4	2	10	Accept
	Payment (ExCU)	-25	-25	-25	-25		
Player C	Earnings (ExCU)	5	5	5	5		
Player B	Contribution (CU)	8	3	4	2	17	Accept
	Contribution Costs (ExCU)	-12	-4.5	-6	-3		
	Earnings (ExCU)	18	25.5	24	27		
Player D	Contribution (CU)	9	5	6	3	23	Accept
	Contribution Costs (ExCU)	-13.5	-7.5	-9	-4.5		
	Earnings (ExCU)	16.5	22.5	21	25.5		
Status quo	Contribution (CU)	0	0	0	0	0	Accept
	Payment (ExCU)	-25	-25	-25	-25		
	Earnings (ExCU)	5	5	5	5		

Examples for the calculation of earnings:

Example 1:

The players in a group provide the following individual contributions which add up to a **total contribution of 10 CU:**

- Player A: 1 CU with costs of 1.5 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU.

Example 2:

The players in a group provide the following individual contributions which add up to a **total contribution of 17 CU:**

- Player A: 8 CU with costs of 12 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **reached** in this case. Accordingly, Player A for example receives earnings of 30 ExCU − 12 ExCU = 18 ExCU. In contrast, Player C receives earnings of 30 ExCU − 6 ExCU = 24 ExCU.

Please note that, with the beginning of the second voting round, you may recall the **results from preceding rounds** during each decision by clicking on the button “Result Round X” for the respective Round X. By clicking on the button “Back to Decision” you can return to the current voting round.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only

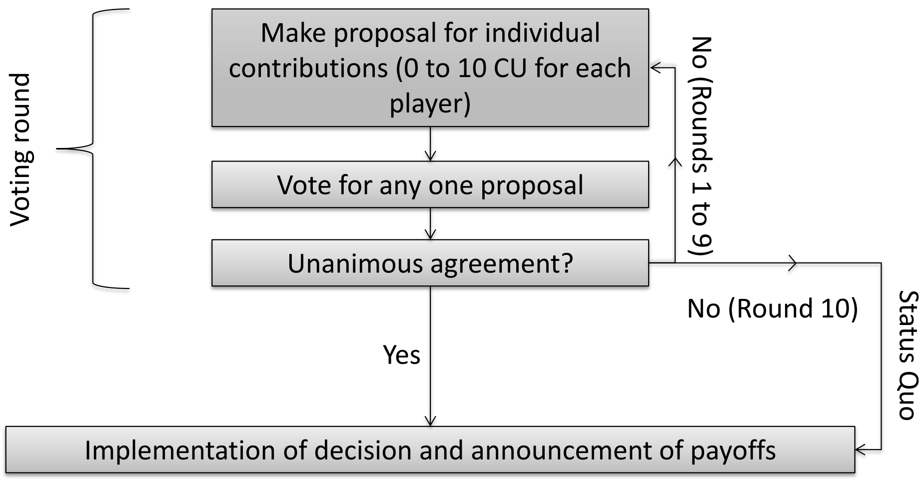


Figure A.3: Experimental procedure of treatment VHOM.

ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.1.4 Treatment RHOM

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €5 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment, that is, in all **ten rounds**.

THE PROJECT Your task in each of the ten rounds is to choose your contribution to a project. At the same time, all other players in your group also choose their own contributions to this project. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players each choose **your own contribution to a project.** This occurs repeatedly in a total of **ten decision rounds**, which all proceed as follows:

1. Choice of contributions to the project

2. Result: project successful?

The experiment consists of a **total of ten such independent decisions** in a total of ten rounds. **Only one of these rounds is relevant for your payoff, however.** Which of these rounds is paid will be determined at the end of the experiment, individually for each player. In doing so, each of the ten rounds has the same probability of being chosen.

DETAILS OF THE PROCEDURE

1. Choice of contributions to the project

   At the beginning of each round, each player has an **endowment which is measure in Experimental Currency Units (ExCU). The exact amount of this endowment is the same for all players:**

   Players A, B, C, D Endowment of **30 ExCU**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

Each player's contribution is measured in Contribution Units (CU). In every single round, each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution in each round can therefore amount to up to 40 Contribution Units.

The costs per provided Contribution Unit are the same for all players:

Players A, B, C, D	1 Contribution Unit costs 1.5 Experimental Currency Units **(1 CU = 1.5 ExCU)**

At the same time as all of the other players in his group, each player chooses his own contribution to the project. In order to do so, he chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on **"Calculate values"** you can make the program display the corresponding amount in Experimental Currency Units, as well. **The individual contributions of all players are automatically summed up to a total contribution.**

2. Result: project successful?

   In each round the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached in a particular round, each player must make a **payment in Experimental Currency Units**, which is deducted from his earnings in the respective round. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

   The payment if the minimum contribution is not reached is the same for all players:

Players A, B, C, D	Payment of **25 ExCU**

   (a) Total contribution **greater than or equal to** 16 CU

   Every player pays his **individual contribution costs**.

   Earnings= your endowment (in ExCU) − your contribution costs (in ExCU)

   (b) Total contribution **less than** 16 CU

   Every player pays 25 ExCU

   Earnings = your endowment (in ExCU) − 25 ExCU

   After all players in your group have made their contribution choice, all players are shown the total contribution of their group as well as the resulting earnings of all players. The contributions and contribution costs of the other players in the group are displayed, too.

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, one of the ten rounds is selected at random. All rounds have the same probability of being selected. **This means that you receive only the final earnings of a single round.** The results of the remaining rounds are no longer relevant for your payoff, no matter whether or not the minimum contribution was reached in these rounds. The earnings obtained in the randomly selected round are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€5).

Example for the procedure of a round:

Example 1:

The players in a group provide the following individual contributions in this round which add up to a **total contribution of 10 CU:**

- Player A: 1 CU with costs of 1.5 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU in this round.

Example 2:

The players in a group provide the following individual contributions in this round which add up to a **total contribution of 17 CU:**

- Player A: 8 CU with costs of 12 ExCU
- Player B: 3 CU with costs of 4.5 ExCU
- Player C: 4 CU with costs of 6 ExCU
- Player D: 2 CU with costs of 3 ExCU

The minimum contribution of 16 CU is **reached** in this case. Accordingly, Player A for example receives earnings of 30 ExCU − 12 ExCU = 18 ExCU. In contrast, Player C receives earnings of 30 ExCU − 6 ExCU = 24 ExCU.

Please note that, with the beginning of the second round, you may recall the **results from preceding rounds** during each decision by clicking on the button “Result Round X” for the respective Round X. By clicking on the button “Back to Decision” you can return to the current round. After choosing your contribution (Button “Confirm Choice”) you have one additional opportunity to correct this choice if necessary. As soon as you click the button “Confirm Choice and Continue”, your choice is final.

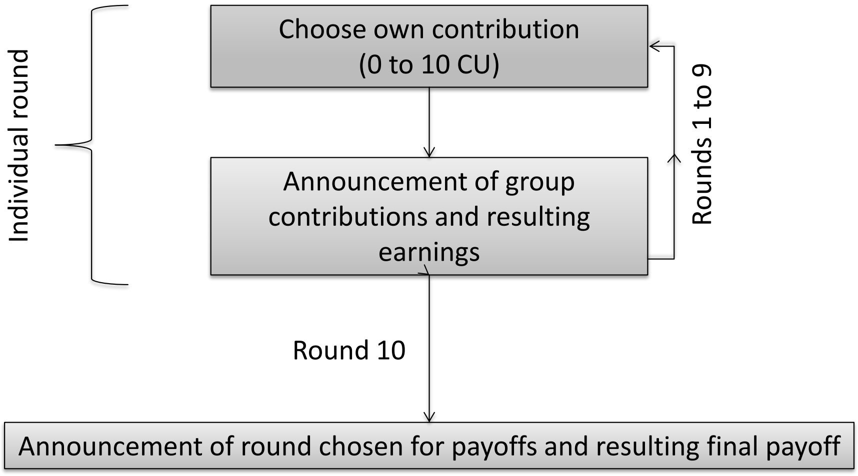


Figure A.4: Experimental procedure of treatment RHOM.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.1.5 Treatment VCOST

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment.

THE PROJECT Your task in this experiment is to choose your and your fellow players' contributions to a project. Your decision consists in a **vote on the individual contributions of all players in a group**. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players vote on the **individual contributions of all group players to a project.** This happens in **up to ten voting rounds** and proceeds as follows:

1. Proposals for contributions to the project
2. Unanimous vote on the proposals
3. Result: project successful?

If there is **no unanimous agreement**, Steps 1. and 2. are repeated, i.e., **new proposals** are made and **new votes** are cast. After the tenth unsuccessful voting round, the **status quo** is implemented, which means that nobody contributes anything.

DETAILS OF THE PROCEDURE

1. Proposals for contributions to the project

   At the beginning of the experiment, each player has an **endowment of 30 Experimental Currency Units (ExCU).**

   Each player's contribution is measured in Contribution Units (CU). Each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution can therefore amount to up to 40 Contribution Units.

   The costs per provided Contribution Unit differ among the players:

Players A and B	1 Contribution Unit costs 1 Experimental Currency Unit **(1 CU = 1 ExCU)**
Players C and D	1 Contribution Unit costs 3 Experimental Currency Units **(1 CU = 3 ExCU)**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   Each player makes a proposal for the contribution of every single player. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). **The individual contributions from each proposal are automatically summed up to a total contribution.**

   By clicking on **"Calculate values"** you can make the program display the total contribution, as well as each player's contribution costs and earnings in Experimental Currency Units.

   The proposals (that is, contribution costs, total contribution, and resulting earnings) are shown to all players in a list (see Table A.3). Among these is also a proposal called **"status quo"**. This proposal means that each player makes a contribution of 0 Contribution Units (total contribution 0 CU). Next to each proposal there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Including the status quo, there can accordingly be up to five different contribution proposals.

2. Unanimous vote on the proposals

   At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal please click on "Accept" in the column directly to the right of the proposal. Each player then learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative.

   (a) **Unanimous decision** (all four players vote for the same proposal):

   The experiment ends with the calculation of earnings and payoffs.

   (b) **No unanimous decision:**

Rounds 1 to 9: New proposals are made (see above, 1.), on which new votes are then cast.

Round 10: The **status quo** (each player makes a contribution of 0 Contribution Units, total contribution of 0 Contribution Units, individual earnings of 5 Experimental Currency Units) is used for the calculation of payoffs.

3. Result: project successful?

   In the experiment the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached, each player must make a **payment in Experimental Currency Units**, which is deducted from his endowment. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

   The payment if the minimum contribution is not reached is the same for all players:

   Players A, B, C, D Payment of **25 ExCU**

   (a) Total contribution **greater than or equal to** 16 CU

   Every player pays his contribution costs.

   Earnings = your endowment (in ExCU) − your contribution costs (in ExCU)

   (b) Total contribution **less than** 16 CU

   Every player pays 25 ExCU

   Earnings = your endowment (in ExCU) − 25 ExCU

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, the obtained earnings are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€3).

Example for the procedure of a voting round:
A total of five proposals for the group players' individual contributions:

(See Table A.3)

The proposal "1.60 CU, 2.20 CU, 4.40 CU, 3.60 CU" with a total contribution of 11.80 CU has been made twice, but only counts as a single alternative. As the minimum contribution is missed with this proposal, each player must make a payment of 25 ExCU instead of contribution costs.

