ASYMMETRIC PUBLIC-GOOD GAMES

EXPERIMENTS ON CONTRIBUTION NORMS ENCOURAGING COOPERATION

Dissertation

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1. General Introduction

The objective of this dissertation is to disentangle the effects of endowment asymmetries on human behavior in a public good environment. The focus on groups with endowment asymmetries is motivated by the fact that a substantial share of economic interactions is characterized by economic agents with different endowments, whether in the form of skills, funds or other attributes. The presence of asymmetries influences the dependency of group members from one another, as well as their bargaining position. Group members with a lower endowment depend stronger on the contributions by the other group members, but also benefit the most from cooperation. Based on their disadvantageous position, low endowment players may expect higher contributions from the high endowment players, while the latter, on the other hand, may demand higher contributions (as a share of their endowment) by low endowment players because of their dependency on group contributions to achieve higher payoffs. Another relevant factor might be the attention players pay towards their own or other player types. Low endowment players may direct their attention to contributions by high endowment players, since they have the highest payoff relevance for themselves, while high endowment players might mainly compare each other. Therefore, asymmetry itself induces several dimensions to the problem. Besides asymmetry per se, one also has to consider the degree of asymmetry. Therefore, another aspect addressed is the dependency of contributions behavior on the degree of asymmetry. When the endowment structure shifts from being symmetric to a strong asymmetry, especially high endowment players are expected to lower their contributions. For small changes no differences are expected since endowment should be perceived as “quasi” symmetric, but this is unlikely to be the case for stronger asymmetries.

We use the voluntary contributions mechanism (VCM) (e.g. Isaac and Walker (1988a)) as the framework to analyze group behavior under asymmetry, within small groups. The combination of a public good game and endowment asymmetry is especially interesting since interactions in small groups of agents (individuals as well as parties) are often characterized by such a constellation, and may fail to achieve cooperation. Examples reach from small groups, facing the trade-off between investing time, money and energy in either a group or a private project, over parties in the parliament which need to cooperate to pass bills and may be forced to invest their credibility, to international projects where nations could benefit from cooperation. Investments in the reduction of carbon dioxide emissions and the struggle against climatic change may serve as an example for the latter case.[1] Endowment asymmetries between poor and wealthy countries make it difficult to find the common

[1] Following Tavoni et al. (2011) one may also say that all parties involved focus on avoiding a public bad.

sense level of investment or cooperation at all. Although this problem is too complex to be comprehensively modelled within a linear public good game, the basic setup can serve as a tool to narrow down behavioral patterns that emerge in asymmetric environments.

To tackle the problem of cooperation in asymmetric environments, several steps need to be undertaken. First, one has to identify if there are behavioral differences depending on the degree of asymmetry. Given some positive level of contribution to the public good takes place, it is reasonable to assume that groups with a symmetric or weakly asymmetric endowment tend to contribute more than groups with a higher degree of asymmetry. In a second step, mechanisms are implemented that aim to induce a cooperation norm. The first mechanism used is a mandatory minimum contribution. This approach is based on the idea of setting a standard with potential norm giving character that might stimulate cooperation. The second mechanism implements the possibility to punish group members. This opens the possibility to signal disagreement about the contribution behavior of group members and the punishment of free-riding behavior.

While the basic economic approach assumes, as an abstraction, all economic actors to act solely based on individual profit maximization, from the experimental and behavioral economics literature it is known that human behavior is influenced by norms that originate from concepts such as, e.g., cooperation and reciprocity (e.g. Keser and van Winden (2000)). Although generalizing experimental results and deriving general economic recommendations is difficult, this approach may help to identify and to tackle underlying problems.

Behavioral and experimental economics are rapidly expanding fields of study. Edward Chamberlin is considered the first scholar to conduct classroom experiments. His intension was to shed light on flaws in the perfect competition models (Holt (2007)). Today a vast range of studies are run in experimental economic laboratories. The models' analysis and benchmark are based on game theoretical equilibrium considerations. The theoretical models partially make strong assumptions about the state of the world and the behavior of economic actors.

Real world data, on the other hand, as used in statistical and econometric analysis, reflect the real world but are very complex. As a result, it is hardly possible to disentangle specific driving factors and thus to draw causal inferences. Taking those shortcomings into account, experimental economics gives the opportunity to zoom in on specific economic aspects and to test theoretical predictions with actual human behavior. Laboratory experiments are conducted with a high degree of control over the environment. Participants are often university students, who are invited to the lab to participate in financially incentivized decision experiments.

1.1 The Public Good

A public good is characterized as nonrival and nonexclusive (Samuelson (1954), Musgrave (1959) and Olson (1965)). Ostrom (2003) comprehensively summarizes the aspects of the discussion by the three aforementioned authors and the resulting classification. Various examples of public goods can be found in the public sector. Highways, light houses or national defense are usually implemented by the state institutions and everybody benefits from them. Another prominent example is environmental protection.

1.2 Public Good Experiments and Behavioral Patterns

In a public-good experiment participants are grouped together and have to invest in a private and/or a public good. Returns from private investments only benefit the investor, while returns from the public good benefit all group members. The group size may influence the incentives to invest into the public good. Isaac and Walker (1988a) argue, based on their experimental findings, that a pure size effect is not observed, but variations in the results appear to be mainly driven by differences in the marginal per capita return (MPCR) of small and large groups.[2]

While many experiments use the same endowment for all players, this dissertation focuses on endowment asymmetries. This is especially interesting given the fact that in general contributions to public goods are provided by households and/or individuals with very different income situations, particularly taking into account the often discussed increase in wealth differences (http://www.oecd.org/social/inequality.htm (December 21 2015)). While endowment asymmetries are one way to implement asymmetries into the public-good game, differences solely between the individuals' MPCR is the second approach. This reflects a situation where everybody in a group or society has the same income or resources, but the individual utility from the public good differs. By implementing a MPCR asymmetry, some individuals will profit more from the public good than others.

With respect to a player's endowment, every group member has to invest her endowment in one or both available goods. These investments are either one-shot, that is, group members interact only

[2] The experiment of Isaac and Walker (1988a) focuses on groups of four or ten players and each group size faces in different treatments either a high or a low marginal per capita return (MPCR). These variations are used to be able to distinguish whether observed changes in contributions are due to changes in the group size or the MPCR.

once with each other, or repeated, where participants interact over several rounds. Repeated interactions take place either with the same group members in all rounds, called “partners design”, or each round with new members, called “strangers design”. The main purpose of a strangers treatment is to avoid reputation and time effects between group members.

Another distinction can be made between different payoff structures. The basic version is the linear public-good game, as used by, e.g., Isaac and Walker (1988a). Every contribution to the private and public good yields a fixed return. The parameters are set such that the individual return from the private good is larger than from the public good. At the same time, if everybody contributes everything to the public good, the individual return from the public good is higher than from the private good. This creates a dilemma situation, where everybody has an individual profit maximizing incentive to invest the whole endowment in the private good and to free ride on potential contributions by others to the public good. At the same time the social optimum implies full contribution to the public good. This means, complete cooperation allows a higher payoff for all group members as compared to exclusive investments to the private good.[3] The second version of the public-good game offers an interior solution. One has to distinguish between an interior Nash equilibrium, were a player’s best response to the other players’ behavior leads to an interior solution, and an interior dominant strategy equilibrium, where each player splits her contributions between both goods, irrespective the decisions of the other players. Andreoni (1993) conducts an experiment employing a Nash equilibrium with interior solution to discuss the crowding-out effect of taxations on the contribution behavior. The findings indicate an incomplete crowding out of voluntary contributions. Actual contributions lay between the Nash equilibrium and the Pareto efficient outcome. Chan et al. (1996) conduct experiments based on the theoretical frameworks by Warr (1983) and Bergstrom, Blume and Varian (1986), to test the model’s finding of an interior Nash equilibrium with positive public good provision and the results independence of redistribution of income. They find, for varying degrees of asymmetry, significant contributions above the predicted interior Nash equilibrium. In Keser (1996), on the other hand, the dominant strategy model is used to argue against the claim that observed public good contributions result from decision errors by the participants. For this to be the case deviations from the interior solution should be with same frequency higher and lower than the dominant strategy solution. The results show participants deviate significantly more often towards the cooperative outcome. Sefton and Steinberg (1996) compare the contribution behavior in the interior Nash equilibrium and the interior dominant strategy model, using a strangers matching. Both models show public good contribution above the predicted level.

[3] For a broader discussion of the public good experiment see Ledyard (1995).

In the paragraphs above, the focus was on modelling aspects of the public good game. This part turns to the most relevant behavioral patterns for the studies in chapter 2 to 5. In this context, conditional cooperation and reciprocity are the most relevant norms. They acknowledge the strategic dimension within cooperation behavior of a repeated public good game. Keser and van Winden (2000) show that individuals choose their behavior according to the dynamics of group interactions and discuss two features of conditional cooperation. The authors distinguish between future orientated behavior and reactive behavior. The first aspect reflects considerations of future interactions. Individuals realize the need to signal their willingness to cooperate in order to motivate others to cooperate as well. If successful, this holds until the individuals approach the end of their repeated interactions, where the latter triggers end game behavior; which is characterized by collapsing cooperation in the last rounds of an experiment. The lack of future interactions diminishes the value of investments in cooperation. The second dimension is short term and takes a round-to-round comparison into account. After each interaction, everybody will evaluate their own performance relative to the performance of the others. If others contribute more, the individual will increase her own contributions, and vice versa (Keser and van Winden (2000)). This results in individuals matching their present behavior with the other players' behavior in the previous interaction. Behavior of this type plays an important role in the public-good experiments presented in this dissertation and appears to be one of the main driving factors in group contributions. Changes in group contributions are partially explained by an individual's relative performance compared to its group members, as will be discussed later on.

Besides the above described versions of the public good games, further experiments focus on different aspects, which target on the effectiveness of institutions, communication possibilities or coordination mechanisms. The first to be mentioned here is the punishment mechanism, as used by e.g. Fehr and Gächter (2000). In that framework, participants are informed about the contributions by all group members and have the opportunity to allocate punishment points which usually come at a cost to both sides. This approach will also be used in chapter 4. Further extensions make use of e.g. communication between the group members, which standard theory considers only cheap talk, but may in fact influence group contributions, as e.g. Isaac and Walker (1988b), as well as third parties that may not profit from the public good but are installed to coordinate or facilitate cooperation, e.g. Dickson et al. (2009).

1.3 Content of the Experiments

Placed in the vast literature of public-good experiments, the following studies focus on the group dynamics within asymmetric groups. As described in chapter 1.2, one has to distinguish between asymmetries in endowment and asymmetries in MPCR. The following studies focus exclusively on endowment asymmetry.

The initial setup, discussed in chapter 2[4], emphasizes various degrees of asymmetry. The baseline treatment uses a symmetric setup with four players, which is compared to treatments with varying degrees of asymmetries. The treatment with the strongest asymmetry creates a situation where the high endowment player does not benefit any longer from reaching the social optimum. The used MPCR is 0.5, which means the individual return from an investment in the public good is half of the private good. Baring the theoretical prediction of zero contribution in mind, results from this experiment show average contribution levels range between 40% and 60%. Furthermore, we find in our weakly asymmetric treatment that contributions by all player types translate to a situation where all contribute roughly the same share of their endowment. This behavioral pattern is questioned under strong asymmetry. The high endowment player can basically "live" outside the group, while the low endowment players are free to join their own symmetric public-good game. This setup is motivated by large differences in wealth where the majority of the population is much less wealthy than the very high endowment minority. For the strong asymmetry treatment, we choose a Gini index of 35. This value is on a similar level as the real-world Gini indices of Germany (30.6), the UK (38) and the US (41.1) (http://data.worldbank.org/indicator/SI.POV.GINI (August 18 2015)). This shift in behavior, from a quasi fair-share towards the same absolute contributions, is an interesting observation, considering the unimportance of cooperation for the high endowment player. Overall, public goods serve as a redistribution mechanism and vehicle to reduce inequality in a group or society. Extrapolating this finding to the public sector, it is encouraging to see that even the very high endowment players seem to contribute to society, although this contribution means only a small fraction of their endowment and is only at the level of low endowment players.

Even though the first experiment shows some cooperation, there is further room for improvement, especially considering the decline in group contributions. Therefore, two more experimental setups

[4] Joint work with Claudia Keser, Andreas Markstädter, and Cornelius Schnitzler. cege Discussion Paper, No. 217, University of Göttingen, October 2014. Download: http://wwwuser.gwdg.de/~cege/Diskussionspapiere/DP217.pdf.

are used to explore their effect on the provision of public goods. In the first approach the focus is on minimum contributions, while the second approach is analyzing the effect of punishment.

The second experiment[5] puts participants in situations where they face compulsory minimum contributions to the public good. Although results in the weakly asymmetry treatment of the first experiment show that individual contributions translate into the same share of endowment, there is also an indication that low endowment players tend to contribute a larger share of their endowment. The low asymmetry treatment serves as a benchmark and is compared to three minimum contributions mechanisms. In a first control treatment all players face the same minimum contribution, in the second treatment all players have to contribute at least 40 percent of their endowment, and in the last treatment players face progressive compulsory contribution, where the high endowment player has to contribute the most and the low endowment player the least. We tackle the question which enforced contribution method translates into higher group contributions, compared to the status quo where all group members freely decide on integer contributions between zero and their own endowment. If the minimum contribution is perceived as the ideal level, we should observe participants to only contribute the compulsory minimum, which is at the same time the game theoretical solution. In this case, one can speak of completely crowding out of intrinsic motivation. This touches the discussion by Andreoni (1993) on the effect of a lump sum "tax" on voluntary contributions. A mandatory contribution is considered successful in fostering cooperation, if the total contribution to the public good significantly exceeds the baseline treatment. One has to keep in mind that it is not the target to patronize the participants, which is clearly the case if the mandatory level is above the contribution levels observed in the baseline treatment. The results show that only the progressive minimum contribution achieves significantly higher contribution levels than the baseline treatment. The relative minimum contribution leads to a group contribution level that lies between the progressive and the two other treatments and shows no significant difference in any direction. With regard to type behavior, the baseline and the relative treatment again display the fair-share rule, while in the remaining treatments the player type with the highest mandatory contribution, relatively to her own endowment, also contributes more than the others. Furthermore, the motivational crowding-out, a measure that corresponds to the share of the free disposable income, indicates that only the fixed minimum contribution leads to a significant crowding-out compared to the baseline treatment.

While the second experiment includes exogenously given rules to change group behavior, the third paper[6] uses a punishment mechanism. Every player is free to incur costs to impose punishment on

[5] Joint work with Claudia Keser and Andreas Markstädter. Games and Economic Behavior, (forthcoming).
[6] Joint work with Claudia Keser.

other group members. Those inflicted costs are four times higher for the punished player than for the punisher. The maximum punishment is capped to eight and sufficient funds are required, but no additional restrictions are imposed. Furthermore, players cannot clearly identify their punisher, although the overview on group contributions might give some indication. Because of the structure of the punishment mechanism, punishment of contributors and free-riders is possible. From previous studies, such as Fehr and Gächter (2000), it is known that punishment mechanisms tend to increase group contributions. At the same time, due to punishment costs, total payoffs are usually not higher than in no-punishment experiments. Punishment is especially high in the beginning of the experiment. Players have to get used to the game and also try to coordinate with their group members. Therefore, it is reasonable to look at payoffs in the second half of the game, which suggests that profits in the punishment treatments outperform those in no-punishment treatments.[7] This is driven by stable contributions in the punishment treatments, compared to declining contributions in the no-punishment treatments, as well as decreasing punishment over time. In this experiment the group size is reduce to three players and two player types, with the objective to look at groups where one player type outnumbers the other. This way, we aim at analyzing the effect of punishment on contributions in asymmetric groups and, at the same time, control for differences in the punishment depending on the target. We ask if punishment shows significant differences depending on the punisher's and punished player's types. In line with previous studies, we find higher group contributions in the punishment treatments, but the same total payoffs as in the no punishment treatment. Again, profits in the second half of the experiment tend to outperform those in the no punishment condition. When it comes to punishment, there are indications that high endowment players punish each other more, while in case of a majority of low endowment players the punishment is higher for the high endowment player.

The last experiment[8] investigates if contributions in relative or absolute values are preferred, if this is depending on the complexity of the situation and whether contribution behavior shows structural differences between players choosing an absolute or relative display method. In the first experiment we observed a norm shift from quasi fair-share contributions towards contributing the same in absolute terms when reaching a high endowment asymmetry. This raises the question whether there is also an active shift in the method how participants decide on their own contribution. Therefore, in every round participants are asked whether they want to contribute in absolute terms or shares of their endowment. We expect treatments with strong asymmetry to exhibit more frequently the choice of absolute contributions then under weak asymmetry. Despite the actual choice, it is interesting to

[7] Gächter et al. (2008) show that experiments with punishment mechanism outperform no-punishment treatments in the long run.
[8] Joint work with Claudia Keser and Jörn Kroll.

analyze whether choosing the relative contribution mechanism also leads to higher contributions. If relative contributions are linked to fair-share contributions, and taking the reciprocity finding by Keser and van Winden (2000) into account, this may lead to boosted contributions. To tackle this question, we again reduced the group size. The motivation behind this approach is to solely focus on bilateral interactions. Again, the previously used three endowment settings symmetry, weak asymmetry and strong asymmetry are applied. An additional treatment was conducted which resembles the four players weak asymmetry treatment from the first experiment but with choice option. This treatment serves to control if the implementation of the choice influences group contributions and if group size matters for the choice of absolute or relative. We find that the majority of participants prefer to contribute in absolute terms, while contributions roughly translate into the fair-share. This behavior is in line with the psychology literature, arguing that working with percentages creates difficulties for the human brain (e.g. Kruger and Vargas (2008), Mix et al. (1999), Chen and Rao (2007), Parker and Leinhart (1995)). Furthermore, the players in the symmetric treatment choose significantly more often the absolute mechanism relative to both other two player treatments.

1.4 Contribution to the Literature

This dissertation extends the understanding of asymmetric group behavior in the provision of public goods. Previous studies, using an asymmetric framework, have so far focused on situations where all players profit from the social optimum. The discussion in chapter 2 breaks with this tradition in order to show how strong inequalities may decrease group contributions, as the high endowment players only cooperate on a low level. This is relevant since it shows how a big rift in the income of a society – with only a few being endowed with a large share of the society's wealth – may proof disadvantageous.

The approach in chapter 3, on the other hand, joins the discussion on crowding-out of intrinsic motivation as well as the question which mandatory contribution mechanism performs the best. It shows how progressive mandatory contributions stimulate the highest level of public good provision, while displaying the same level of motivational crowding-out as in the treatment without mandatory contributions. Furthermore, it suggests that high endowment players accept this norm and contribute even more.

The fourth chapter puts the emphasis on peer punishment. Although in earlier studies no differences in punishment behavior between different player types have been documented, this experiment shows that especially high endowment players' contributions are observed closely and deviations from expected contributions are punished.

The last experiment in chapter 5 contributes to the methodological literature by focusing on the importance of the display mechanism. It shows that there are differences in preferences, whether to contribute in absolute terms or in shares of the endowment. However, this has no effect on contributions. At the same time, participants adapt their preferences depending on the actual design of the experiment. This is reflected in the observation that more participants pick the relative contribution method the stronger the asymmetry.

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2. Social Costs of Inequality – Heterogeneous Endowments in Public-Good Experiments

with Claudia Keser, Andreas Markstädter and Cornelius Schnitzler

Abstract: We compare voluntary contributions to the financing of a public good in a symmetric setting to those in asymmetric settings, in which four players have different, randomly allocated endowments. We observe that a weak asymmetry in the endowment distribution leads to the same contribution level as symmetry. Players tend to contribute the same proportion of their respective endowment. In a strongly asymmetric setting, where one player has a higher endowment than the three other players together, we observe significantly lower group contributions than in the other settings. The super-rich player does not contribute significantly more than what the others contribute on average and thus a much lower proportion of the endowment.

JEL classification: C92, D63, H41.

Keywords: Experimental economics; public goods; heterogeneous endowments

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2.1 Introduction

In international relations the provision of global public goods plays an extensive role. The reduction of greenhouse gas emissions, cross-border crime prevention and disease control are well-known examples. Since it is difficult to exclude non-contributing parties from the consumption of a public good, there exist incentives to free ride on the contributions of others, which lead to inefficiently low provision levels (Olson, 1965). The relatively small number of parties typically involved in the decision making on the provision of global public goods is marked by their heterogeneity in interests and resources. The interaction of industrialized, emerging and development countries, evidently involves a strong inequality in wealth. Besides these international interactions, wealth heterogeneity is also omnipresent on national scales. Income inequalities are on the rise in many, even highly developed, countries. Income inequality measured by the Gini coefficient, a standard measure that ranges from 0 (when everybody has the same income) to 1 (when all income belongs to one person), has on average risen by almost 10 percent from the mid-1980s to the late 2000s in the OECD countries, latterly averaging 0.316. Inequality lies, for example, in Germany with 0.295 slightly below and in the United States with 0.378 above the average (OECD, 2011). The general question is how these international and national inequalities affect outcomes in situations that involve cooperation and consensus among heterogeneous parties. Our study contributes to answering this question and asks whether wealth heterogeneity is likely to affect outcomes related to the provision of public goods in an experimental-economics setting that involves wealth distributions that approximate the reported OECD average.

From a theoretical point of view, Warr's (1983) neutrality theorem states that the provision of a single public good is unaffected by a redistribution of wealth. Bergstrom et al. (1986) elaborate on this theorem, confirming that small redistributions will not change the equilibrium supply of a public good. However, this is true only as long as the set of contributors remains unchanged. They argue that large redistributions will change the set of contributors and thus the supply of a public good. Maurice et al. (2013) present a laboratory experiment on a (non-linear) Voluntary-Contributions Mechanism (VCM), investigating the effect of un-equalizing or equalizing redistributions of endowments. They observe no significant effect on the contribution level and interpret this result as an indication for the validity of Warr's theorem.

In the extensive literature on VCM experiments it has mostly been neglected that (the degree of) asymmetry in the endowments and/or interests in the provision of a public good could impact the voluntary contribution level. The bulk of experiments is based on the simple linear game introduced by Marwell and Ames (1979) and Isaac et al. (1984) and uses a symmetric parameterization, implying that each of the players has the same endowment and the same marginal return from the public good. Even though each player's dominant strategy is to make zero contribution to the public good, experiment participants typically contribute between 40 and 60 percent of their endowment (Ledyard, 1995). Many studies examine to what extent the actual contribution level depends on various factors, including, for example, the marginal per-capita return (MPCR) from the public good (i.e., the individual value of one unit contributed to the public good relative to the value of its private consumption), the group size, or the interaction of both (e.g., Isaac and Walker, 1988; Weimann et al., 2014). However, compared to the large amount of work that has been conducted using homogeneous endowments, there has been less attention to asymmetric settings.

To fill this gap in the literature, our study investigates whether and how inequalities in endowments affect contribution levels, without making reference to redistribution as in Maurice et al. (2013). We present a (linear) VCM experiment, in which we compare, in a between-subject design, contributions under a symmetric, weakly asymmetric and strongly asymmetric allocation of endowments among four players with respective initial Gini coefficients of 0.000, 0.125, and 0.350. We assume that, independent of their endowments, all players in the public-good game have the same profit function, which implies the same return from the public good. The novelty in our setting is that in the strongly asymmetric situation, one player has no interest in achieving the social optimum, in which the sum of profits is maximized. This player's equilibrium profit is higher than the individual profit in the social optimum.

In our experiment, we observe that a weak asymmetry in the endowment distribution (with a Gini coefficient of 0.125) has no effect on the overall public-good provision and leads to the same contribution level as in the case of symmetry. In this weakly asymmetrical setting players tend to contribute the same proportion of their respective endowment. In contrast, in the strongly asymmetric setting (with a Gini coefficient of 0.350), where the very high endowment player has a higher endowment than the three other players together, we observe significantly lower group contributions than in the other settings. The super-rich player does not contribute significantly more than what the others contribute on average and thus a much lower proportion of the endowment. We interpret the difference in the behavioral patterns between the weakly and strongly asymmetric settings as a shift in the contribution norm from relative to absolute equality of contributions.