The proposal "5.80 CU, 3.50 CU, 4.60 CU, 2.40 CU" with a total contribution of 16.30 CU exceeds the minimum contribution of 16 CU. Each player must therefore pay his contribution costs.

All four players vote for "B". The other three different proposals ("Status quo", "A, C", "D") do not receive any votes this time.

The voting procedure ends in this example with the selection of proposal "B" and a total contribution of 16.3 CU.

Table A.3: Reproduction of screenshot for voting decision in treatment VCOST.

Voting round 2 of up to 10

You are Player B

Please accept one of the following proposals!

If the total contribution is smaller than 16.00 CU, every player must make a payment of 25 ExCU **instead** of the contributed amount.

Every player has an **endowment of 30 ExCU.**

Results Round 1 Back to decision

Proposal		**Player A**	**Player B**	**Player C**	**Player D**	**Total Contribution (CU)**	
Player A	Contribution (CU)	1.60	2.20	4.40	3.60	11.80	Accept
Player C	Payment (ExCU)	-25.00	-25.00	-25.00	-25.00		
	Earnings (ExCU)	5.00	5.00	5.00	5.00		
Player B (your	Contribution (CU)	5.80	3.50	4.60	2.40	16.30	Accept
proposal)	Contribution Costs (ExCU)	-5.80	-3.50	-13.80	-7.20		
	Earnings (ExCU)	24.20	26.50	16.20	22.80		
Player D	Contribution (CU)	9.00	3.80	5.40	4.90	23.10	Accept
	Contribution Costs (ExCU)	-9.00	-3.80	-16.20	-14.70		
	Earnings (ExCU)	21.00	26.20	13.80	15.30		
Status quo	Contribution (CU)	0.00	0.00	0.00	0.00	0.00	Accept
	Payment (ExCU)	-25.00	-25.00	-25.00	-25.00		
	Earnings (ExCU)	5.00	5.00	5.00	5.00		

Examples for the calculation of earnings:
Example 1:
The players in a group provide the following individual contributions which add up to a **total contribution of 11.4 CU:**

- Player A: 1.2 CU (1.2*1 ExCU = 1.2 ExCU)
- Player B: 3.4 CU (3.4*1 ExCU = 3.4 ExCU)
- Player C: 4.5 CU (4.5*3 ExCU = 13.5 ExCU)
- Player D: 2.3 CU (2.3*3 ExCU = 6.9 ExCU)

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU.

Example 2:
The players in a group provide the following individual contributions which add up to a **total contribution of 16.3 CU:**

- Player A: 5.8 CU (5.8*1 ExCU = 5.8 ExCU)
- Player B: 3.5 CU (3.5*1 ExCU = 3.5 ExCU)
- Player C: 4.6 CU (4.6*3 ExCU = 13.8 ExCU)
- Player D: 2.4 CU (2.4*3 ExCU = 7.2 ExCU)

The minimum contribution of 16 CU is **reached** in this case. Player A (contribution costs of 1 ExCU per invested CU) therefore receives earnings of 30 ExCU − 5.8 ExCU = 24.2 ExCU. A payment of 25 ExCU is not incurred in this case, because the minimum contribution has been reached.

Please note that, with the beginning of the second voting round, you may recall the **results from preceding rounds** during each decision by clicking on the button “Result Round X” for the respective Round X. By clicking on the button “Back to Decision” you can return to the current voting round.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your

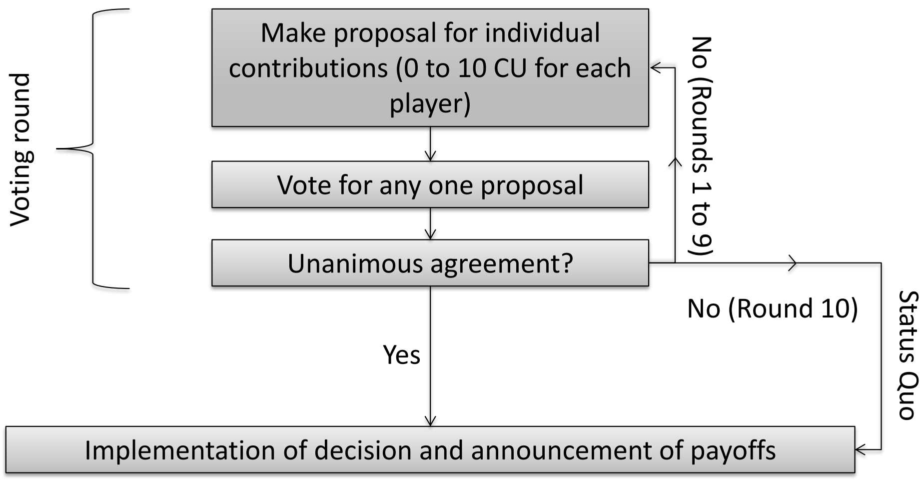


Figure A.5: Experimental procedure of treatment VCOST.

seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

A.1.6 Treatment RCOST

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment, that is, in all **ten rounds**.

THE PROJECT Your task in each of the ten rounds is to choose your contribution to a project. At the same time, all other players in your group also choose their own contributions to this project. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution.** If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players each choose **your own contribution to a project.** This occurs repeatedly in a total of **ten decision rounds**, which all proceed as follows:

1. Choice of contributions to the project

2. Result: project successful?

The experiment consists of a **total of ten such independent decisions** in a total of ten rounds. **Only one of these rounds is relevant for your payoff, however.** Which of these rounds is paid will be determined at the end of the experiment, individually for each player. In doing so, each of the ten rounds has the same probability of being chosen.

DETAILS OF THE PROCEDURE

1. Choice of contributions to the project

   At the beginning of each round, each player has an **endowment of 30 Experimental Currency Units (ExCU).**

   Each player's contribution is measured in Contribution Units (CU). In every single round, each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution in each round can therefore amount to up to 40 Contribution Units.

   The costs per provided Contribution Unit differ among the players:

Players A and B	1 Contribution Unit costs 1 Experimental Currency Unit **(1 CU = 1 ExCU)**
Players C and D	1 Contribution Unit costs 3 Experimental Currency Units **(1 CU = 3 ExCU)**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   At the same time as all of the other players in his group, each player chooses his own contribution to the project. In order to do so, he chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on **"Calculate values"** you can make the program display the corresponding amount in Experimental Currency Units, as well. **The individual contributions of all players are automatically summed up to a total contribution.**

2. Result: project successful?

   In each round the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached in a particular round, each player must make a **payment in Experimental Currency Units**, which is deducted from his earnings in the respective round. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

   The payment if the minimum contribution is not reached is the same for all players:

   Players A, B, C, D Payment of **25 ExCU**

   (a) Total contribution **greater than or equal to** 16 CU

   Every player pays his **individual contribution costs**.

   Earnings= your endowment (in ExCU) − your contribution costs (in ExCU)

   (b) Total contribution **less than** 16 CU

   Every player pays 25 ExCU

   Earnings = your endowment (in ExCU) − 25 ExCU

After all players in your group have made their contribution choice, all players are shown the total contribution of their group as well as the resulting earnings of all players. The contributions and contribution costs of the other players in the group are displayed, too.

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, one of the ten rounds is selected at random. All rounds have the same probability of being selected. **This means that you receive only the final earnings of a single round.** The results of the remaining rounds are no longer relevant for your payoff, no matter whether or not the minimum contribution was reached in these rounds. The earnings obtained in the randomly selected round are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€3).

Example for the procedure of a round:
Example 1:
The players in a group provide the following individual contributions in this round which add up to a **total contribution of 11.4 CU:**

- Player A: 1.2 CU (1.2*1 ExCU = 1.2 ExCU)
- Player B: 3.4 CU (3.4*1 ExCU = 3.4 ExCU)
- Player C: 4.5 CU (4.5*3 ExCU = 13.5 ExCU)
- Player D: 2.3 CU (2.3*3 ExCU = 6.9 ExCU)

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU in this round.

Example 2:
The players in a group provide the following individual contributions in this round which add up to a **total contribution of 16.3 CU:**

- Player A: 5.8 CU (5.8*1 ExCU = 5.8 ExCU)
- Player B: 3.5 CU (3.5*1 ExCU = 3.5 ExCU)
- Player C: 4.6 CU (4.6*3 ExCU = 13.8 ExCU)
- Player D: 2.4 CU (2.4*3 ExCU = 7.2 ExCU)

The minimum contribution of 16 CU is **reached** in this case. Player A (contribution costs of 1 ExCU per invested CU) therefore receives earnings of 30 ExCU − 5.8 ExCU = 24.2 ExCU in this round. A payment of 25 ExCU is not incurred in this case, because the minimum contribution has been reached.

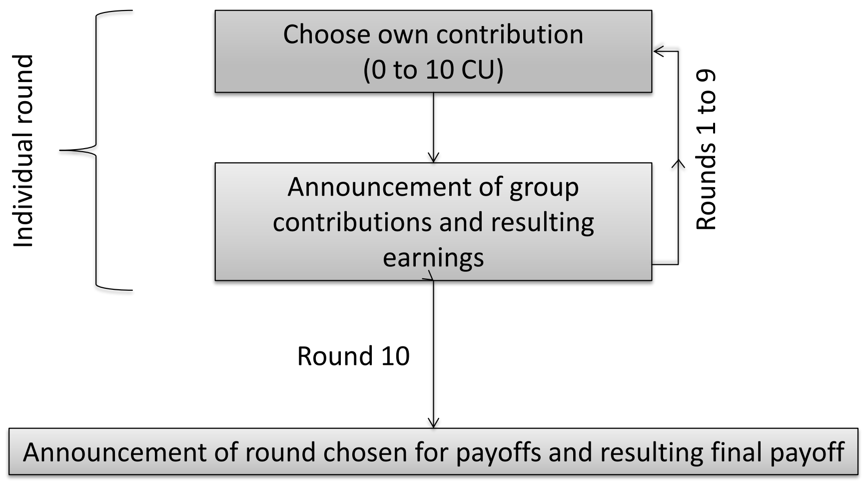


Figure A.6: Experimental procedure of treatment RCOST.

Please note that, with the beginning of the second round, you may recall the **results from preceding rounds** during each decision by clicking on the button “Result Round X” for the respective Round X. By clicking on the button “Back to Decision” you can return to the current round. After choosing your contribution (Button “Confirm Choice”) you have one additional opportunity to correct this choice if necessary. As soon as you click the button “Confirm Choice and Continue”, your choice is final.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

A.1.7 Treatment VTRANS

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment.

THE PROJECT Your task in this experiment is to choose your and your fellow players' contributions to a project. Your decision consists in a **vote on the individual contributions of all players in a group**. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution. In the case of success, transfer payments** can be made subsequently. If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players vote on the **individual contributions of all group players to a project.** Together with the individual contributions, you also vote on **transfer payments between the group players.** This happens in **up to ten voting rounds** and proceeds as follows:

1. Proposals for contributions to the project and for transfer payments between the players
2. Unanimous vote on the proposals
3. Result: project successful?