This paper is structured as follows. In Section 2 we embed our study into the related literature. Section 3 presents the model and experimental design. In Section 4 we show the results. Section 5 concludes this paper with a discussion.

2.2 Related Literature

Keser (2002) hypothesizes that cooperation is easier to achieve in the case of symmetry than asymmetry among the players: assuming that reciprocity is used as an instrument to achieve cooperation, the cooperative goal is most easily determined in the symmetric case, where equal contribution is an obvious requirement. It is not so clear, though, where and how players in an asymmetric situation are supposed to cooperate. This relates to an observation made by Selten et al. (1997). In a strategy experiment on an asymmetric duopoly, they identify decisions guided by ideal points defined in conflicting ways. It thus comes as no surprise that, applying similar settings, Mason et al. (1992) and Keser (2000) observe more cooperative outcomes in symmetric than in asymmetric oligopolies.

There are only few studies investigating asymmetries in public-good experiments and their results are mixed. Fisher et al. (1995) conduct linear VCM experiments with heterogeneous demand for public goods. They observe that the contribution level in groups with two players with a high MPCR and two players with a low MPCR lies between the levels of homogeneous groups, in which all players either have a low or a high MPCR. They find a strong effect of an individual's own MPCR on the contribution: even in heterogeneous groups, low-MPCR types contribute less than high-MPCR types.

Investigating endowment heterogeneity in a linear VCM game, Hofmeyr et al. (2007) find that endowment heterogeneity does not have any significant impact on the group-contribution level. Similarly, Sadrieh and Verbon (2006) observe that the contribution level is neither affected by the degree nor the skew of endowment inequality in a dynamic public-good game, where each round's earnings are added to a player's available endowment in the following round. In contrast, Cherry et al. (2005) observe that endowment heterogeneity in a one-shot linear VCM game decreases the contribution level relative to homogeneous endowments. Their experiment, though, is less controlled than the experiments in Hofmeyr et al. and in our study in that it does not keep constant the sum of endowments across the homogeneous and heterogeneous treatments.

Hofmeyr et al. observe that low and high endowment players contribute the same fraction of their endowment. They call this the "fair-share rule". In contrast, Buckley and Croson (2006) observe in their linear VCM experiment with heterogeneous endowments that the players less wealthy in endowment give the same absolute amount and thus more as a percentage of their endowment as the more wealthy players. They demonstrate that this result is contradicting the assumptions of inequity aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and altruism (Becker, 1974). Inequity aversion would predict (in addition to full free riding and full contribution) a higher proportion of endowment contributed to the public good by the wealthier participants. Inequity aversion is thus contradicted also by the experiments by Hofmeyr et al. and by us. Altruism would simply predict higher absolute contributions by the wealthier participant; the results by Hofmeyr et al. and our study are in accordance with this.

Van Dijk and Wilke (1994) observe in a one-shot public-good experiment with heterogeneous endowments that the more endowment participants possess, the more they contribute and interpret it as "noblesse oblige". They observe, however, that it plays a role whether endowments have been randomly allocated or the difference in endowments has been justified by (making the subjects believe in) the requirement to spend an unequal time in the experiment: the difference between the contributions of low-endowment and high-endowment players is larger in former than the latter case.

The asymmetry in our experiment is based on a random allocation of heterogeneous endowments. We are aware that it can make a difference, whether endowments are randomly allocated or have to be earned in a laboratory task, although Cherry et al. (2005) observe that the origin of heterogeneous endowments does not have a significant effect on voluntary contributions in a one-shot public-good game. In bargaining and dictator games, earned endowments tend to lead to more inequitable outcomes than randomly allocated endowments (e.g., Hoffman and Spitzer, 1985; Loomes and Burrows, 1994; Cherry et al., 2002). Nonetheless, we needed to make a choice for this study and have opted for random allocation of endowments, in order to maintain maximum control over their distribution. In a real-effort pregame, we could only have achieved this control through a tournament element, which might impact behavior in the public-good game in an uncontrolled way.

The provision of public goods and the appropriation of common pool resources are two related instances of collective action. Cardenas and Carpenter (2008) report field experiments on common pool resources, where the players are heterogeneous in their real-life status: Cardenas (2003) shows how the mixing of economic classes affects play in a CPR game. Groups composed of mostly poor people conserve common property better than groups that are mixed between poor people and more affluent local property owners. Likewise, Cardenas and Carpenter (2004) show that mixed groups of students from different countries perform noticeably worse than homogenous groups in a CPR game. These results suggest that the lower level of contributions that we observe in the strongly asymmetric setting of this study is likely to have some external validity.

2.3 The experiment

2.3.1 The Game

In our public-good game *n* players form a group. Each player i $(i = 1, \dots, n)$ is endowed with a fixed number of tokens, e_i, which have to be allocated between two possible types of investment, a *private* and a *public* investment. The amount allocated to the private investment is denoted as x_i, with $0 \leq x_i \leq e_i$, and the amount allocated to the public investment is denoted as y_i, with $0 \leq y_i \leq e_i$. Since the entire endowment has to be allocated, $x_i + y_i = e_i$ has to be satisfied.

The profit of each player *i* depends on his individual private investment and the sum of all public investments. Each token that he allocates to the private investment yields him an individual return of α, while each token that he allocates to the public investment yields himself and any other group member a return of β, with $\alpha > \beta$ and $n\beta > \alpha$. The profit function of player i can thus be written as:

$$\Pi_i\left(x_i, \sum_{j=1}^{n} y_j\right) = \alpha x_i + \beta \sum_{j=1}^{n} y_j \quad (1)$$

The game-theoretical solution of this game is straightforward. Due to the linear form of the profit function and a player's individual return on private investment being larger than on the public investment $(\alpha > \beta)$, the game has an equilibrium in dominant strategies, where each player contributes the entire endowment to the private and nothing to the public investment ($x_i^* = e_i, y_i^* = 0$). If this game is played over a finite number of T periods, the subgame-perfect equilibrium solution prescribes, based on backward induction, that in each period t $(t = 1, \dots, T)$ each player contributes the entire endowment to the private and nothing to the public investment ($x_{i,t}^* = e_i, y_{i,t}^* = 0$).

Due to $n\beta > \alpha$, the sum of profits of all n players is maximized if all tokens are allocated to the public investment. The group optimum in a repeated game is thus found, where all players allocate in each round their entire endowments to the public investment. The game-theoretical solution (subgame-perfect equilibrium) is thus collectively inefficient.

2.3.2 Experimental Design

We conducted the computerized experiment in the *Göttingen Laboratory of Behavioral Economics* at the Georg-August-Universität Göttingen, Germany, between December 2009 and March 2010. The lab consists of 24 computers in isolated booths, such that vision of someone else's computer screen or verbal communication with other participants is impossible. In total, 108 students from various disciplines participated in the experiment. They were randomly selected from a subject pool of students who volunteered for participation in experiments on decision making, in which they can earn money. On average, a roughly equal number of female and male students participated in the experiment. According to subject availability, we conducted sessions with 12 or 16 participants each. This implies that we collected three or four independent observations per session. The experiment software was based on z-Tree (Fischbacher, 2007).

The procedure was as follows. Before the experiment, the participants get together with the experimenter in a meeting room, where the experimenter distributes written instructions and reads them aloud to all participants. From this moment on, participants are neither allowed to communicate with each other nor to ask questions regarding the instructions in front of everybody else. Each of the participants gets randomly assigned a participation number, which corresponds to a computer terminal in the laboratory.

After the reading of the instructions, the participants get seated at their respective computer terminals. First they have to go through a computerized questionnaire regarding the instructions. They have the opportunity to individually clarify with the experimenter any open questions they might have. Only when all participants have correctly answered to all questions of comprehension the experiment begins.

The participants are randomly assigned to groups of four to play a four-player public-good game (with $n = 4$). The group compositions stay unmodified during the entire experiment session, i.e., we use a so-called *partners* design (Andreoni, 1988). Subjects do not know the identity of the other participants with whom they interact.

The parameters of the profit function are $\alpha = 2$ and $\beta = 1$. This implies that the marginal per-capita return (MPCR)[9] of the investment in the public account is constant and amounts to 0.5.

[9] The MPCR is defined as the ratio of the private value of one token invested into the public account to the private value of one token invested into the private account.

The game is to be played for $T = 25$ rounds, which is known to each participant. Each player in a group is assigned a player number from one to four, which is communicated to each player in private in the beginning of the experiment. In each round, each participant has to make an allocation decision in integers, i.e., only entire tokens can be allocated to the private or public investment. At the end of each round, each participant is informed of the contribution to the public investment made by each of the three other players in the group, identified by their player numbers but otherwise anonymous. The record of all previous rounds is also displayed on the screen.

The participants are informed in the instructions that the total profit gained during the experiment and measured in Experimental Currency Unit (ECU) will be multiplied by a conversion factor of 0.01 € per ECU and anonymously paid after the experiment. The conversion factor is the same for each player.

Table 2-1 presents the treatment design. We consider three different treatments: (1) homogeneous endowments of 15 (*Sym* treatment), (2) heterogeneous endowments of 10, 15, 15, 20 (*AsymWeak* treatment) and (3) heterogeneous endowments of 8, 8, 8, 36 (*AsymStrong* treatment). In all three treatments the total endowment of the four players is equal to 60. The AsymStrong treatment is specific in that player 4 has an endowment that is larger than the sum of the endowments of the three other players. Player 4 thus has no interest in achieving the group optimum, where the sum of profits is maximized.

Table 2-1: Treatments

Treatment	Endowment Player 1	Player 2	Player 3	Player 4	Total	# Observations
Sym	15	15	15	15	60	7
AsymWeak	10	15	15	20	60	10
AsymStrong	8	8	8	36	60	10

An experiment session lasted about 60 to 90 minutes, including the reading of the instructions, the questionnaire to make sure that every participant has understood the rules of the game, the experiment, an ex-post questionnaire and the pay-out. In addition to the money gained in the experiment, we paid a show-up fee of 3 €. The average payoff earned was 14.25 €.

2.4 Results

To analyze our data, we use non-parametric statistics based on seven independent observations for the Sym and ten observations, each, for the AsymWeak and AsymStrong treatments. The analysis is based on the Stata Statistical Software, Release 10. We denote the Wilcoxon-Mann-Whitney U test (also called rank-sum test) simply as *U test* and the Wilcoxon matched-pairs signed-rank test as *signed-rank* test. All tests are two-sided.

The analysis will be geared at the testing of four hypotheses.

Hypothesis 1: *The overall contribution level is independent of the endowment distribution.*

Hypothesis 2: *All player types contribute the same proportion of their respective endowment ("fair-share rule").*

The first two hypotheses are based on the respective results by Hofmeyr et al. (2007), whose experiment is very similar to ours.

Hypothesis 3: *Players use the reciprocity principle.*

Keser and van Winden (2000) interpret behavior in the public-good experiment in terms of "conditional cooperation, which is characterized by both forward-looking and reactive behavior". In other words, they observe participants to use reciprocity as an instrument to achieve a cooperation goal. Forward-looking behavior shows, among others, in the so-called end-game effect (i.e., the break-down of cooperation toward the end of the game).

Hypothesis 4: *In the case of endowment heterogeneity, public-good provision leads to a reduction in the inequity of wealth.*

Van Dijk and Wilke (1994) point out that the provision of a public good is an indirect opportunity to reallocate wealth. In the extreme, if all players contribute all of their endowments to the public investment, they end up equally wealthy, independent of the distribution of their initial endowments. In that respect, any inequity in the endowments can be reduced by the provision of a public good. At the same time, if players make different contributions to the public investment, some differences in wealth will be created. This un-equalizing effect will necessarily be visible in the case of equal endowments, but it might be overcompensated by the equalizing effect due to the public good provided in the case of endowment heterogeneity. Since we expect significantly positive contributions in all treatments and thus important equalizing effects, we hypothesize that in the treatments with endowment heterogeneity, the inequality in final wealth will be smaller than the inequality in the endowments.

These four hypotheses are to be addressed in the four subsections.