If there is **no unanimous agreement**, Steps 1. and 2. are repeated, i.e., **new proposals** are made and **new votes** are cast. After the tenth unsuccessful voting round, the **status quo** is implemented, which means that nobody contributes anything.

DETAILS OF THE PROCEDURE

1. <u>Proposals for contributions to the project and for transfer payments between the players</u>

   At the beginning of the experiment, each player has an **endowment of 30 Experimental Currency Units (ExCU).**

   Each player's contribution is measured in Contribution Units (CU). Each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution can therefore amount to up to 40 Contribution Units.

   The costs per provided Contribution Unit differ among the players:

Players A and B	1 Contribution Unit costs 1 Experimental Currency Unit **(1 CU = 1 ExCU)**
Players C and D	1 Contribution Unit costs 3 Experimental Currency Units **(1 CU = 3 ExCU)**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   If the minimum contribution of 16 CU is reached, Players C and D make transfer payments to Players A and B. In doing so, the sum of transfer payments **paid** by C and D must correspond to the sum of transfer payments **received** by A and B. Players C and D may each provide a **maximum of 30 ExCU minus contribution costs** as transfer payments.

   Each player makes a proposal for the contribution of every single player. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). **The individual contributions from each proposal are automatically summed up to a total contribution.**

   If the proposed total contribution is greater than or equal to the minimum contribution of 16 CU, you can also propose transfer payments between the players. In addition to the four contribution values, the proposal then contains four additional numbers: the respective transfer payments paid by Players C and D and the respective transfer payments received by Players A and B.

By clicking on **"Calculate values"** you can make the program display the total contribution, as well as each player's contribution costs and earnings in Experimental Currency Units.

The proposals (that is, contribution costs, total contribution, transfer payments, and resulting earnings) are shown to all players in a list (see Table A.4). This proposal means that each player makes a contribution of 0 Contribution Units (total contribution 0 CU) , so that no transfer payments are possible. Next to each proposal there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Including the status quo, there can accordingly be up to five different contribution proposals.

2. Unanimous vote on the proposals

   At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal please click on "Accept" in the column directly to the right of the proposal. Each player then learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative.

   (a) **Unanimous decision** (all four players vote for the same proposal):
   The experiment ends with the calculation of earnings and payoffs.

   (b) **No unanimous decision:**
   Rounds 1 to 9: New proposals are made (see above, 1.), on which new votes are then cast.
   Round 10: The **status quo** (each player makes a contribution of 0 Contribution Units, total contribution of 0 Contribution Units, no transfer payments, individual earnings of 5 Experimental Currency Units) is used for the calculation of payoffs.

3. Result: project successful?

   In the experiment the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached, each player must make a **payment in Experimental Currency Units**, which is deducted from his endowment. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

   The payment if the minimum contribution is not reached is the same for all players:

   Players A, B, C, D Payment of **25 ExCU**

   (a) Total contribution **greater than or equal to** 16 CU
   Every player pays his contribution costs.
   Earnings = your endowment (in ExCU) − your contribution costs (in ExCU)

Players A and B:

Earnings = your endowment (in ExCU) − your contribution costs (in ExCU) + received transfers (in ExCU

Players C and D:

Earnings = your endowment (in ExCU) − your contribution costs (in ExCU) − paid transfers (in ExCU

(b) Total contribution **less than** 16 CU

Every player pays 25 ExCU

All players:

Earnings = your endowment (in ExCU) − 25 ExCU

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, the obtained earnings are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€3).

Example for the procedure of a voting round:
A total of five proposals for the group players' individual contributions:

(See Table A.4)

The proposal "1.60 CU, 2.20 CU, 4.40 CU, 3.60 CU" with a total contribution of 11.80 CU has been made twice, but only counts as a single alternative. As the minimum contribution is missed with this proposal, each player must make a payment of 25 ExCU instead of contribution costs. Transfer payments are not possible in this case.

The proposal "5.80 CU, 3.50 CU, 4.60 CU, 2.40 CU" with a total contribution of 16.30 CU exceeds the minimum contribution of 16 CU. Each player must therefore pay his contribution costs. In addition Players C and D make transfer payments to Players A and B.

All four players vote for "B". The other three different proposals ("Status quo", "A, C", "D") do not receive any votes this time.

The voting procedure ends in this example with the selection of proposal "B" and a total contribution of 16.3 CU.

Table A.4: Reproduction of screenshot for voting decision in treatment VTRANS.

Voting round 2 of up to 10
You are Player C
Please accept one of the following proposals!
If the total contribution is smaller than 16.00 CU, every player must make a payment of 25 ExCU **instead** of the contributed amount.
Every player has an **endowment of 30 ExCU.**

Results Round 1 | Back to decision

Proposal		**Player A**	**Player B**	**Player C**	**Player D**	**Total Contribution (CU)**	
Player A	Contribution (CU)	1.60	2.20	4.40	3.60	11.80	Accept
Player C (your	Payment (ExCU)	-25.00	-25.00	-25.00	-25.00		
proposal)	Transfer (ExCU)	0.00	0.00	-0.00	-0.00		
	Earnings (ExCU)	5.00	5.00	5.00	5.00		
Player B	Contribution (CU)	5.80	3.50	4.60	2.40	16.30	Accept
	Contribution Costs (ExCU)	-5.80	-3.50	-13.80	-7.20		
	Transfer (ExCU)	2.40	3.90	-2.80	-3.50		
	Earnings (ExCU)	26.60	30.40	13.40	19.30		
Player D	Contribution (CU)	9.00	3.80	5.40	4.90	23.10	Accept
	Contribution Costs (ExCU)	-9.00	-3.80	-16.20	-14.70		
	Transfer (ExCU)	5.30	6.00	-7.30	-4.00		
	Earnings (ExCU)	26.30	32.20	6.50	15.30		
Status quo	Contribution (CU)	0.00	0.00	0.00	0.00	0.00	Accept
	Payment (ExCU)	-25.00	-25.00	-25.00	-25.00		
	Transfer (ExCU)	0.00	0.00	-0.00	-0.00		
	Earnings (ExCU)	5.00	5.00	5.00	5.00		

Examples for the calculation of earnings:

Example 1:

The players in a group provide the following individual contributions which add up to a **total contribution of 11.4 CU:**

- Player A: 1.2 CU (1.2*1 ExCU = 1.2 ExCU)
- Player B: 3.4 CU (3.4*1 ExCU = 3.4 ExCU)
- Player C: 4.5 CU (4.5*3 ExCU = 13.5 ExCU)
- Player D: 2.3 CU (2.3*3 ExCU = 6.9 ExCU)

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU.

Example 2:

The players in a group provide the following individual contributions which add up to a **total contribution of 16.3 CU:**

- Player A: 5.8 CU (5.8*1 ExCU = 5.8 ExCU)
- Player B: 3.5 CU (3.5*1 ExCU = 3.5 ExCU)
- Player C: 4.6 CU (4.6*3 ExCU = 13.8 ExCU)
- Player D: 2.4 CU (2.4*3 ExCU = 7.2 ExCU)

The minimum contribution of 16 CU is **reached** in this case. Player A (contribution costs of 1 ExCU per invested CU) therefore receives earnings of 30 ExCU − 5.8 ExCU = 24.2 ExCU. A payment of 25 ExCU is not incurred in this case, because the minimum contribution has been reached.

Example for a transfer payment

In the above Example 2, the following transfer payments are now made:

Paid transfers:

- Player C: 2.8 ExCU Sum of paid transfers (C and D) = **6.3 ExCU**
- Player D: 3.5 ExCU

Received transfers:

- Player A: 2.4 ExCU Sum of received transfers (A and B) = **6.3 ExCU**
- Player B: 3.9 ExCU

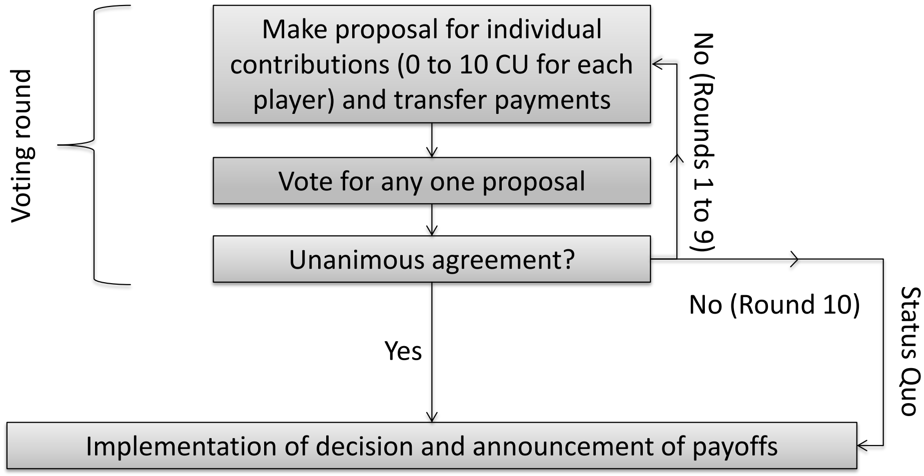


Figure A.7: Experimental procedure of treatment VTRANS.

Player A (contribution costs of 1 ExCU per invested CU) therefore receives earnings including transfer payments of 30 ExCU − 5.8 ExCU + 2.4 ExCU = 26.6 ExCU.

Please note that, with the beginning of the second voting round, you may recall the **results from preceding rounds** during each decision by clicking on the button “Result Round X” for the respective Round X. By clicking on the button “Back to Decision” you can return to the current voting round.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.1.8 Treatment RTRANS

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3 Over the course of the experiment you can earn an additional amount of up to €15. The precise amount is influenced by the decisions of the other participants. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with three other players**. The composition of this group is determined randomly at the beginning of the experiment and will not change throughout the entire experiment, that is, in all **ten rounds**.

THE PROJECT Your task in each of the ten rounds is to choose your contribution to a project. At the same time, all other players in your group also choose their own contributions to this project. The contributions of all players in a group are added up to a **total contribution**. **For the project to be successful, your group's total contribution must reach a minimum contribution. In the case of success, transfer payments** can be made subsequently. If the project is **not successful**, the contributions of all players are refunded just as if nobody had made any contribution. Instead of the contributions, the players then must make a **fixed payment**.

PROCEDURE OF THE DECISION In the experiment, you and your fellow players each choose **your own contribution to a project.** This occurs repeatedly in a total of **ten decision rounds**, which all proceed as follows:

1. Choice of contributions to the project and for transfer payments between the players
2. Preliminary result: project successful?
3. Choice of transfer payments
4. Final result

Attention! Steps 3. and 4. are *not* carried out, if the project was *not* successful (see below).

The experiment consists of a **total of ten such independent decisions** in a total of ten rounds. **Only one of these rounds is relevant for your payoff, however.** Which of these rounds is paid will be determined at the end of the experiment, individually for each player. In doing so, each of the ten rounds has the same probability of being chosen.

DETAILS OF THE PROCEDURE

1. Choice of contributions to the project

   At the beginning of each round, each player has an **endowment of 30 Experimental Currency Units (ExCU).**

   Each player's contribution is measured in Contribution Units (CU). In every single round, each player can provide **up to 10 Contribution Units** by investing Experimental Currency Units from his endowment. The group's total contribution in each round can therefore amount to up to 40 Contribution Units.