2.4.1 Group contribution

Figure 2-1 exhibits, for each of the three treatments, the average group contribution to the public investment in each of the 25 rounds. The contribution level in the AsymStrong treatment lies in each period clearly below the contribution levels in the other two treatments. On average over all 25 rounds, we observe a group contribution of 34.48 in Sym, 33.05 in AsymWeak and 22.02 in AsymStrong. The Kruskal-Wallis test indicates that there is a statistically significant difference between the three treatments (p = 0.0012). Pair-wise comparisons (U tests) show that the group contribution in AsymWeak is not significantly different from the one in Sym ($p = 0.7694$). However, the group contribution in AsymStrong is significantly below the one in Sym ($p = 0.0034$) and in AsymWeak ($p = 0.0011$). Similarly, a comparison of the median values of individual contributions to the public investment (10 in Sym, 8 in AsymWeak, and 6 in AsymStrong) shows no statistically significant difference between Sym and AsymWeak ($p = 0.3756$). However, we observe statistically significant differences between Sym and AsymStrong ($p = 0.0291$) and between AsymWeak and AsymStrong ($p = 0.0998$). We conclude that the average and median contributions in the AsymStrong treatment are significantly lower than in the two other treatments.

The standard deviations of group contributions (averages over the standard deviations of the independent groups) are 13.24 in Sym, 12.39 in AsymWeak and 10.39 in AsymStrong, implying variation coefficients of 38 percent (in Sym and Asymweak) and 47 percent (in AsymStrong). Neither the Kruskal-Wallis test nor pairwise comparisons based on the U test show statistically significant differences, requiring significance at the 10-percent level in two-sided testing (Kruskal-Wallis test: $p = 0.2515$; Sym vs. AsymWeak: $p = 0.5582$; Sym vs. AsymStrong: $p = 0.1719$; AsymWeak vs. AsymStrong: $p = 0.1736$).

Regarding the dynamics in the game, Figure 2-1 exhibits, in all three treatments, a decline of the group contribution over time, including a relatively sharp decline in the final rounds—the so-called *end-game effect* (Selten and Stoecker, 1986). Comparing the average group contribution in periods 1-10 to the one in periods 11-20, we observe a statistically significant decline in the Sym treatment, but none in the others.[10] From periods 11-20 to the final periods 21-25, we observe no difference in the Sym treatment but a significant decline in the average group contribution in the AsymWeak and AsymStrong treatments.[11]

In none of the three treatments do we observe a significant change in the standard deviation of the group contributions over time, when we compare (1) periods 1-10 with 11-20 and (2) periods 11-20 with 21-25, requiring significance at the 10-percent level.[12]

Result 1: *There is no significant difference in the contribution level between the Sym and the AsymWeak treatments—a result consistent with Hypothesis 1 and the similar experiment by Hofmeyr et al. (2007). However, in the AsymStrong treatment we do observe a significantly lower contribution level than in the two other treatments.*

The lower contribution level in AsymStrong than in Sym could potentially be considered as a confirmation of the result by Cherry et al. (2005). However, to compare their one-shot game in an adequate way with our repeated game, we consider either the very first period or the last period of the game. In neither period, considered individually, do we observe a significant difference among the three treatments.[13]

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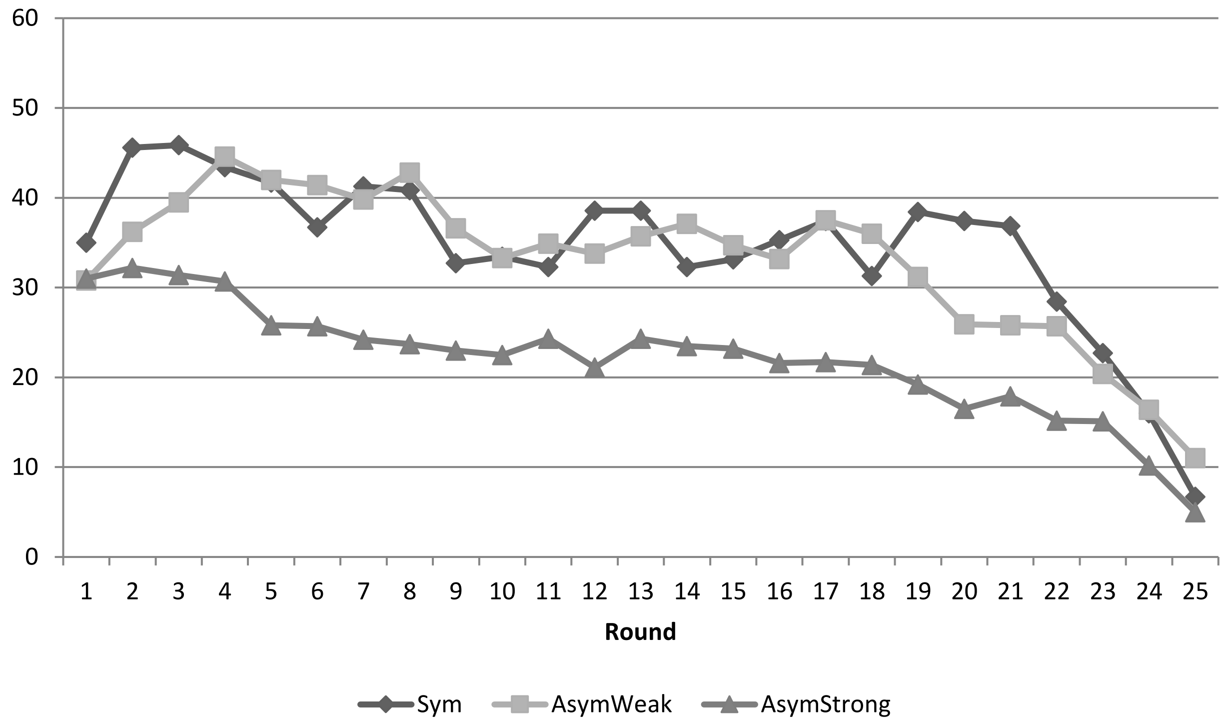
[10] The p-values of the signed-rank tests are 0.0180, 0.1688, and 0.1394 in Sym, AsymWeak and AsymStrong, respectively.

[11] The p-values of the signed-rank tests are 0.1282, 0.0051, and 0.0051 in Sym, AsymWeak and AsymStrong, respectively. The lack of significance for the end-game effect in the Sym treatment is due to one outlier out of seven.

[12] Signed-rank tests. Sym: $p(1) = 0.8658$ and $p(2) = 0.4990$; AsymWeak: $p(1) = 0.0926$ and $p(2) = 0.7213$; AsymStrong: $p(1) = 0.4446$ and $p(2) = 0.6465$.

[13] First round: Kruskal-Wallis test $p = 0.6912$. Pairwise comparisons based on U tests, Sym and AsymWeak $p = 0.4344$, Sym and AsymStrong $p = 0.4639$, AsymWeak and AsymStrong $p = 1.0000$.
Last round: Kruskal-Wallis test $p = 0.3575$. Pairwise comparisons based on U tests, Sym and AsymWeak $p = 0.4902$, Sym and AsymStrong $p = 0.6175$, AsymWeak and AsymStrong $p = 0.1438$.

Figure 2-1: Group contribution to the public investment over the 25 rounds



2.4.2 Contributions by player types

For a better understanding of what is going on in the asymmetric treatments, we analyze the contributions by the various player types, as defined by their endowments. We proceed with an examination of the AsymWeak treatment, first, and the AsymStrong treatment, second.

In the **AsymWeak treatment**, we denote the player with an endowment of 10 as *poor*, the players with an endowment of 15 as *wealthy* and the player with an endowment of 20 as *rich*. The average contribution levels of the poor, wealthy and rich are, 6.31, 7.65 and 11.44, respectively. This corresponds to a percentage of the endowment of 63.1, 51.0 and 57.1, respectively for the poor, wealthy and rich (see also Figure 2-2 for the development over time).

Comparing poor and wealthy group members, we observe no statistically significant difference, neither in the average contribution nor in the contribution as a share of the endowment (signed-rank tests, p-values of 0.2842 and 0.2411, respectively).

Comparing poor and rich group members, we observe a significantly different (higher) contribution level of the rich (signed-rank test, $p = 0.0218$) but no significant difference in the contribution as a share of the endowment (signed-rank test, $p = 0.6098$).

Comparing wealthy and rich group members, we observe a significantly different (higher) contribution level of the rich (signed-rank test, $p = 0.0051$) but no significant difference in the contribution as a share of the endowment (signed-rank test, $p = 0.1386$).

Result 2a: *In the AsymWeak treatment, the poor, wealthy and rich tend to contribute the same proportion of their respective endowment. This confirms Hypothesis 2 (fair-share rule) and replicates the result by Hofmeyr et al. (2007).*

In the **AsymStrong treatment**, we denote the players with an endowment of 8 as *poor* and the player with an endowment of 36 as *rich*. The average contribution levels of poor and rich players are 4.79 and 7.63, respectively. This corresponds to 59.9 and 21.2 percent of the corresponding endowment (see also Figure 2-3 for the development over time). We observe that the contribution levels are not significantly different, requiring significance at the 10-percent level (signed-rank test, $p = 0.1141$). However, the poor contribute a significantly different (higher) percentage of their endowment than the rich ($p = 0.0069$).

Result 2b*: In the AsymStrong treatment, the rich player tends to contribute the same amount as the poor players and thus a much lower percentage of the individual endowment. This contradicts Hypothesis 2 (fair-share rule).*

We provide the following interpretation of this result, which would need confirmation in further studies. The AsymStrong treatment is based on a parameterization that exhibits a special characteristic, which is not typical in public-good experiments: the rich player has no interest in achieving the group optimum as defined by the maximum of the sum of profits. The rich player's Nash equilibrium profit is higher than the individual profit in the group optimum. Thus, the contribution of the same proportion of endowment seems not to be considered as "fair" any more. However, there exists another potential cooperative goal that appears to define fair contributions in the AsymStrong treatment: the group optimum under the constraint that each player contributes the same amount. We call this the "constrained optimum". In the AsymStrong treatment the constrained optimum makes all players, including the rich player, better off than in the Nash equilibrium.

This interpretation finds support in the observation that we can assign the independent AsymStrong groups to two, equally large categories. The first category comprises groups, in which the rich player starts with a high contribution (far above the endowment of a poor player) but drops the contribution, after a few periods, to the endowment level of a poor player and then stays there. The reason appears to be anger about the poor players not contributing their entire endowments. The second category comprises groups, in which, from the beginning, the rich player does not contribute more than the maximum amount that a poor player may contribute.

The above results related to Hypothesis 2 find confirmation in random-effects regressions on the proportion of the endowment contributed to the public investment in AsymWeak (Model 1) and AsymStrong (Model 2). The regression results are presented in Table 2-2. In Asymweak, neither the dummy variable for the rich player (Rich) nor for the poor player (Poor) show a significantly positive or negative coefficient. In AsymStrong, the dummy variable for the rich player (Rich) shows a significantly negative coefficient. In both models, we observe a significantly negative end-game effect (Last5Periods) and a significantly negative overall time trend (Period).

With respect to the individual contribution decisions, we recall that in linear public-good experiments their distribution typically has peaks at both zero and the contribution of one's entire endowment. Table 2-3 exhibits the relative frequencies of individual contributions at these peaks in the three treatments. In the Sym treatment, 20 percent of the individual contributions are at zero and 30 percent at full contribution, roughly. This also holds for the wealthy players in AsymWeak having the same endowment as the players in SYM. The poor players in AsymWeak and AsymStrong show higher relative frequencies of full contribution, around 40 percent, while the rich players in AsymStrong hardly ever contribute their entire endowment to the public good.

Figure 2-2: Proportion of endowment contributed in AsymWeak

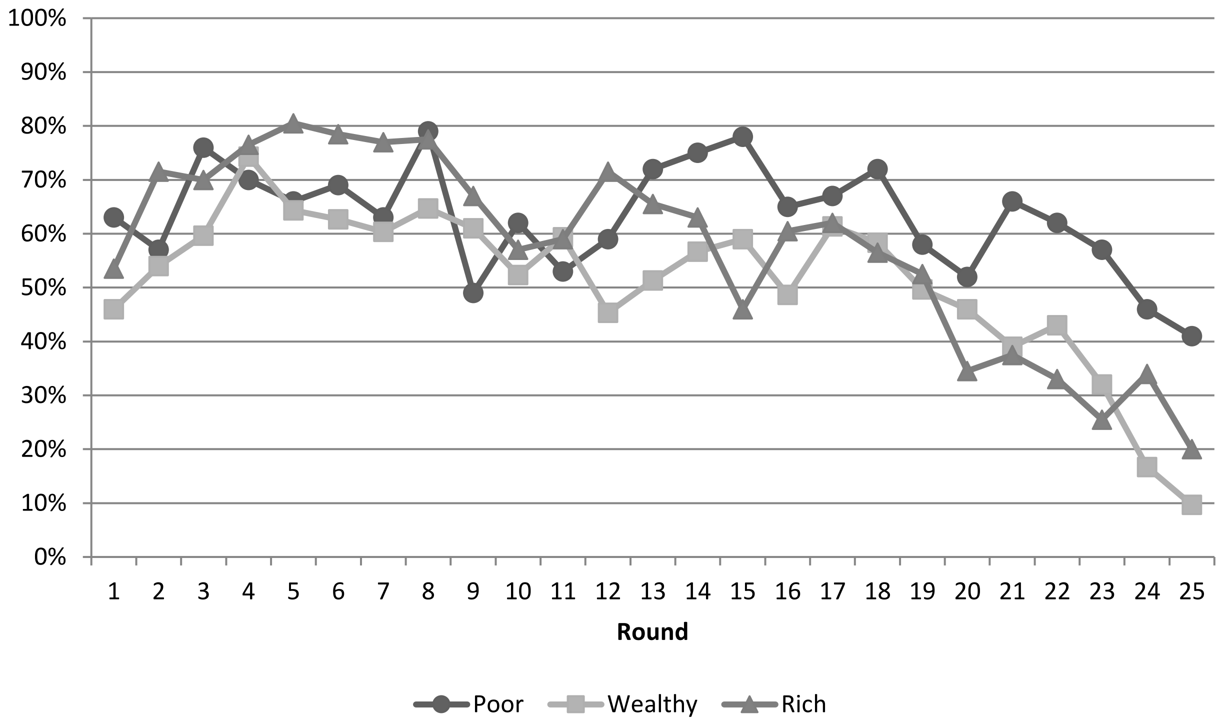


Figure 2-3: Proportion of endowment contributed in AsymStrong

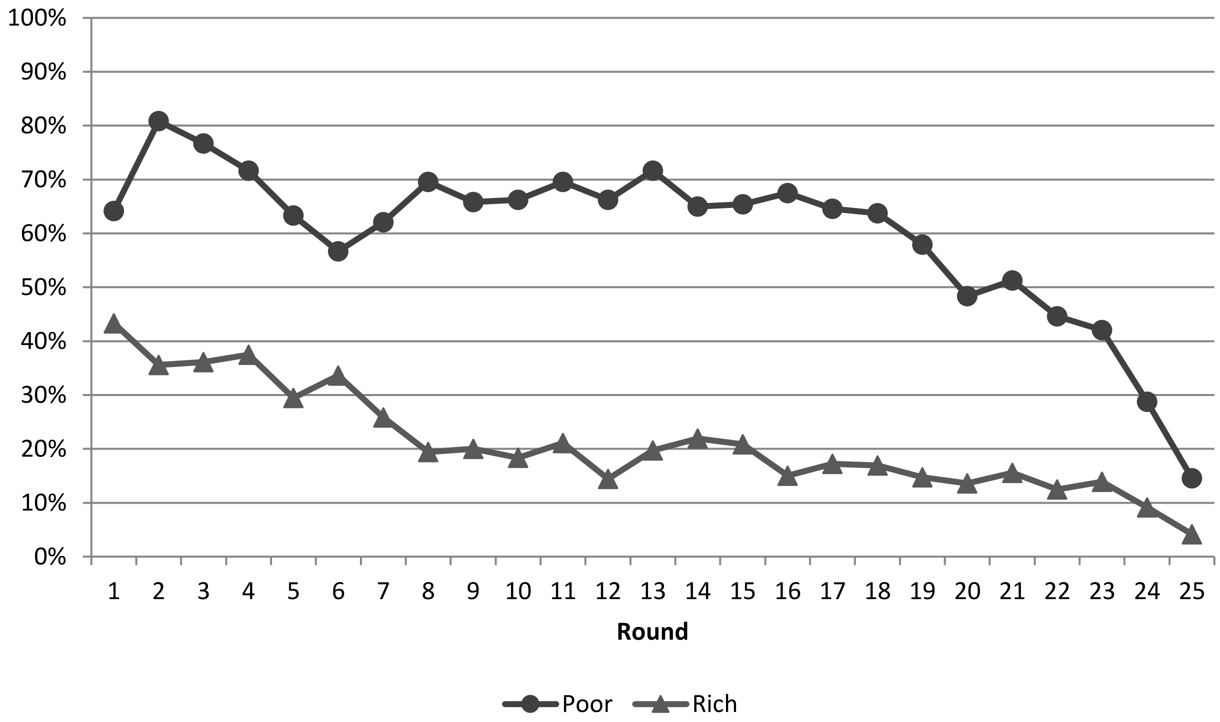


Table 2-2: Random-effects regressions on the proportion of the endowment contributed to the public investment

	Model 1 AsymWeak	Model 2 AsymStrong
Rich	.0619	-.3873***
Poor	.1207	
Period	-.0067***	-.0089***
Last5Periods	-.1217***	-.1422***
Intercept	.6317***	.7438***
σ_u	.223	.123
σ_e	.300	.324
R^2	.095	.254
N	1000	1000

*** 1-percent significance

Table 2-3: Relative frequency of individual decisions, which were either zero or full contribution to the public investment

	Zero contribution (in percent)	Full contribution (in percent)
Sym	18.1	29.4
AsymWeak – poor	18.0	**41.2**
AsymWeak – wealthy	21.2	28.6
AsymWeak – rich	18.0	28.4
AsymStrong – poor	20.7	**37.9**
AsymStrong – rich	23.6	**1.6**

2.4.3 Reciprocity

Keser and van Winden (2000) define reciprocity in a qualitative way*: if a player changes his contribution from one period to the next, he tends to decrease his contribution if it was above the average and to increase his contribution if it was below the average.* In the case of heterogeneous endowments, we need to distinguish between the considerations of absolute or relative contribution levels. We determine for each independent group of the same player type whether or not it reacts in the majority of cases in the predicted direction. Since almost all (groups of) players of type Sym, AsymWeak-poor, AsymWeak-wealthy, AsymWeak-rich, and AsymStrong-poor do react as predicted, we conclude that we have significant evidence of reciprocity both with respect to absolute and relative contributions. For the AsymStrong-rich player, however, we find significant evidence of reciprocity only with respect to absolute values.

Since this is a very conservative way of testing, we examine reciprocity in OLS regressions on the difference between the proportion of one's endowment contributed in the current and in the previous period (Model 3 for AsymWeak and Model 4 for Asymstrong). The results are presented in Table 2-4. LaggedDeviation measures the lagged difference of one's own proportion of the endowment contributed and the average proportion of endowment contributed by the others. The estimated coefficient of this variable is significantly negative in both treatments, which indicates the type of reciprocity defined above: ceteris paribus, if I have contributed a higher percentage than the others, I tend to decrease my contribution relative to the endowment, and vice versa. The estimates of Model 3 (AsymWeak) suggest, ceteris paribus, neither an increase nor a decrease in the percentage of endowment contributed by wealthy and rich players, but a significant increase by the poor players. Similarly, the estimates of Model 4 (AsymStrong) suggest, ceteris paribus, an increase for the poor players, but a decrease for the rich ones.

Result 3: *In keeping with Hypothesis 3, we do observe reciprocity for all player types in our experiment.*

Table 2-4: OLS regressions on the changes in the proportion of one's endowment contributed to the public investment

	Model 3 AsymWeak	Model 4 AsymStrong
Period	-0.0044**	-0.0014
Last5Periods	0.0143	-0.0472
LaggedDeviation	-0.3975***	-0.5456***
Rich	0.0345	-0.3642***
Poor	0.0618**	
Intercept	0.0205	0.1582***
adjusted R^2	0.204	0.284
N	960	960

** 5-percent significance, *** 1-percent significance

2.4.4 Profits and Gini coefficients

Table 2-5 exhibits the average profits realized per period. The Kruskal-Wallis test shows a significant difference between the average sum of profits per period in the three treatments ($p = 0.0012$). The comparison between Sym and AsymWeak shows no significant difference (U test, $p = 0.7694$). The comparisons between Sym and AsymStrong ($p = 0.0034$) and between AsymWeak and AsymStrong ($p = 0.0011$) show significant differences based on two-sided U tests. We conclude that the average sum of profits per period is significantly lower in AsymStrong than in the other two treatments. This directly relates to the differences in the group contribution levels observed above.

The comparison of the average profit per period realized in Sym (where all group members are "wealthy" with an endowment of 15) and by the wealthy type in AsymWeak shows no significant difference (U test, $p = 0.2828$).

The comparison of the endowment types within the AsymWeak treatment based on two-sided signed rank tests shows a significant difference between the poor and the wealthy ($p = 0.0125$), a significant difference between the poor and the rich ($p = 0.0166$) and a weakly significant difference between the wealthy and the rich ($p = 0.0827$). Also the comparison of the endowment types within the AsymStrong treatment shows a strongly significant difference between the poor and the rich ($p = 0.0051$).

The two Asym treatments start with an inequality in wealth, i.e., an inequality in the endowments. After each decision round, the distribution of wealth might have changed, i.e., the distribution of profits might be different from the distribution of initial endowments. To analyze the change in the inequality in wealth from the initial endowment distribution to the end of the experiment, we calculate Gini coefficients.[14]

Table 2-6 presents the average Gini coefficients for the distribution of the players' initial endowments and for the final distribution of players' total profits accumulated over the 25 rounds of the game within each group. For the sake of completeness, we do this for all three treatments. For the Sym treatment the initial-endowment Gini coefficient is zero and thus the coefficient may only stay the same or increase for the distribution of the final wealth. As discussed above, differences in the individual contributions may render the distribution of wealth less equal. The Gini coefficients for the initial endowment distributions in AsymWeak and AsymStrong might seem surprising given the numbers reported in the UN Human Development Report 2011 (UNDP, 2011). It provides Gini coefficients of 0.283 for Germany, or 0.585 for Colombia.

We observe that, based on the Gini coefficients, the inequality decreases by 51 percent in the AsymWeak and by 31 percent in the AsymStrong treatment. These reductions in inequality are statistically significant (signed-rank tests, $p = 0.0051$). The reduction is significantly more important in AsymWeak than in AsymStrong (U test, $p = 0.0696$). Note that in the extreme, i.e., the provision of the public good at the social optimum, the Gini coefficient would be zero. In contrast, the equilibrium outcome of zero contribution would leave the initial Gini coefficient unchanged. In the Asym treatments, an increase of the Gini coefficient through public-good provision would be technically feasible.

Result 4: *In accordance with Hypothesis 4, we do observe a significant reduction in inequality in the experiments with heterogeneous endowments. The reduction is significantly more important under AsymWeak than under AsymStrong.*

[14] The Gini coefficient is a measure of statistical dispersion and it is commonly used as a measure of inequality of income or wealth. It is usually defined mathematically based on the Lorenz curve. It can be thought of as the ratio of the area that lies between the line of equality and the Lorenz curve and the total area under the line of equality. The Gini coefficient can range from 0 to 1. A low Gini coefficient indicates a more equal distribution, with 0 corresponding to complete equality, while higher Gini coefficients indicate more unequal distributions, with 1 corresponding to complete inequality.