   The costs per provided Contribution Unit differ among the players:

Players A and B	1 Contribution Unit costs 1 Experimental Currency Unit **(1 CU = 1 ExCU)**
Players C and D	1 Contribution Unit costs 3 Experimental Currency Units **(1 CU = 3 ExCU)**

   At the beginning of the experiment you will be told which player you are (A, B, C, D). This is determined randomly.

   At the same time as all of the other players in his group, each player chooses his own contribution to the project. In order to do so, he chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on **"Calculate values"** you can make the program display the corresponding amount in Experimental Currency Units, as well. **The individual contributions of all players are automatically summed up to a total contribution.**

2. Preliminary result: project successful?

   In each round the provided contributions must reach a **minimum contribution of 16 Contribution Units.** If the minimum contribution is *not* reached in a particular round, each player must make a **payment in Experimental Currency Units**, which is deducted from his earnings in the respective round. The provided contributions are **refunded** in this case, so that except for the payment not additional costs are incurred.

The payment if the minimum contribution is not reached is the same for all players:

Players A, B, C, D Payment of **25 ExCU**

(a) Total contribution **greater than or equal to** 16 CU

Every player pays his **individual contribution costs**.

Earnings before transfers = your endowment (in ExCU) − your contribution costs (in ExCU)

(b) Total contribution **less than** 16 CU (no transfer payments!)

Every player pays 25 ExCU

Final Earnings = your endowment (in ExCU) − 25 ExCU

After all players in your group have made their contribution choice, all players are shown the total contribution of their group as well as the resulting earnings of all players. The contributions and contribution costs of the other players in the group are displayed, too

3. Choice of transfer payments

If the minimum contribution of 16 CU is reached, Players C and D subsequently make individual transfer payments to Players A and B. **Players C and D choose their transfer payments at the same time.** Each of the two players makes two separate payments, one directed at Player A and one directed at Player B. In doing so, the sum of transfer payments to A and B by the transferring player (C or D) may not exceed the preliminary earnings of this player (30 ExCU minus contribution costs) in this round. The sum of transfer payments **paid** by C or D, respectively, corresponds to the sum of transfer payments **received** by A and B.

4. Final result

After Players C and D have chosen their transfer payments, each player is informed about these decisions and the resulting final earnings for this round.

Final earnings after transfer payments:

(a) Total contribution **greater than or equal to** 16 CU

Players A and B: **Final earnings = your endowment (in ExCU) − your contribution costs (in ExCU) + received transfers (in ExCU)**

Players C and D: **Final earnings = your endowment (in ExCU) − your contribution costs (in ExCU) − paid transfers (in ExCU)**

(b) Total contribution **less than** 16 CU

Final earnings = 30 ExCU − 25 ExCU = 5 ExCU

YOUR PAYOFF In order to calculate the total payoff at the end of the experiment, one of the ten rounds is selected at random. All rounds have the same probability of being selected. **This means that you receive only the final earnings of a single round.** The results of the remaining rounds are no longer relevant for your payoff, no matter whether or not the minimum contribution was reached in these rounds. The earnings obtained in the randomly selected round are converted into euros **(2 ExCU = €1)** and added to your show-up fee (€3).

Example for the procedure of a round:

Example 1:

The players in a group provide the following individual contributions in this round which add up to a **total contribution of 11.4 CU:**

- Player A: 1.2 CU (1.2*1 ExCU = 1.2 ExCU)
- Player B: 3.4 CU (3.4*1 ExCU = 3.4 ExCU)
- Player C: 4.5 CU (4.5*3 ExCU = 13.5 ExCU)
- Player D: 2.3 CU (2.3*3 ExCU = 6.9 ExCU)

The minimum contribution of 16 CU is **missed** in this case. Each player is refunded the contributions he provided. Instead each player is deducted a payment of 25 ExCU, because the minimum contribution has not been reached. Accordingly, each player receives earnings of 5 ExCU in this round. Transfer payments are *not* possible in this case, because the minimum contribution has not been reached.

Example 2:

The players in a group provide the following individual contributions in this round which add up to a **total contribution of 16.3 CU:**

- Player A: 5.8 CU (5.8*1 ExCU = 5.8 ExCU)
- Player B: 3.5 CU (3.5*1 ExCU = 3.5 ExCU)
- Player C: 4.6 CU (4.6*3 ExCU = 13.8 ExCU)
- Player D: 2.4 CU (2.4*3 ExCU = 7.2 ExCU)

The minimum contribution of 16 CU is **reached** in this case. Player A (contribution costs of 1 ExCU per invested CU) therefore receives earnings before transfers of 30 ExCU − 5.8 ExCU = 24.2 ExCU in this round. A payment of 25 ExCU is not incurred in this case, because the minimum contribution has been reached.

Example for a transfer payment

Assume that the minimum contribution has been reached and the **Player C** has **earnings before transfers of 16.2 ExCU** after paying his contribution costs. From this amount he pays **0.9 ExCU to Player A** and **1.9 ExCU to Player B**. After transfer payments, Player C therefore has 16.2 ExCU − 0.9 ExCU − 1.9 ExCU = 13.4 ExCU.

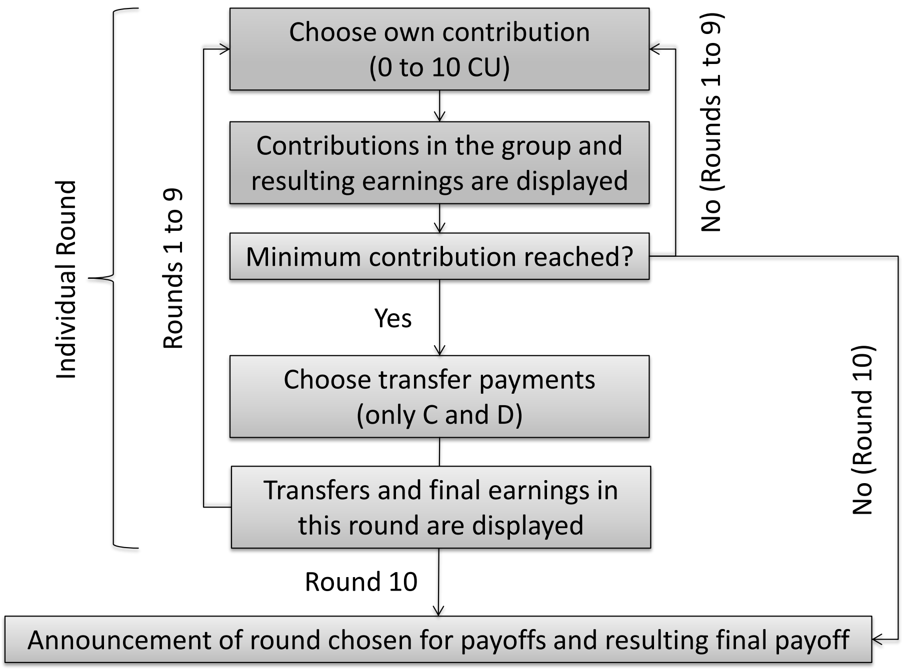


Figure A.8: Experimental procedure of treatment RTRANS.

Please note that, with the beginning of the second round, you may recall the **results from preceding rounds** during each decision by clicking on the button "Result Round X" for the respective Round X. By clicking on the button "Back to Decision" you can return to the current round. After choosing your contribution (Button "Confirm Choice") you have one additional opportunity to correct this choice if necessary. As soon as you click the button "Confirm Choice and Continue", your choice is final.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34).

If you have any questions of your own during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. In any event, you should only ask questions about the instructions and not about strategies! Furthermore, please not that the game only continues after all players have made their decisions.

Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we will ask you to fill in a questionnaire. Please remain seated after completing the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then will you be able to receive your payoff.

Thank you very much for your participation and good luck!

A.2 Instructions to Chapter 6

A.2.1 Treatment TDHOM

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with four other players.** The composition of this group will not change throughout the entire experiment (in both parts and in all rounds). You begin the experiment with an **endowment of 25 Experimental Currency Units.**

Your task in this experiment is to choose your and your fellow players' contributions to a project. Each player can contribute up to 10 Experimental Currency Units. The group's total contribution can therefore amount to up to 50 Experimental Currency Units.

The decision occurs in **two parts**.

1. First you vote on the **total contribution** of all players in your group.

2. Then you vote on which **share of the total contribution** each individual player has to contribute.

For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost. The exact amount of this minimum contribution is determined randomly. You are told this information only at the end of the experiment. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his payoff.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

PROCEDURE OF THE FIRST PART In the first part you and your fellow players vote on **your group's total contribution**. This happens in up to five voting rounds and proceeds as follows:

1. At the same time as the other players, each player makes a **proposal for the total contribution**. In order to do this, he or she chooses an amount **between 0 and 50 Experimental Currency Units**.

2. The proposals are shown to all players in a table (see Table A.5). Among them is also a proposal called **"Status Quo"**, corresponding to a total contribution of **0 Experimental Currency Units**. Next to each proposal, there is a list of the player(s) who made this proposal. If a proposal has been made multiple times, it is displayed only once, together with all players who made this proposal. Accordingly, there can be up to six different proposals.

3. Each player casts a vote for exactly one of these proposals. All votes are cast individually and at the same time. In order to vote for a proposal, please click on "Accept" in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the **second part of the experiment begins**. Otherwise, Steps 1. to 4. are repeated up to four times. In every repetition new proposals can be made.

5. If there is also **no agreement in the fifth voting round**, the **Status Quo** (total contribution of 0 Experimental Currency Units) is chosen as your group's total contribution.

Table A.5: Reproduction of screenshot for voting decision in the first part of treatment TDHOM.

Voting round 2 of up to 5 Please accept one of the following proposals! The minimum contribution takes on one of the following nine values: 16 ExCU, 17 ExCU, 18 ExCU, 19 ExCU, 20 ExCU, 21 ExCU, 22 ExCU, 23 ExCU, 24 ExCU		
Back to current round	Show later round	Show earlier round
Proposal	**Total Contribution (ExCU)**	
Player A, B, D (your proposal), E	0	Accept
Player C	5	Accept
Status quo	0	Accept

6. If the first part results in a **total contribution of 0 Experimental Currency Units, no further voting** occurs in this group, meaning that the second part of the experiment is omitted. Each player then automatically makes an individual contribution of 0 Experimental Currency Units and the experiment ends with the calculation of payoffs.

Example for the procedure of the first part:

- Round 1:
  - A total of six proposals for the total contribution (in ExCU): 0 (Status Quo), 16, 17, 17, 18, 19
  - Total contribution “17 ExCU” has been proposed twice, but only counts as a single alternative.
  - Two player vote for “18 ExCU”, three players for “16 ExCU”. “0 ExCU”, “17 ExCU”, and “19 ExCU” receive no votes at this time.
  - There is no agreement, so the procedure is repeated in an additional round.
- Round 2:
  - Again a total of six proposals for the total contribution (in ExCU): 0 (Status Quo), 16, 17, 17, 17, 19
  - Total contribution “17 ExCU” has been proposed three times, but only counts as a single alternative.
  - Now all five players vote for “19 ExCU”. “0 ExCU”, “16 ExCU”, and “17 ExCU” receive no votes at this time.

– Thus, a total contribution of “19 ExCU” is accepted and chosen for the second part.