Table 2-5: Per-period profits realized (per-period profits in equilibrium; social optimum; constrained optimum)

	Sym	AsymWeak	AsymStrong
Average sum of profits	188.96 (120; 240; 240)	186.10 (120; 240;200)	164.03 (120; 240; 182)
Average profit – Poor	---	40.44 (20; 60; 40)	28.42 (16; 60; 32)
Average profit – Wealthy	47.24 (30; 60; 60)	47.75 (30; 60; 50)	---
Average profit – Rich	---	50.17 (40; 60; 60)	78.75 (72; 60; 88)

Table 2-6: Gini Coefficients (averages over Gini coefficients within groups)

Treatment	Gini coefficient for the initial endowments	Gini coefficient for the final total profits	Reduction (in percent)
Sym	0.0000	0.0449	-
AsymWeak	0.1250	0.0639	51.11
AsymStrong	0.3500	0.2422	30.79*

* Significantly different from AsymWeak

2.5 Discussion

In the case of weak asymmetry in the distribution of players' endowments in a public-good game, we observe that the overall contribution level remains unchanged relative to a similar situation with a symmetric distribution of the same sum of endowments. Our experiment thus replicates the neutrality result by Hofmeyr et al. (2007), which gives hope for its robustness. However, our experiment also shows that a strong asymmetry in endowments may lead to significantly lower contributions. The asymmetry in our AsymStrong treatment is so important that this treatment differs from the typical VCM experiments in one crucial aspect: there exists a super-rich player that is not interested in achieving the social optimum.

Our experimental results of the AsymWeak treatment confirm the observation by Hofmeyr et al. (2007) that cooperation is largely based on a "fair-share rule", i.e., the principle that players contribute the same proportion of their respective endowment to the public investment. This is not what we observe in the strongly asymmetric treatment, though. The super-rich player tends to contribute an amount that is not significantly different from the average contribution of the poor players.

This difference in the behavioral patterns between the AsymWeak and AsymStrong treatments indicates a potential norm shift that can be interpreted as follows. In the weakly asymmetric treatment, full contribution defines the ultimate cooperative goal for each of the three player types. We observe reciprocating behavior, in which contributing the same proportion of one's endowment appears to play a larger role than contributing the same absolute amount. This suggests that there exists a behavioral norm based on the fair-share rule. However, in our strongly asymmetric treatment, the super-rich player has no interest in achieving the full-contribution social optimum, where the sum of all players' profits would be maximized. The social optimum would imply equal profit for all players, and for the rich player a profit far below the Nash-equilibrium profit. While public-good provision in the case of heterogeneous endowments generally enhances social efficiency and involves an equalizing redistribution aspect, this aspect becomes—at some critical level of public-good provision below the social optimum—unfavorable to the super-rich player in the AsymStrong treatment. The critical level of public-good provision can be identified by a "constrained social optimum", i.e., the socially optimal solution under the restriction that everybody contributes the same amount. This implies that everybody contributes an amount equal to the poorest player's endowment, which imposes an upper limit on the absolute contribution of the richer players. It is in every individual player's interest to reach this constrained optimum. Thus, the behavioral norm in the AsymStrong treatment requires that everybody contributes the same absolute amount.

Our result could surely be taken into account in the discussions and evaluations of global and national endeavors on public-good provision and can potentially partly explain why negotiations and other social interactions do not lead to the desired cooperative outcomes. In the light of rising asymmetries within countries our research findings clearly convey a warning against this trend. Inequality has its price: In the case of strong asymmetries in the financial resources of the parties involved, the voluntary contributions mechanism might lead to outcomes that are far from being socially efficient.

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2.7 Appendix: Additional Data Tables

Table 2-7: Average group contribution in rounds 1-10, 11-20 and 21-25

Treatment	Rounds 1-10		Rounds 11-20		Rounds 21-25	
	Average	Std.	Average	Std.	Average	Std.
Sym	39.66	9.37	35.47	9.47	22.14	12.49
AsymWeak	38.70	7.41	34.00	9.48	19.86	10.74
AsymStrong	27.02	12.67	21.68	8.51	12.68	8.77

Table 2-8 - Average individual contributions in Sym

Group	Player e = 15		
	Mean	% e	Median
Sym1	7.53	50.2	10
Sym2	7.27	48.5	5
Sym3	13.77	91.8	15
Sym4	9.82	65.5	15
Sym5	7.35	49.0	8.5
Sym6	7.35	49.0	9.5
Sym7	7.25	48.3	5
Average over groups	8.62	57.5	9.71

Table 2-9: Average individual contributions by player type in AsymWeak

Group	Player type *e* = 10			Player type *e* = 15			Player type *e* = 20		
	Mean	% e	Median	Mean	% e	Median	Mean	% e	Median
AsymWeak1	4.00	40.0	3	6.12	40.8	5	9.36	46.8	0
AsymWeak2	9.80	98.0	10	14.24	94.9	15	19.08	95.4	20
AsymWeak3	5.72	57.2	5	6.90	46.0	5	11.48	57.4	12
AsymWeak4	8.40	84.0	10	8.12	54.1	5	9.60	48.0	10
AsymWeak5	1.44	14.4	0	5.00	33.3	4	14.16	70.8	17
AsymWeak6	4.56	45.6	5	10.24	68.3	10	12.8	64.0	14
AsymWeak7	9.32	93.2	10	4.58	30.5	5	7.24	36.2	8
AsymWeak8	8.16	81.6	10	5.32	35.5	5	6.60	29.1	8
AsymWeak9	6.88	68.8	8	6.76	45.1	6.5	9.84	43.3	10
AsymWeak10	4.80	48.0	5	9.24	61.6	10	14.24	37.0	20
Average over groups	6.31	63.1	6.6	7.65	51.0	7.1	11.44	52.8	11.9

Table 2-10: Average individual contributions by player type in AsymStrong

Group	Player *e* = 8			Player *e* = 36		
	Mean	% e	Median	Mean	% e	Median
AsymStrong1	4.67	58.3	5	6.88	19.1	2
AsymStrong2	6.08	76	8	2.24	6.2	0
AsymStrong3	5.61	70.2	8	8	22.2	8
AsymStrong4	5.63	70.3	8	3.6	10	4
AsymStrong5	4.29	53.7	5	5.48	15.2	6
AsymStrong6	4.89	61.2	5	19.88	55.2	20
AsymStrong7	3.63	45.3	4	7.56	21	3
AsymStrong8	4.09	51.2	4	5.88	16.3	6
AsymStrong9	4.04	50.5	4	11.92	33.1	8
AsymStrong10	5.01	62.7	6	4.88	13.5	6
Average over groups	4.79	59.9	5.7	7.63	21.2	6.3

3. Mandatory Minimum Contributions, Heterogeneous Endowments and Voluntary Public-Good Provision

with Claudia Keser and Andreas Markstädter

Abstract: In a public-good experiment with heterogeneous endowments, we investigate if and how the contribution level as well as the previously observed "fair-share" rule of equal contributions relative to one's endowment (Hofmeyr et al., 2007 and Keser et al., 2014) are influenced by minimum-contribution requirements. We consider three different schedules: FixMin, requiring the same absolute contributions, RelMin, requiring the same relative contributions, and ProgMin, requiring minimum contributions that progressively increase with the endowment. We find that minimum contributions exert norm-giving character and may lead to an increase in average group contributions. This is especially true for the progressive schedule. On the individual level, this schedule leads to higher relative contributions by the wealthier players and thus violates the "fair-share" norm. On the group level, it leads to the highest contribution level and the lowest inequality in total profits as measured by the Gini index.

JEL classification: C92; D63; H41

Keywords: Experimental economics; public goods; heterogeneous endowments; mandatory minimum contributions; norms

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3.1 Introduction

When it comes to their funding, several public institutions, such as, for example, museums, theaters, and operas, rely on a two-tier model. They apply mandatory admission charges that may be voluntarily supplemented by charitable donations. Given that these institutions provide merit goods, their two-tier funding situation may be modeled in a public-good game, where mandatory levies are requested and additional contributions are possible. Such a model has been introduced by James Andreoni (1993) to investigate crowding-out effects of public intervention in a laboratory experiment. He observes that voluntary contributions are partially crowded out by a lump-sum "tax". It still remains an open question, though, how such mandatory levies should be designed to maximize the revenues of public institutions, taking into account that agents possess unequal economic possibilities (wealth) and differ in their willingness to pay.

An extensive experimental literature on the voluntary contribution mechanism (VCM) finds that behavior in public-good games cannot solely be explained by standard economic preferences. Contributions, though declining over time, are generally higher than the Nash-equilibrium prediction. This is true whether the dominant strategy is to contribute nothing (e.g., Marwell and Ames, 1979, 1980) or whether it lies in the interior of the strategy space (e.g., Keser, 1996). Survey studies suggest that, when the dominant strategy is to contribute nothing and participants are equally endowed, initial contributions typically lie between 40 and 60 percent of the endowment but decay over time. In the last round about 70 percent of subjects contribute nothing (e.g., Davis and Holt, 1993; Dawes and Thaler, 1988; Ledyard, 1995; Ostrom, 2000). Although contributions are higher than theoretically predicted, they are at a considerable distance from the social optimum. There is ample evidence that subjects tend to coordinate their contributions by conditional cooperation, i.e., they begin cooperatively and reciprocate depending on the actions of others (e.g., Keser and van Winden, 2000; Fischbacher et al., 2001). How such cooperation is affected by an inequality in endowments (wealth) is, however, not yet well understood. John Ledyard's conjecture that homogeneity in endowments has a positive effect on group contributions, or in other words, that heterogeneity has negative effects (Ledyard, 1995), has only partly been confirmed in the recent literature. Group contributions in weakly asymmetric environments tend to be equal to those in symmetric settings, where the same total endowment is allocated evenly over all group members. Thereby, players tend to follow a "fair-share" rule, where they coordinate on equal relative contributions of the endowment (Hofmeyr et al., 2007; Keser et al., 2014; Keser and Schmidt, 2014). The "fair-share" rule has its limitations, though. When the asymmetry in the endowments becomes so large that one of the players loses interest in the group optimum, the norm shifts from equal relative to equal absolute contributions and the group contribution level declines significantly (Keser et al., 2014).

In this study, we consider an environment with heterogeneous endowments where the "fair-share" norm applies (the AsymWeak treatment of Keser et al. (2014)) and investigate if and how this norm as well as the group contribution level may be influenced by minimum contribution requirements similar to the "taxes" in Andreoni (1993). In our experiment, we implement various minimum-contribution schedules (MCS) charging subjects with different endowments with different levies. These levies are compulsory minimum contributions. The staggering of our MCS is motivated by common tax structures to be found in real-life settings. We consider a treatment with a lump-sum "tax" (FixMin), requiring the same absolute minimum contributions from all players, a treatment with a flat "tax" rate (RelMin) that requires the same minimum contribution relative to their respective levels of endowment from all players, and a treatment with a progressive "tax" schedule (ProgMin), where the more wealthy players are requested to provide a higher minimum contribution relative to their endowment than the less wealthy ones. The AsymWeak treatment of Keser et al. (2014) serves as the baseline treatment (NoMin) without any minimum-contribution requirement.[15] We do not see the mandatory levies in our study as taxes in the strict sense. Tax burdens impose tax levels, which are not intended to be overspent by taxpayers. Our minimum-contribution schedules more closely resemble the mandatory admission charges mentioned above. We consider them as a policy tool to potentially impose norms.

Despite the fact that in our experimental game there are no "standard economic" incentives for contributions above the compulsory minimum values, we expect our different minimum contribution schemes to exert "expressive power" (e.g., Cooter, 1998; Galbiati and Vertova, 2008), while driving contributions beyond the enforced minima due to incomplete crowding-out (Andreoni, 1993). Thereby, we anticipate that the miscellaneous schedules differently affect the sense of justice and the willingness to contribute among the group members. To investigate this, we define a measure of motivational crowding-out for our experimental setup. This measure relates to the classic crowding-out in the analysis of public policy (Andreoni, 1993; Andreoni and Payne, 2011) but it is different in that it considers the percentage of the freely disposable endowment that is contributed, rather than the absolute amount contributed. The motivational crowding-out measure indicates zero crowding-out if subjects that contribute, for example, 50 percent of their endowment in the absence of mandatory minimum contribution requirements will still contribute 50 percent of their freely disposable endowment (endowment beyond the mandatory contribution) in the presence of such

[15] The differentiation of mandatory contribution levels in the treatments with the relative and the progressive MCS can be seen as a kind of third degree price discrimination, where the levies vary by wealth status.

requirements. Full motivational crowding-out implies contributions equal to the mandatory contribution levels.