Please note that, starting with the second voting round, you may call up the **results from previous votes** whenever you make a decision by clicking the button “Show earlier round” (see Table A.5). Clicking the button again shows even earlier rounds. By clicking the buttons “Show later round” or “Back to current round” you may advance again in the history or, respectively, jump immediately to the current decision round.

PROCEDURE OF THE SECOND PART In the second part you and your fellow players vote on how the total contribution determined in the first part is to be provided by the **individual contributions of all group players**. This happens in up to five voting rounds and proceeds as follows:

1. Each player makes a **proposal for the contribution of every single player**. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Experimental Currency Units (in steps of 0.1 ExCU). **Caution! The sum of these contributions must be equal to the total contribution determined in Part 1!**

2. The proposals are shown to all players in a list. Among these is again a proposal called **“Status Quo”**. Here, this proposal means that each player provides a contribution of **0 Experimental Currency Units**, **no matter what amount has been chosen as a total contribution in Part 1**. Next to each proposal, there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Accordingly, there can again be up to six different distribution proposals.

3. At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal, please click on “Accept” in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the experiment ends with the calculation of payoffs. Otherwise, Steps 1. to 4. are repeated up to four times.

5. If there is also **no agreement in the fifth voting round**, the **Status Quo** (each player provides a contribution of 0 Experimental Currency Units, total contribution of 0 Experimental Currency Units) is selected to calculate payoffs. **This is the case, even if a different total contribution has been chosen in the first part.**

Example for the procedure of the second part (total contribution 19 ExCU):

- Round 1:
  - A total of six proposals for the allocation of the total contribution:

	Individual contributions (ExCU)				
Proposal	**Player A**	**Player B**	**Player C**	**Player D**	**Player E**
Player A, C	1	2	4	3	9
Player B, E	3	1	2	6.5	6.5
Player D	9	3	2	1	4
Status Quo	0	0	0	0	0

  - The allocation "1 ExCU; 2 ExCU; 4 ExCU; 3 ExCU; 9 ExCU" has been proposed twice, but only counts as a single alternative.
  - The same applies to the allocation "3 ExCU; 1 ExCU; 2 ExCU; 6.5 ExCU; 6.5 ExCU".
  - All five players vote for "A, C". The other three different proposals ("Status Quo", "B, E", "D") receive no votes this time.
- In this example, the voting procedure ends with a total contribution of 19 ExCU and the following individually payable contributions:
  - Player A: 1 ExCU
  - Player B: 2 ExCU
  - Player C: 4 ExCU
  - Player D: 3 ExCU
  - Player E: 9 ExCU

Please note that, starting with the second voting round, you may call up the **results from previous votes in this part** whenever you make a decision by clicking the button "Show earlier round". Clicking the button again shows even earlier rounds. By clicking the buttons "Show later round" or "Back to current round" you may advance again in the history or, respectively, jump immediately to the current decision round.

YOUR PAYOFF The payoff of each player calculates as follows:

- Please note that the contributed amount is deducted from your account balance in any case, even if the total contribution has not reached the minimum contribution.
- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  payoff for reaching the minimum contribution = 25 ExCU – your contributed amount

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  payoff for missing the minimum contribution = 25 ExCU − your contributed amount − 10 ExCU

In order to determine the total payoff at the end of the experiment, the resulting amount is converted into euros and added to your show-up fee. The payoff from a subsequent separate experiment is later added to this amount.

Example for payoffs (total contribution 19 ExCU):
Assume that the minimum contribution amount to 20 ExCU. Then a total contribution of 19 ExCU fails to reach this minimum contribution. Accordingly, for Player A from the previous example (contributed amount of 1 ExCU) a payoff of 25 ExCU − 1 ExCU − 10 ExCU = 14 ExCU results. An amount of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume that the minimum contribution amounts to 18 ExCU. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 ExCU a payoff of 25 ExCU − 1 ExCU = 24 ExCU results. In this case nothing is deducted, because the minimum contribution has been reached.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

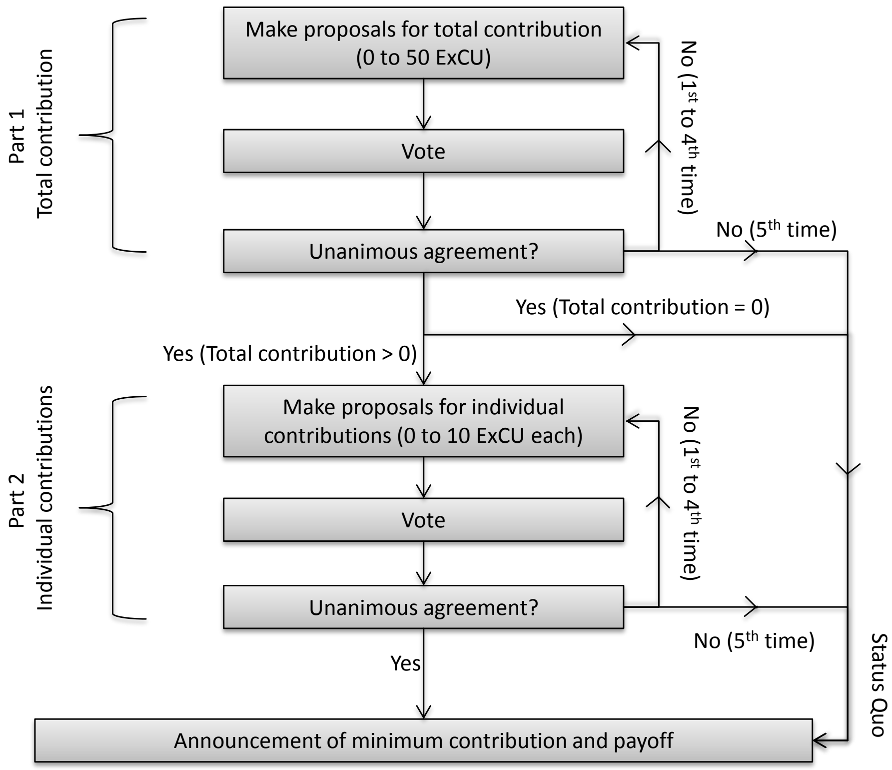


Figure A.9: Experimental procedure of treatment TDHOM.

A.2.2 Treatment TDHET

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you and **four other players** form a **group of five.** The composition of this group is determined randomly at the beginning of the experiment and does not change throughout the entire experiment (in both parts and in all rounds). You begin the experiment with an **endowment of 25 Experimental Currency Units.**

Your task in this experiment is to choose your and your fellow players' contributions to a project. **Each player's contribution is measured in Contribution Units (CU).** Each player can contribute **up to 10 Contribution Units**, by investing Experimental Currency Units from his or her endowment. The decision occurs in **two parts**.

1. First you vote on the **total contribution** of all players in your group. This total contribution can amount to **up to 50 Contribution Units**.

2. Then you vote on which **share of the total contribution** each individual player has to contribute.

The costs of contributions in Experimental Currency Units differ among the players:

Players A and B	1 Contribution Unit costs 0.77 Experimental Currency Unit **(1 CU = 0.77 ExCU)**
Players C, D and E	1 Contribution Unit costs 1.25 Experimental Currency Units **(1 CU = 1.25 ExCU)**

Which player you are (A, B, C, D, E) is determined randomly at the beginning of the experiment. You are told who you are before the first decision.

For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost. The exact amount of this minimum contribution is determined randomly. You are told this information only at the end of the experiment. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his payoff.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

PROCEDURE OF THE FIRST PART In the first part you and your fellow players vote on **your group's total contribution**. This happens in up to five voting rounds and proceeds as follows:

1. At the same time as the other players, each player makes a **proposal for the total contribution**. In order to do this, he or she chooses an amount **between 0 and 50 Contribution Units**.

2. The proposals are shown to all players in a table (see Table A.6). Among them is also a proposal called **"Status Quo"**, corresponding to a total contribution of **0 Contribution Units**. Next to each proposal, there is a list of the player(s) who made this proposal. If a proposal has been made multiple times, it is displayed only once, together with all players who made this proposal. Accordingly, there can be up to six different proposals.

3. Each player casts a vote for exactly one of these proposals. All votes are cast individually and at the same time. In order to vote for a proposal, please click on "Accept" in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the **second part of the experiment begins**. Otherwise, Steps 1. to 4. are repeated up to four times. In every repetition new proposals can be made.

5. If there is also **no agreement in the fifth voting round**, the **Status Quo** (total contribution of 0 Contribution Units) is chosen as your group's total contribution.

6. If the first part results in a **total contribution of 0 Contribution Units, no further voting** occurs in this group, meaning that the second part of the experiment is omitted. Each player then automatically makes an individual contribution of 0 Experimental Currency Units and the experiment ends with the calculation of payoffs.

Table A.6: Reproduction of screenshot for voting decision in the first part of treatment TDHET.

Voting round 2 of up to 5 Please accept one of the following proposals! The minimum contribution takes on one of the following nine values: 16 CU, 17 CU, 18 CU, 19 CU, 20 CU, 21 CU, 22 CU, 23 CU, 24 CU		
Back to current round	Show later round	Show earlier round
Proposal	**Total Contribution (CU)**	
Player A, B, E	17	Accept
Player C (your proposal)	19	Accept
Player D	16	Accept
Status quo	0	Accept

Example for the procedure of the first part:

- Round 1:
  - A total of six proposals for the total contribution (in CU): 0 (Status Quo), 16, 17, 17, 18, 19
  - Total contribution "17 CU" has been proposed twice, but only counts as a single alternative.
  - Two player vote for "18 CU", three players for "16 CU". "0 CU", "17 CU", and "19 CU" receive no votes at this time.
  - There is no agreement, so the procedure is repeated in an additional round.
- Round 2:
  - Again a total of six proposals for the total contribution (in CU): 0 (Status Quo), 16, 17, 17, 17, 19
  - Total contribution "17 CU" has been proposed three times, but only counts as a single alternative.
  - Now all five players vote for "19 CU". "0 CU", "16 CU", and "17 CU" receive no votes at this time.

- Thus, a total contribution of “19 CU” is accepted and chosen for the second part.

Please note that, starting with the second voting round, you may call up the **results from previous votes** whenever you make a decision by clicking the button “Show earlier round” (see Table A.6). Clicking the button again shows even earlier rounds. By clicking the buttons “Show later round” or “Back to current round” you may advance again in the history or, respectively, jump immediately to the current decision round.

PROCEDURE OF THE SECOND PART In the second part you and your fellow players vote on how the total contribution determined in the first part is to be provided by the **individual contributions of all group players**. This happens in up to five voting rounds and proceeds as follows:

1. Each player makes a **proposal for the contribution of every single player**. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on “Calculate values” you can also display the corresponding values in Experimental Currency Units. **Caution! The sum of these contributions must be equal to the total contribution determined in Part 1!**

2. The proposals are shown to all players in a table (in CU as well as in ExCU). Among these is again a proposal called **“Status Quo”**. Here, this proposal means that each player provides a contribution of **0 Experimental Currency Units**, **no matter what amount has been chosen as a total contribution in Part 1**. Next to each proposal, there is a list of the player(s) who made this proposal. If the same proposal has been made several times, it is shown only once, with all players who made this proposal. Accordingly, there can again be up to six different distribution proposals.

3. At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal, please click on “Accept” in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the experiment ends with the calculation of payoffs. Otherwise, Steps 1. to 4. are repeated up to four times.

5. If there is also **no agreement in the fifth voting round**, the **Status Quo** (each player provides a contribution of 0 Contribution Units, total contribution of 0 Contribution Units) is selected to calculate payoffs. **This is the case, even if a different total contribution has been chosen in the first part.**

Example for the procedure of the second part (total contribution 19 ExCU):

- Round 1:
  - A total of six proposals for the allocation of the total contribution:

	Individual contributions in CU (costs in ExCU)				
Proposal	**Player A**	**Player B**	**Player C**	**Player D**	**Player E**
Player(s) A, C	1 (0.77)	2 (1.54)	4 (5)	3 (3.75)	9 (11.25)
Player(s) B, E	3 (2.31)	1 (0.77)	2 (2.5)	6.5 (8.12)	6.5 (8.12)
Player(s) D	9 (6.93)	3 (2.31)	2 (2.5)	1 (1.25)	4 (5)
Status Quo	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

  - The allocation "1 CU; 2 CU; 4 CU; 3 CU; 9 CU" has been proposed twice, but only counts as a single alternative.
  - The same applies to the allocation "3 CU; 1 CU; 2 CU; 6.5 CU; 6.5 CU".
  - All five players vote for "A, C". The other three different proposals ("Status Quo", "B, E", "D") receive no votes this time.
- In this example, the voting procedure ends with a total contribution of 19 CU and the following individual contributions:
  - Player A: 1 CU (1*0.77 ExCU = 0.77 ExCU)
  - Player B: 2 CU (2*0.77 ExCU = 1.54 ExCU)
  - Player C: 4 CU (4*1.25 ExCU = 5 ExCU)
  - Player D: 3 CU (3*1.25 ExCU = 3.75 ExCU)
  - Player E: 9 CU (9*1.25 ExCU = 11.25 ExCU)

Please note that, starting with the second voting round, you may call up the **results from previous votes in this part** whenever you make a decision by clicking the button "Show earlier round". Clicking the button again shows even earlier rounds. By clicking the buttons "Show later round" or "Back to current round" you may advance again in the history or, respectively, jump immediately to the current decision round.

YOUR PAYOFF The payoff of each player calculates as follows:

- Please note that you have to pay the costs of your contribution in any case, even if the total contribution has not reached the minimum contribution.
- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  payoff for reaching the minimum contribution = 25 ExCU − your costs (in ExCU)

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  payoff for missing the minimum contribution = 25 ExCU − your costs (in ExCU) − 10 ExCU

In order to determine the final payoff at the end of the experiment, the resulting amount is converted into euros **2 ExCU = 1 euro)** and added to your show-up fee. The payoff from a subsequent separate experiment is later added to this amount.

Example for payoffs (total contribution 19 CU):
Assume a **minimum contribution of 20 CU**. Then a total contribution of 19 CU fails to reach this minimum contribution. Accordingly, for Player A from the previous example (costs of 0.77 ExCU for 1 CU) this results in a payoff of 25 ExCU − 0.77 ExCU − 10 ExCU = 14.23 ExCU results. A payment of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume a **minimum contribution of 18 CU**. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 CU (costs of 0.77 ExCU) a payoff of 25 ExCU − 0.77 ExCU = 24.23 ExCU results. In this case, no additional payment is deducted, because the minimum contribution has been reached.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

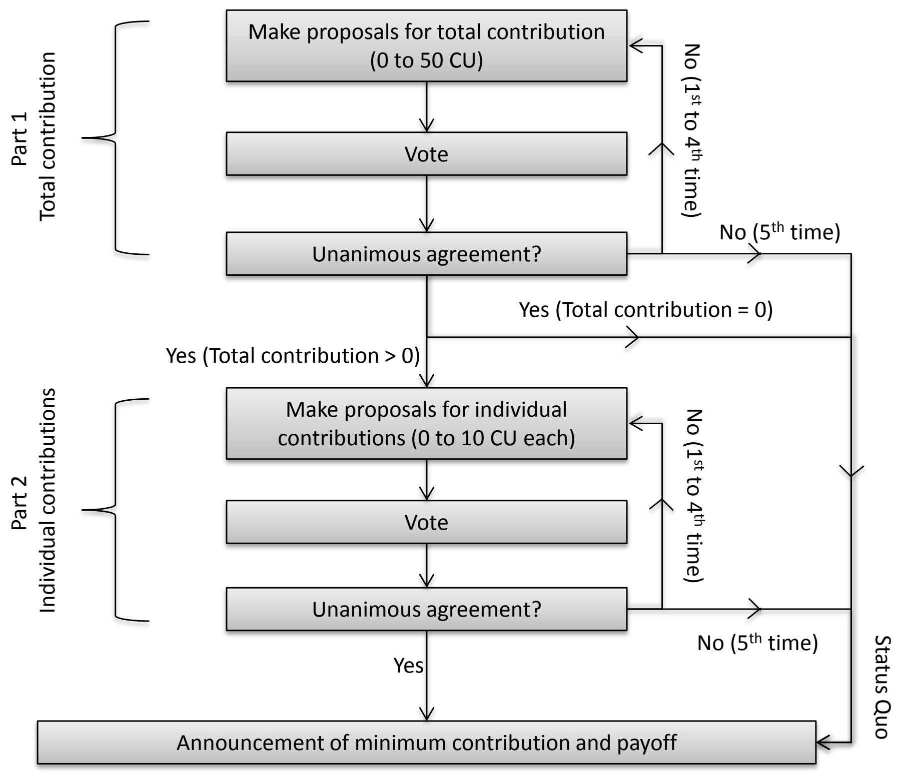


Figure A.10: Experimental procedure of treatment TDHET.

A.2.3 Treatment BUHOM

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you form **a group with four other players.** The composition of this group will not change throughout the entire experiment. You begin the experiment with an **endowment of 25 Experimental Currency Units.**

Your task in this experiment is to choose your and your fellow players' contributions to a project. Each player can contribute up to 10 Experimental Currency Units. The group's total contribution can therefore amount to up to 50 Experimental Currency Units. Your decision consists in a **vote on the individual contributions of all players in the group.** These contributions are added up to a **total contribution**.

For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost. The exact amount of this minimum contribution is determined randomly. You are told this information only at the end of the experiment. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his payoff.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

VOTING PROCEDURE In the experiment you and your fellow players vote on the **individual contributions of all group players**. This happens in **up to ten voting rounds** and proceeds as follows:

1. Each player makes a **proposal for the contribution of every single player**. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Experimental Currency Units (in steps of 0.1 ExCU). The individual contributions from each proposal are automatically summed up to a total contribution.

2. The proposals and corresponding total contributions are shown to all players in a list. Among these is also a proposal called **"Status Quo"**. This proposal means that each player provides a contribution of **0 Experimental Currency Units**. Next to each proposal, there is a list of the player(s) who made this proposal. Identical proposals are displayed only once, together with all players who made this proposal. Accordingly, there can again be up to six different distribution proposals.

3. At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal, please click on "Accept" in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the experiment ends with the calculation of payoffs. Otherwise, Steps 1. to 4. are repeated up to nine times.

5. If there is also **no agreement in the tenth voting round**, the **Status Quo** (each player provides a contribution of 0 Experimental Currency Units, total contribution of 0 Experimental Currency Units) is selected to calculate payoffs.

Table A.7: Reproduction of screenshot for voting decision in treatment BUHOM.

Voting round 5 of up to 10 You are Player D Please accept one of the following proposals! The minimum contribution takes on one of the following nine values: 16 ExCU, 17 ExCU, 18 ExCU, 19 ExCU, 20 ExCU, 21 ExCU, 22 ExCU, 23 ExCU, 24 ExCU			Back to current round		Show later round		Show earlier round
Proposal	**Contribution Player A (ExCU)**	**Contribution Player B (ExCU)**	**Contribution Player C (ExCU)**	**Contribution Player D (ExCU)**	**Contribution Player E (ExCU)**	**Total Contribution (ExCU)**	
Player A, C	1.0	2.0	4.0	3.0	9.0	19.0	Accept
Player B, E	6.5	1.0	2.0	6.5	0.0	16.0	Accept
Player D (your proposal)	9.0	3.0	5.0	4.0	1.0	22.0	Accept
Status quo	0.0	0.0	0.0	0.0	0.0	0.0	Accept

Example for the procedure of the experiment:

- Round 1:
  - A total of six proposals for the individual contributions of all players in the group:

    (See Table A.7)

  - The allocation "1 ExCU; 2 ExCU; 4 ExCU; 3 ExCU; 9 ExCU" with a total contribution of 19 ExCU has been proposed twice, but only counts as a single alternative.
  - The same applies to the allocation "6.5 ExCU; 1 ExCU; 2 ExCU; 6.5 ExCU; 0 ExCU" with a total contribution of 16 ExCU.
  - All five players vote for "A, C". The other three different proposals ("Status Quo", "B, E", "D") receive no votes this time.
- In this example, the voting procedure ends with a total contribution of 19 ExCU and the following individually payable contributions:
  - Player A: 1 ExCU
  - Player B: 2 ExCU
  - Player C: 4 ExCU
  - Player D: 3 ExCU
  - Player E: 9 ExCU

Please note that, starting with the second voting round, you may call up the **results from previous votes in this part** whenever you make a decision by clicking the button "Show earlier round". Clicking the button again shows even earlier rounds. By clicking the buttons "Show later round" or "Back to current round" you may advance again in the history or, respectively, jump immediately to the current decision round.

YOUR PAYOFF The payoff of each player calculates as follows:

- Please note that the contributed amount is deducted from your account balance in any case, even if the total contribution has not reached the minimum contribution.
- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  payoff for reaching the minimum contribution = 25 ExCU − your contributed amount

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  payoff for missing the minimum contribution = 25 ExCU − your contributed amount − 10 ExCU

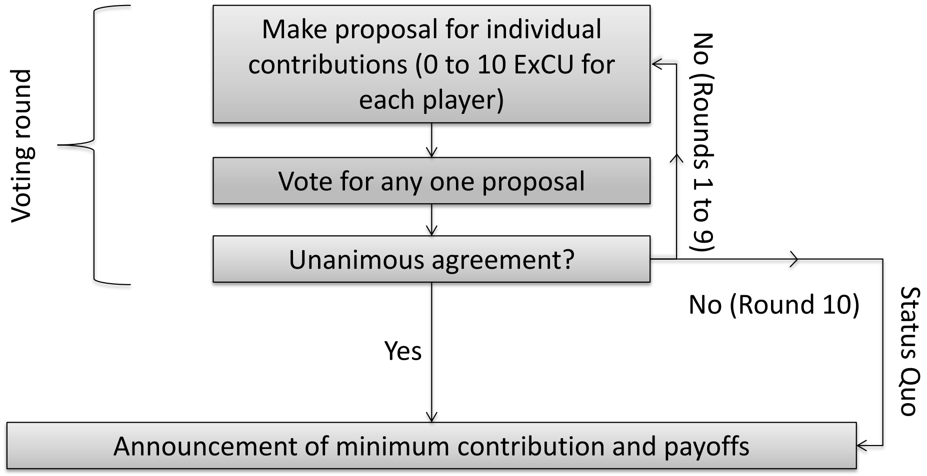


Figure A.11: Experimental procedure of treatment BUHOM.