In the choice of the different minimum-contribution schedules, we pay attention to two features. Firstly, the total amount of minimum contributions is constant across all treatments. Secondly, minimum contributions for the individual player types are lower than the respective average contributions in the baseline treatment (without mandatory minimum contributions) and thus sum up to less than the (unenforced) average total group contribution in the baseline treatment.[16] This is necessary, since we are not interested in increasing contributions to the public good by mandatory contributions that are high enough to exceed the amount that people would contribute voluntarily, anyway. We strive to investigate if and how different distributions of a given total mandatory levy may change individual and group contribution patterns.

As discussed above, our study relates to two literature strands. The first one deals with the "expressive power" of law and is thus particularly relevant to the part of our study that deals with the impact of the various minimum contribution schemes on contribution norms. Law can be defined as an obligation, and, according to the expressive-power hypothesis, it might have psychological effects on individual preferences. In other words, actors might view an obligation as an internal value. Law can thus create a focal point by creating values (e.g., Cooter, 1998; Galbiati and Vertova, 2008). The second literature strand deals with the impact of external interventions on intrinsic motivation with respect to crowding-out or crowding-in (e.g., Deci et al., 1999). Given the finding of incomplete crowding-out of voluntary contributions by minimum-contribution requirements (Andreoni, 1993; Chan et al., 2002), we expect our tax systems to increase group contributions. Both literature strands are presented in more detail in Section 3.2.

The main findings of our experiments can be summarized as follows. We find that mandatory minimum contributions do have a norm-giving character (expressive power). Group contribution levels are significantly higher in ProgMin than in NoMin and FixMin. On the individual level, we observe in all treatments that individuals with higher endowments make on average higher contributions than those with lower endowments. Furthermore, in RelMin, we replicate the "fair-share" rule observed in NoMin (Keser et al., 2014). In FixMin, we find relative contributions to be higher for the less than for the more wealthy players, but we observe the opposite in ProgMin. This suggests that the contribution norm

[16] To investigate crowding-out, Andreoni (1993) chooses a "tax" below the interior solution of the non-linear public-good game. Our linear public good game does not have an interior Nash equilibrium but has a dominant strategy solution to contribute nothing. The outcome of the baseline treatment, however, lies in the interior of the strategy space and can be presented as a quantal response equilibrium under the assumption of altruism and error making (Anderson et al., 1998).

can indeed be influenced through a deliberate intervention like a minimum contribution requirement. As a consequence, the progressive contribution schedule leads to a significant increase in average group contributions relative to the baseline treatment without minimum contribution requirements. While we observe motivational crowding-out in FixMin, we have no evidence for motivational crowding-out in ProgMin and RelMin.

The remainder of this paper is structured as follows. Section 3.2 gives a short overview over the related literature. Section 3.3 presents the experimental design and derives testable hypotheses. Section 3.4 reviews these hypotheses in the face of the experimental results. Section 3.5 provides a summary and conclusions.

3.2 Related literature

We consider two ways how mandatory minimum contributions schedules could impact voluntary contributions to a public good. The first is derived from the literature on expressive law that hypothesizes that obligations have a potential to influence behavior. They may create focal points or norms, which channel individuals' beliefs about the behavior of others and act as coordination devices (Cooter, 1998; Galbiati and Vertova, 2008; McAdams and Nadler, 2005). Rational individuals internalize a norm (i.e., change their behavior) when commitment promises an advantage (Cooter, 1998). A norm set by the mandatory minimum contribution levels that is perceived as appropriate to enhance one's profit is hence potentially able to increase individual and group contributions.

Galbiati and Vertova (2008), for example, study expressive law with weakly incentivized non-binding obligations in a public-good game. These obligations are presented as minimum contributions that are not mandatory and thus leave the players' decision spaces unaffected. However, participants know that they will be probabilistically audited and penalized or rewarded if they have under- or over-fulfilled their obligations. In a repeated linear public-good game with groups of six equally endowed subjects, Galbiati and Vertova test whether different obligation levels imply different levels of cooperation. They find that obligations in repeated interactions significantly affect the average level of individual contributions and the rate of decrease in cooperation over time. Higher obligations reduce the pace of the decline in average contributions. Unexpected changes in the level of minimum contributions have asymmetric effects on the level of cooperation: "a reduction does not alter the pattern of deterioration of cooperation over time, whereas an increase triggers a re-start in cooperation" (p. 148). In a follow-up study, Galbiati and Vertova (2014) disentangle the effects of obligations and incentives. They consider non-binding incentives (such that zero contribution to the public good still remains the dominant strategy for risk-neutral players) with a low and a high probability of an audit. They find obligations and non-binding incentives to be complementary, jointly supporting high levels of contribution. Incentives alone do not significantly increase contributions, while high obligations in the form of recommendations moderately increase them.

In a similar study, using a repeated public-good game with groups of two identically endowed subjects, Riedel and Schildberg-Hörisch (2013) find that obligations increase contributions in the first rounds. Contributions toward the end of the game, however, are not statistically distinguishable to the case without obligations. Individual contributions are affected by the own obligation but independently from the partners obligation. For a given obligation, behavior is not significantly different between symmetric and asymmetric obligation treatments. However, the fraction of non-compliers is higher for subjects with higher inflicted obligation. Given that the decline in contributions is only significant for individuals with high obligations, subjects seem to incur non-monetary costs while disobeying obligations. People are not more likely to violate an obligation if it is perceived unfair.

The three studies above differ from our study in that the therein employed obligations, i.e., minimum contributions, are not binding. That means that in these studies participants face the same decision space whether obligations are imposed or not, i.e., under- or over-fulfillment of the obligation is possible. In our study the decision space is reduced by the minimum contribution requirements in the MCS treatments such that only over-fulfillment of the obligation is possible.

The second potential impact channel of minimum contributions relates to the literature on the impact of external interventions on intrinsic motivation. According to Ryan and Deci (2000) "[i]ntrinsic motivation is defined as the doing of an activity for its inherent satisfaction rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards" (p. 56). It is argued that, given a task that is performed voluntarily or for the sake of its own, any form of outside interference may affect the intrinsic motivation on which the initial action is based and thus change the amount of effort exerted in the task. Crowding-out of intrinsic motivation is reinforced, when the external intervention is perceived as controlling (Falk and Kosfeld, 2006) or when it has a negative effect on people's feeling of self-determination, competence and self-esteem (Deci, 1971; Nyborg and Rege, 2003; Rotter, 1966).

Titmuss (1970) was the first to establish the hypothesis that monetary rewards may crowd out intrinsic motivation. He came up with the example of blood donations, where present donors may reduce donations, if they perceive that their intrinsic motivation is not appreciated, when monetary incentives for their donations are offered. The result is what Condry and Chambers (1978) call "hidden costs of reward" as rewards tend to distract attention from the process of the task activity itself to the goal of getting a reward. This hypothesis was confirmed by Uptom (1973). Since Titmuss (1970) a large body of literature found indication for his hypothesis in a variety of other circumstances[17]. Note, however, that in contrast to the said, interventions, might also be perceived as supportive and promote self-esteem. If this is the case, they might even crowd in intrinsic motivation (Frey and Jegen, 2001).

In the case of the funding of a public good, a specific additional factor could play a crucial role: the perception of one's moral responsibility for the provision of the good. If the government enforces minimum contribution levels, individuals may perceive a decay of their responsibility for the provision, leading to a crowding-out of (additional) voluntary contributions. If however, the intervention is able to communicate morally ideal contribution levels, which are perceived as symbolic, even a crowding-in is possible (Brekke et al., 2003; Nyborg and Rege, 2003).

Theoretical models on government intervention in the provision of public goods, for models with an interior equilibrium, predict complete crowding-out of private voluntary by public contributions (e.g., Warr, 1982, 1983; Roberts, 1984, 1987; Bergstrom et al., 1986; Bernheim, 1986). Indeed, crowding-out of voluntary public-good provision by governmental provision is found in several empirical studies. In the context of charitable giving Abrams and Schmitz (1978, 1984) find crowding-out of about 30 percent and that in addition to governmental charitable payments the need of the recipients plays a crucial role in the decision for private charitable donations. Payne (1998) observes crowding-out of about 50 percent of private donations to non-profit organizations (NGOs) with increased government funding. In a laboratory experiment, based on a public-good game with an interior equilibrium, Andreoni (1993) finds crowding-out of about 70 percent by mandatory contributions. In a similar study Chan et al. (2002) also find that crowding-out is incomplete and that enforced contributions significantly increase total contributions to the public good.

[17] See, for example, Deci (1971, 1972), Deci et al. (1999), Frey (1993, 1994, 1997a, 1997b), Frey et al. (1996), Frey and Oberholzer-Gee (1997), Frey and Goette (1999), Frey and Jegen (2001), Gneezy and Rustichini (2000a, 2000b), and Lepper et al. (1973).

3.3 The experiment

3.3.1 The game

In our public-good game n players form a group. Each player i ($i = 1, \dots, n$) is endowed with a number of tokens, e_i, which have to be allocated between a private and a public investment. Let x_i denote the amount allocated to the private investment and y_i the amount allocated to the public investment by player i, with $x_i, y_i \geq 0$. The investments have to be in entire tokens and have to add up to the endowment. Furthermore, there is a minimum contribution requirement to the public investment c_i, with $c_i \geq 0$. Thus, $0 \leq x_i \leq e_i - c_i$, $c_i \leq y_i \leq e_i$, and $x_i + y_i = e_i$. The profit of each player i depends on his individual private investment and the sum of all public investments in his group. Each token that he allocates to the private investment yields him an individual return of α, while each token that he allocates to the public investment yields him and each other group member a return of β, with $\alpha > \beta$ and $n\beta > \alpha$. The profit function of player i can thus be written as:

$$\pi_i\left(x_i, \sum_{i=1}^{n} y_i\right) = \alpha x_i + \beta \sum_{i=1}^{n} y_i \tag{1}$$

Since a player's individual return in the private investment is larger than in the public investment ($\alpha > \beta$), the game has an equilibrium in dominant strategies, where each player contributes the required minimum to the public investment and all remaining tokens to his private investment ($x_i^* = e_i - c_i$, $y_i^* = c_i$). If this game is played over a finite number of T rounds, the subgame perfect equilibrium solution prescribes, based on backward induction, that in each round $t \in (1, \dots, T)$ each player contributes the required minimum to the public investment and all remaining tokens to his private investment ($x_{it}^* = e_i - c_i,\ y_{it}^* = c_i$).

Given that $n\beta > \alpha$, the sum of profits of all n players is maximized if all tokens are allocated to the public investment. Hence, in the social optimum all players allocate in each round their entire endowment to the public investment. The game-theoretical solution (subgame-perfect equilibrium) is thus collectively inefficient.

Given the evidence from earlier experiments on this kind of linear public-good game, where contributions, significantly deviate from the Nash equilibrium solution, also other equilibrium concepts are conceivable. For example, the so-called quantal response equilibrium, which is based on the assumption that subjects' decisions are determined by altruism and decision-error, can explain why mean contributions deviate from the Nash equilibrium (Anderson et al., 1998). Based on the quantal response equilibrium concept, the crowding-out measure by Andreoni (1993), which is based on the assumption that the Nash equilibrium (before and after taxation) lies in the interior of the decision space and that the lump-sum tax is smaller than the equilibrium contribution, can also be used in the context of our study to evaluate the impact of our minimum contribution schedules on individual and group contributions.

3.3.2 Procedure

We conducted the computerized experiment in the Göttingen Laboratory of Behavioral Economics at the University of Göttingen, Germany, based on the z-tree software package (Fischbacher, 2007).[18] Participants were 160 bachelor and master students from various disciplines (mostly economics and business administration). Recruited via ORSEE (Greiner, 2004), they had previously volunteered to participate in decision-making experiments. On average, a roughly equal number of female and male students participated in the experiments; the number of women and men approximately balanced during all sessions. According to subject availability, we conducted sessions with three to four groups each, implying three to four independent observations per session. In total 40 independent observations were collected in four different treatments.

The procedure of the experiment was as follows. Upon arrival in the meeting room each participant got a randomly assigned participation number corresponding to a computer terminal in the lab. As soon as the required number of participants had shown up, the experimenter distributed written instructions (a translation of these is provided in 3.8) and read them aloud to all participants.