In order to determine the total payoff at the end of the experiment, the resulting amount is converted into euros and added to your show-up fee. The payoff from a subsequent separate experiment is later added to this amount.

Example for payoffs (total contribution 19 ExCU):
Assume that the minimum contribution amount to 20 ExCU. Then a total contribution of 19 ExCU fails to reach this minimum contribution. Accordingly, for Player A from the previous example (contributed amount of 1 ExCU) a payoff of 25 ExCU − 1 ExCU − 10 ExCU = 14 ExCU results. An amount of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume that the minimum contribution amounts to 18 ExCU. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 ExCU a payoff of 25 ExCU − 1 ExCU = 24 ExCU results. In this case nothing is deducted, because the minimum contribution has been reached.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

A.2.4 Treatment BUHET

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you and **four other players** form a **group of five.** The composition of this group is determined randomly at the beginning of the experiment and does not change throughout the entire experiment. You begin the experiment with an **endowment of 25 Experimental Currency Units.**

Your task in this experiment is to choose your and your fellow players' contributions to a project. **Each player's contribution is measured in Contribution Units (CU).** Each player can contribute **up to 10 Contribution Units**, by investing Experimental Currency Units from his or her endowment. Your decision consists in a **vote on the individual contributions of all players in a group**. These contributions are added up to a **total contribution of up to 50 Contribution Units**.

The costs of contributions in Experimental Currency Units differ among the players:

Players A and B	1 Contribution Unit costs 0.77 Experimental Currency Unit **(1 CU = 0.77 ExCU)**
Players C, D and E	1 Contribution Unit costs 1.25 Experimental Currency Units **(1 CU = 1.25 ExCU)**

Which player you are (A, B, C, D, E) is determined randomly at the beginning of the experiment. You are told who you are before the first decision.

For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost. The exact amount of this minimum contribution is determined randomly. You are told this information only at the end of the experiment. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his payoff.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

VOTING PROCEDURE In the experiment you and your fellow players vote on the **individual contributions of all group players**. This happens in **up to ten voting rounds** and proceeds as follows:

1. Each player makes a **proposal for the contribution of every single player**. All players make their proposals individually and at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on "Calculate values" you can also display the corresponding values in Experimental Currency Units. The individual contributions from each proposal are automatically summed up to a total contribution.

2. The proposals and corresponding total contributions are shown to all players in a table (both in CU and ExCU) (see Table A.8). Among these is also a proposal called **"Status Quo"**. This proposal means that each player provides a contribution of **0 Experimental Currency Units**. Next to each proposal, there is a list of the player(s) who made this proposal. If the same proposal

has been made several times, it is shown only once, with all players who made this proposal. Accordingly, there can again be up to six different distribution proposals.

3. At the same time as all of the other players in his group, each player casts a vote for exactly one of these proposals. In order to vote for a proposal, please click on "Accept" in the column directly to the right of the proposal.

4. Each player learns the result of the vote, i.e., the number of votes for each proposal as well as which player has voted for which alternative. If all players select the same proposal (**unanimous decision**), the experiment ends with the calculation of payoffs. Otherwise, Steps 1. to 4. are repeated up to nine times.

5. If there is also **no agreement in the tenth voting round**, the **Status Quo** (each player provides a contribution of 0 Contribution Units, total contribution of 0 Contribution Units) is selected to calculate payoffs.

Example for the voting procedure:

- Round 1:
  - A total of six proposals for the individual contributions of all players in the group:

    (See Table A.8)

  - The allocation "1 CU; 2 CU; 4 CU; 3 CU; 9 CU" with a total contribution of 19 CU has been proposed twice, but only counts as a single alternative.
  - The same applies to the allocation "3 CU; 1 CU; 2 CU; 6.5 CU; 6.5 CU" with a total contribution of 16 CU.
  - All five players vote for "A, C". The remaining three different proposals ("Status Quo", "B, E", "D") receive no votes this time.
- In this example, the voting procedure ends with a total contribution of 19 CU and the following individual contributions:
  - Player A: 1 CU (1*0.77 ExCU = 0.77 ExCU)
  - Player B: 2 CU (2*0.77 ExCU = 1.54 ExCU)
  - Player C: 4 CU (4*1.25 ExCU = 5 ExCU)
  - Player D: 3 CU (3*1.25 ExCU = 3.75 ExCU)
  - Player E: 9 CU (9*1.25 ExCU = 11.25 ExCU)

Please note that, starting with the second voting round, you may call up the **results from previous votes** whenever you make a decision by clicking the button "Show earlier round". Clicking the button again shows even earlier rounds. By clicking the buttons "Show later round" or "Back to current round" you may advance again in the history or, respectively, jump immediately to the current decision round.

Table A.8: Reproduction of screenshot for voting decision in treatment BUHET.

Voting round 2 of up to 10 You are Player A Please accept one of the following proposals! The minimum contribution takes on one of the following nine values: 16 CU, 17 CU, 18 CU, 19 CU, 20 CU, 21 CU, 22 CU, 23 CU, 24 CU							
					Back to current round	Show later round	Show earlier round
Proposal	**Player A Contribution in CU (Costs in ExCU)**	**Player B Contribution in CU (Costs in ExCU)**	**Player C Contribution in CU (Costs in ExCU)**	**Player D Contribution in CU (Costs in ExCU)**	**Player E Contribution in CU (Costs in ExCU)**	**Total Contribution (CU)**	
Player A (your proposal), C	1.00 (0.77)	2.00 (1.54)	4.00 (5.00)	3.00 (3.75)	9.00 (11.25)	19.00	Accept
Player B, E	6.50 (5.00)	1.00 (0.77)	2.00 (2.50)	6.50 (8.12)	0.00 (0.00)	16.00	Accept
Player D	9.00 (6.93)	3.00 (2.31)	5.00 (6.25)	4.00 (5.00)	1.00 (1.25)	22.00	Accept
Status quo	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	Accept

YOUR PAYOFF The payoff of each player calculates as follows:

- Please note that you have to pay the costs of your contribution in any case, even if the total contribution has not reached the minimum contribution.
- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  Payoff for reaching the minimum contribution = 25 ExCU − your costs (in ExCU)

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  Payoff for missing the minimum contribution = 25 ExCU − your costs (in ExCU) − 10 ExCU

In order to determine the final payoff at the end of the experiment, the resulting amount is converted into euros **2 ExCU = 1 euro)** and added to your show-up fee. The payoff from a subsequent separate experiment is later added to this amount.

Example for the calculation of payoffs (total contribution 19 CU): Assume a **minimum contribution of 20 CU**. Then a total contribution of 19 CU fails to reach this minimum contribution. Accordingly, for Player A from the previous example (costs of 0.77 ExCU for 1 CU) this results in a payoff of 25 ExCU − 0.77 ExCU − 10 ExCU = 14.23 ExCU results. A payment of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume a **minimum contribution of 18 CU**. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 CU (costs of 0.77 ExCU) a payoff of 25 ExCU − 0.77 ExCU = 24.23 ExCU results. In this case, no additional payment is deducted, because the minimum contribution has been reached.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated

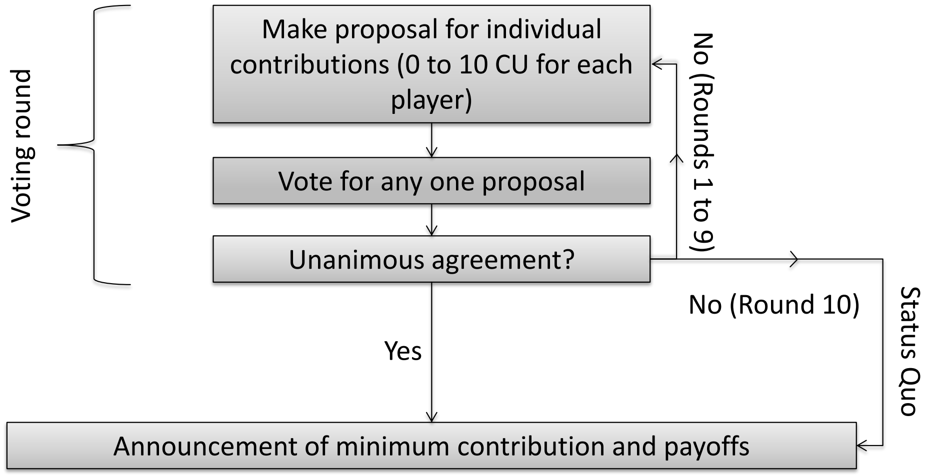


Figure A.12: Experimental procedure of treatment BUHET.

after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

A.2.5 Treatment RGHOM

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you and **four other players** form a **group of five**. The composition of this group will not change throughout the entire experiment, i.e., in all **ten rounds**.

Your task in each of the ten rounds is to choose your contribution to a project. At the same time, every other player in your group chooses his own contribution to this project. The contributions of all players in a group are added up to a **total contribution**. For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost.

The experiment consists of **a total of ten independent decisions of this kind** in a total of ten rounds. **However, only one of these rounds will matter for your payoff.** Which of these rounds is paid will be determined randomly at the end of the experiment, individually for each player. For this purpose, each of the ten rounds has the same probability of being chosen.

At the beginning of each round, each player has an **endowment of 25 Experimental Currency Units**. In every individual round, each player can contribute up to 10 Experimental Currency Units. The group's total contribution in each round can therefore amount to up to 50 Experimental Currency Units.

The exact amount of the minimum contribution is determined randomly and separately for each round. You are told this information only at the end of the respective round, i.e., after the contributions have been chosen. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached in a particular round, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his earnings in the respective round.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

PROCEDURE OF THE DECISION In the experiment you and your fellow players each choose **your own contribution to the project**. This happens in **ten decision rounds** which all proceed as follows:

1. Each player chooses his own contribution to the project. All players choose their contributions at the same time. In order to do this, each player chooses an amount between 0 and 10 Experimental Currency Units (in steps of 0.1 ExCU). The individual contributions of all players in a group are automatically summed up to a total contribution.

2. After all group members have made their contribution choice, each player is told the required minimum contribution, his group's total contribution, as well as his resulting earnings. The contributions of the other players in the group are also displayed.

YOUR PAYOFF The **earnings of each player in the respective round** calculate as follows:

- Please note that the contributed amount is deducted from your account balance in any case, even if the total contribution has not reached the minimum contribution.

- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  Earnings for reaching the minimum contribution = 25 ExCU − your contributed amount

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  Earnings for missing the minimum contribution = 25 ExCU − your contributed amount − 10 ExCU

In order to determine the **total payoff at the end of the experiment**, one of the ten rounds is chosen randomly. All rounds have the same probability of being chosen. **This means that you receive the earnings from only a single round.** The results from the remaining rounds are no longer relevant to your payoff, no matter if the minimum contribution has been reached in these rounds or not.

The earnings from the randomly chosen round are converted into euros (**2 ExCU = €1**) and added to your show-up fee (€3). The payoff from a subsequent separate experiment is later added to this amount.

Example for the procedure of a particular round
In this round, the players in a given group make the following individual contributions which add up to a **total contribution of 19 ExCU**:

- Player A: 1 ExCU
- Player B: 2 ExCU
- Player C: 4 ExCU
- Player D: 3 ExCU
- Player E: 9 ExCU

Assume that the **minimum contribution amount to 20 ExCU**. Then a total contribution of 19 ExCU fails to reach this minimum contribution. Accordingly, Player A (contributed amount of 1 ExCU) has earnings of 25 ExCU − 1 ExCU − 10 ExCU = 14 ExCU in this round. An amount of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume that the **minimum contribution amounts to 18 ExCU**. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 ExCU earnings of 25 ExCU − 1 ExCU = 24 ExCU result. In this case nothing is deducted, because the minimum contribution has been reached.

Please note that, starting with the second decision round, you may call up the **results from previous rounds** whenever you make a decision by clicking the button "Show earlier results". By clicking the button "Back" you may return to the current decision round. After having chosen your contribution (by clicking "Confirm choice") you have one additional opportunity to correct your decision if necessary. As soon as you click "Confirm choice and continue", your decision is final.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

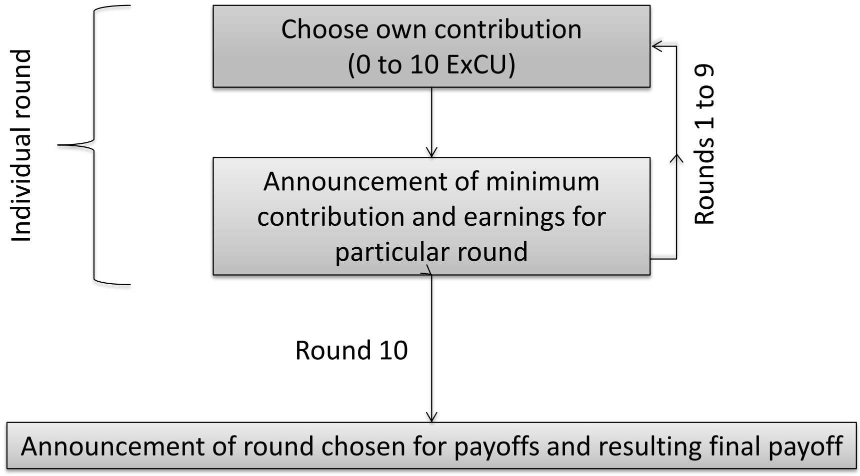


Figure A.13: Experimental procedure of treatment RGHOM.

A.2.6 Treatment RGHET

Welcome to the experiment!

You are now participating in a scientific experiment. Please read the following instructions carefully. Here you will be told everything that you need to know for the participation in the experiment. Please also note the following:

From now on as well as during the entire experiment **no communication** is permitted. Please turn off your cell phones. If you have any questions, please raise your hand. All **decisions are made anonymously**, meaning that none of the other participants learns the identity of those who made a particular decision.

For showing up on time you receive an amount of €3. Over the course of the experiment you can earn two additional amounts of money. The first amount of up to €12.50 results from your decisions in the experiment. This amount is influenced by the decisions of your fellow participants. The second amount ranges from €0.10 to €3.85 and results solely from your individual decision in a subsequent questionnaire. The total amount will be paid to you **in cash** at the end of the experiment. The **payment occurs anonymously, too**, meaning that no participant will known another participant's payoff. This experiment uses the currency "Experimental Currency Units" (ExCU).

Two Experimental Currency Units are equal to €1.

Experimental Procedure

In the experiment you and **four other players** form a **group of five**. The composition of this group is determined randomly at the beginning of the experiment. It will not change throughout the entire experiment, i.e., in all **ten rounds**.

Your task in each of the ten rounds is to choose your contribution to a project. At the same time, every other player in your group chooses his own contribution to this project. The contributions of all players in a group are added up to a **total contribution**. For the project to be successful, **your group's total contribution must reach a minimum contribution.** Otherwise, the project fails and the amount you contributed to the project (as well as the contributions from your fellow players) are lost.

The experiment consists of **a total of ten independent decisions of this kind** in a total of ten rounds. **However, only one of these rounds will matter for your payoff.** Which of these rounds is paid will be determined randomly at the end of the experiment, individually for each player. For this purpose, each of the ten rounds has the same probability of being chosen.

At the beginning of each round, each player has an **endowment of 25 Experimental Currency Units**. **Each player's contribution is measured in Contribution Units (CU).** In every individual round, each player can contribute **up to 10 Contribution Units**, by investing Experimental Currency Units from his or her endowment. The group's total contribution in each round can therefore amount to up to 50 Contribution Units.

The costs of contributions in Experimental Currency Units differ among the players:

Players A and B	1 Contribution Unit costs 0.77 Experimental Currency Unit **(1 CU = 0.77 ExCU)**
Players C, D and E	1 Contribution Unit costs 1.25 Experimental Currency Units **(1 CU = 1.25 ExCU)**

Which player you are (A, B, C, D, E) is determined randomly at the beginning of the experiment. You are told who you are before the first decision.

The exact amount of the **minimum contribution is determined randomly and separately for each round**. You are told this information only at the end of the respective round, i.e., after the contributions have been chosen. You know however that the **minimum contribution** will take on one of the following **nine values in contribution units, each with the same probability:**

16, 17, 18, 19, 20, 21, 22, 23, 24

If the minimum contribution is not reached in a particular round, each player must make an additional **payment of 10 Experimental Currency Units**, which is deducted from his earnings in the respective round.

Total contribution	<16	16	17	18	19	20	21	22	23	24	>24
Probability that minimum contribution is reached (absolute)	0	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	1	1
Probability that minimum contribution is reached (%, rounded)	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	100%

PROCEDURE OF THE DECISION In the experiment you and your fellow players each choose **your own contribution to the project**. This happens in **ten decision rounds** which all proceed as follows:

1. Each player chooses his own contribution to the project. All players choose their contributions at the same time. In order to do this, each player chooses an amount between 0 and 10 Contribution Units (in steps of 0.01 CU). By clicking on "Calculate Values" you can also display the corresponding values in Experimental Currency Units. The individual contributions of all players in a group are automatically summed up to a total contribution.

2. After all group members have made their contribution choice, each player is told the required minimum contribution, his group's total contribution, as well as his resulting earnings. The contributions of the other players in the group are also displayed (in CU and ExCU).

YOUR PAYOFF The **earnings of each player in the respective round** calculate as follows:

- Please note that the contributed amount is deducted from your account balance in any case, even if the total contribution has not reached the minimum contribution.

- If the group's total contribution is greater than or equal to the minimum contribution, then the project is successful and you receive the following payoff:

  Earnings for reaching the minimum contribution = 25 ExCU − your costs (in ExCU)

- If the group's total contribution is less than the minimum contribution, then the project is not successful and you receive the following payoff:

  Earnings for missing the minimum contribution = 25 ExCU − your costs (in ExCU) − 10 ExCU

In order to determine the **total payoff at the end of the experiment**, one of the ten rounds is chosen randomly. All rounds have the same probability of being chosen. **This means that you receive the earnings from only a single round.** The results from the remaining rounds are no longer relevant to your payoff, no matter if the minimum contribution has been reached in these rounds or not.

The earnings from the randomly chosen round are converted into euros (**2 ExCU = €1**) and added to your show-up fee (€3). The payoff from a subsequent separate experiment is later added to this amount.

Example for the procedure of a particular round
In this round, the players in a given group make the following individual contributions which add up to a **total contribution of 19 ExCU**:

- Player A: 1 CU (1*0.77 ExCU = 0.77 ExCU)
- Player B: 2 CU (2*0.77 ExCU = 1.54 ExCU)
- Player C: 4 CU (4*1.25 ExCU = 5 ExCU)
- Player D: 3 CU (3*1.25 ExCU = 3.75 ExCU)
- Player E: 9 CU (9*1.25 ExCU = 11.25 ExCU)

Assume that the **minimum contribution amount to 20 ExCU**. Then a total contribution of 19 ExCU fails to reach this minimum contribution. Accordingly, Player A (costs of 0.77 ExCU for 1 CU) has earnings of 25 ExCU − 0.77 ExCU − 10 ExCU = 14.23 ExCU in this round. An amount of 10 ExCU is deducted here, because the minimum contribution has not been reached.

Assume that the **minimum contribution amounts to 18 ExCU**. Then a total contribution of 19 ExCU reaches this minimum contribution. Now, for a contributed amount of 1 CU (costs of 0.77 ExCU) earnings of 25 ExCU − 0.77 ExCU = 24.23 ExCU result. In this case nothing is deducted, because the minimum contribution has been reached.

Please note that, starting with the second decision round, you may call up the **results from previous rounds** whenever you make a decision by clicking the button "Show earlier results". By clicking the button "Back" you may return to the current decision round. After having chosen your contribution (by clicking "Confirm choice") you have one additional opportunity to correct your decision if necessary. As soon as you click "Confirm choice and continue", your decision is final.

ADDITIONAL REMARKS Please think carefully about all of your decisions, because they determine your payoff at the end of the experiment. Before the actual experiment can begin, you must answer a few questions which ensure that you have understood the procedure of the experiment and your task. You find the questions on the left side of the screen, and you can enter your answers on the right side. Please enter decimal numbers with a point instead of a comma (that is, e.g., 12.34 instead of 12,34). If you have any questions yourself during the experiment, please remain seated quietly and raise your hand. Please wait until the experimenter has come to your seat and then ask your question as quietly as possible. However, questions should only be about the instructions and not about strategies! Furthermore, please note that the game only continues when all players have made their decisions. Feel free to use the last sheet of these instructions for your own notes.

END OF THE EXPERIMENT After the experiment, we ask you to fill in a questionnaire with an additional decision task. When the time has come, we will distribute separate instructions explaining the procedure. Please remain seated after filling in the questionnaire until we call up your place number. Take your instructions with you to the front desk. Only then can you receive your payoff.

Thank you very much for your participation and good luck!

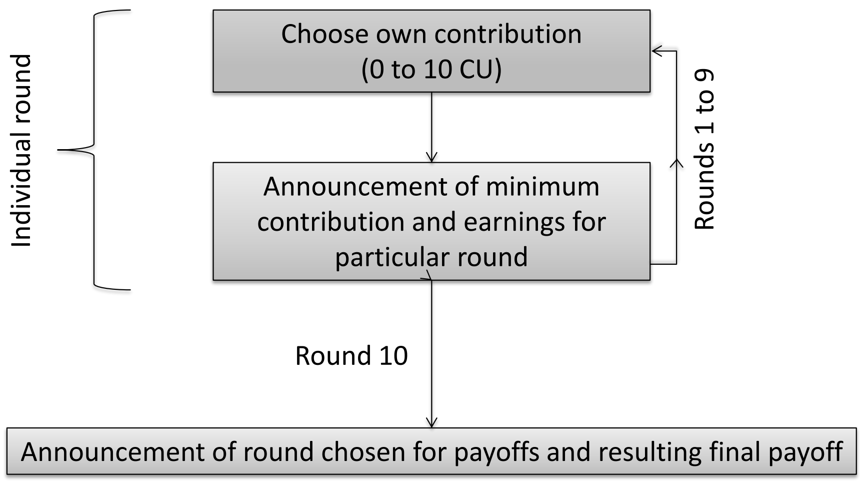


Figure A.14: Experimental procedure of treatment RGHET.

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