Participants were informed that they would be randomly assigned to groups remaining unchanged during the entire experimental session (partners design). Participants, however, did not get to know the identity of the participants with whom they interacted. Each player in a group was randomly assigned a player number from one to four, which was individually communicated at the beginning of the experiment and remained unchanged. Each player number was associated with a certain fixed endowment and minimum contribution requirement per round. At the end of each round, participants were informed about the contributions to the public investment by each of the other players in the group (identified by their player number but otherwise anonymous), the total group contribution, the profit for the current round, and the total profit so far. Moreover, all participants were provided with a history of all previous rounds, containing the same information, on the screen.

[18] The lab consists of 24 computers in isolated booths, such that vision of someone else's computer screen or verbal communication with other participants is highly restricted.

After the reading of the instructions participants were seated at their respective computer terminals. Before the experiment started, we used computerized control questions with regard to the understanding of the instructions. The experiment did not start until all participants had provided correct answers to all questions.

The participants were informed in the instructions that the profits gained in the course of the experiment were measured in Experimental Currency Unit (ECU) and that these profits were to be multiplied by a conversion factor of 0.01 € per ECU (which is the same for all players) for the final payment, in addition to a show-up fee of 3 €. The cash payment was conducted anonymously after the experiment.

An experimental session lasted on average around 75 minutes. The average payoff earned was about 15.50 € (including a 3 € show-up fee).

3.3.3 Parameters and treatments

Participants are assigned to groups of four ($n = 4$), the game is played for 25 rounds ($T = 25$), and the parameters of the profit function are $\alpha = 2$ and $\beta = 1$ (which implies a constant marginal per capita return (MPCR[19]) of 0.5 for the investment in the public account). Furthermore, participants are informed that Player 1 (Type 10) is endowed with 10 ECU, Players 2 and 3 (Type 15) are endowed with 15 ECU, each, and that Player 4 (Type 20) is endowed with 20 ECU. In each round, each participant has to make an allocation decision, conditioned on his minimum contribution requirement to the public good (c_i). Minimum contribution requirements of all player types are common knowledge.

Table 3-1 presents the individual minimum contribution requirements (c_i) for the three player types in our four treatments: (1) NoMin, (2) FixMin, (3) RelMin, and (4) ProgMin. Under NoMin no participant is forced to contribute a mandatory levy; under FixMin every participant is forced to contribute a mandatory levy of 6 ECU; under RelMin each participant is forced to contribute a mandatory levy of 40 percent of her/his endowment; and under ProgMin each Type 10 player has to contribute 2 ECU, each Type 15 player has to contribute 6 ECU, and each Type 20 player has to contribute 10 ECU. The amounts of 2 ECU, 6 ECU, and 10 ECU in ProgMin correspond to progressive MCS rates of 20, 40, and 50 percent, for the three player types. The FixMin treatment is in principle a regressive MCS system, in that poorer individuals have to contribute relatively more of their endowment. The amounts of 6

[19] The MPCR is defined as the ratio of the private value of one token invested into the public investment to the private value of one token invested into the private investment.

ECU correspond to a regressive MCS regime with rates of 60, 40, and 30 percent for the three player types, respectively. In all treatments the total endowment of the four players is equal to 60 and in all MCS treatments the total mandatory levy is equal to 24.

Table 3-1: Treatment overview

Treatment no.	Label	Minimum contributions (c_i)				$\sum_{i=1}^{4} c_i$	# Obs.
		Type 10	Type 15		Type 20		
		Player 1	Player 2	Player 3	Player 4		
1	NoMin	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	10
2	FixMin	6 (60%)	6 (40%)	6 (40%)	6 (30%)	24	10
3	RelMin	4 (40%)	6 (40%)	6 (40%)	8 (40%)	24	10
4	ProgMin	2 (20%)	6 (40%)	6 (40%)	10 (50%)	24	10

3.3.4 Hypotheses

To facilitate the illustration of the results in the following section our analysis focuses on two hypotheses.

Hypothesis 1: *Minimum contribution requirements incompletely crowd out voluntary contributions implying that we observe higher group contributions in the MCS treatments than in NoMin.*

Andreoni (1993) and Chan et al. (2002) measure crowding-out by $(\bar{Y}_0 + C - \bar{Y}_C)/C$, where $\bar{Y}_0$ is the average group contribution to the public good in NoMin, C is the sum of minimum contributions of all group members, and $\bar{Y}_C$ is the average group contribution to the public good in the respective MCS treatment. Thus, crowding-out is 0 percent if $\bar{Y}_C = \bar{Y}_0 + C$ and it is 100 percent if $\bar{Y}_0 = \bar{Y}_C$. Based on this measure, they find that crowding-out is incomplete and, thus, that their public policy interventions by enforced minimum contributions significantly increase total contributions to the public good. Therefore, we expect that the three minimum contribution schedules increase group contributions above the level of NoMin, but not by the full amount of the contribution requirements.

Hypothesis 2: *Players follow a simple "fair-share" rule of equal relative contributions of the endowment in RelMin but not in FixMin and ProgMin.*

Keser et al. (2014) have shown that players in NoMin tend to coordinate their contributions by using the simple “fair-share” rule, where they contribute equal amounts relative to the endowment. Since in RelMin mandatory contributions are staggered relative to the endowment, we expect contributions to follow this rule as well. However, we expect that Type 10 players contribute a higher (lower) share of their endowment than both other types in FixMin (ProgMin), and that Type 20 players contribute a higher (lower) share of their endowment than both other types in ProgMin (FixMin). In other words, we expect the proportional mandatory contributions in RelMin, the regressive mandatory contributions in FixMin, and the progressive mandatory contributions in ProgMin, respectively, to exert their “intended” influence by pushing individual contributions in the direction in which the minimum contribution requirements are staggered). We derive support for this conjecture from the literature on expressive law. This literature suggests that mandatory minimum contributions schedules may exert “expressive power” through the imposed obligations by expressing certain levels of “fair contribution” (Galbiati and Vertova, 2008; Riedel and Schildberg-Hörisch, 2013).

3.4 Results

Beyond the analysis of group contributions in Subsection 3.4.1 (Hypothesis 1) and individual contributions in subsection 3.4.2 (Hypothesis 2), we shall investigate reciprocity in Subsection 3.4.3 and profits in Subsection 3.4.4. All nonparametric tests presented in the following subsections are two-sided. We shall denote the Wilcoxon-Mann-Whitney U test as U test and the Wilcoxon matched-pairs signed-rank test as signed-rank test.

3.4.1 Group contributions

Figure 3-1 presents the development of the average group contributions to the public investment ($\bar{Y}_t$) in the four treatments over the 25 rounds. As can be seen, the ProgMin treatment exhibits the highest contributions.[20] Due to the large end-game effect in NoMin (in approximately the last five rounds), which is impeded by the minimum contribution requirements in the MCS treatments, we report only figures for rounds 1 to 20 in the forthcoming analysis. For this game interval, average group

[20] Over rounds 1-25, the mean group contributions are 43.5 in ProgMin compared to 33.1 in NoMin, 37.7 in FixMin, and 39.8 in RelMin. The respective average standard deviations are 7.5, 12.4, 5.9, and 6.1.

contributions are 36.4 in NoMin, 38.7 in FixMin, 40.2 in RelMin, and 44.7 in ProgMin.[21] This indicates that the mandatory contributions only partially crowd out voluntary contributions. Following Andreoni (1993), crowding-out is 90.2 percent in FixMin, 83.8 percent in RelMin and as little as 65.0 percent in ProgMin. Pairwise treatment comparisons, based on U tests, show that average group contributions in ProgMin are significantly higher than those in NoMin ($p = 0.0343$) and FixMin ($p = 0.0963$); no other pairwise comparison shows a statistically significant difference.

It is important to mention that group contributions in ProgMin do not start from the beginning on a higher level than in the other two MCS treatments. They rather rise during the first rounds of the game and then remain nearly constant until the end-game. In the first round, we find that average group contributions do not differ between the MCS treatments, with respective figures of 39.0, 36.5, and 38.5 in FixMin, RelMin, and ProgMin. The average first-round contribution in NoMin is 30.8; it is significantly lower than in FixMin ($p = 0.0884$) and in ProgMin ($p = 0.0487$), when compared by U tests.[22]

Result 1: *Group contribution levels are significantly higher in ProgMin than in NoMin and FixMin. For ProgMin, this confirms Hypothesis 1 that crowding-out is incomplete.*

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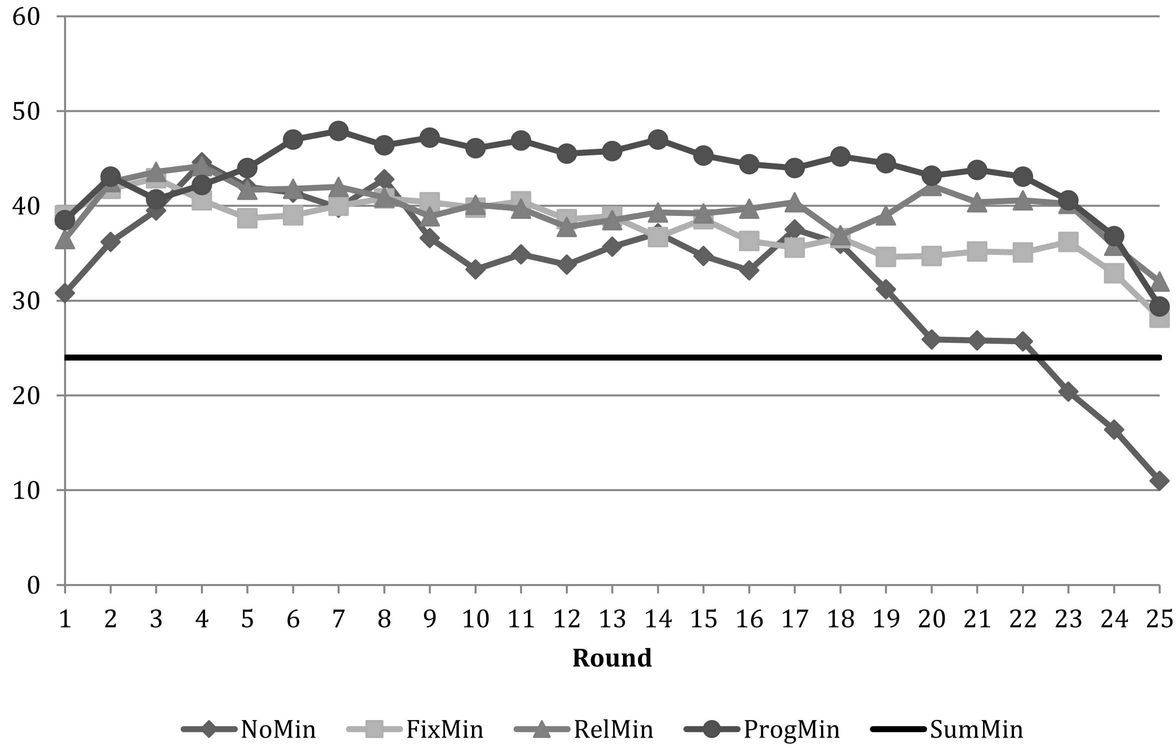
[21] Average standard deviations of total group contributions for rounds 1-20 are 9.9, 5.3, 5.4, and 6.8 for NoMin, FixMin, RelMin, and ProgMin respectively.

[22] Average standard deviations of total group contributions for round 1 are 9.0, 7.4, 6.9, and 7.9 for NoMin, FixMin, RelMin, and ProgMin respectively.

Figure 3-1: Average group contributions per round (by treatment)



Net relative group contributions and motivational crowding-out: To compare voluntary contributions in the NoMin treatment to the contributions in the MCS treatments, while taking into account the different sizes of strategy sets in these two kinds of treatments, we calculate for each round *t* the *net relative group contribution*:

$$Y_t^{Net} = \frac{\sum_{i=1}^{4} y_{it} - \sum_{i=1}^{4} c_i}{\sum_{i=1}^{4} e_{it} - \sum_{i=1}^{4} c_i} = \begin{cases} \dfrac{Y_t}{60} & \text{for NoMin} \\ \dfrac{Y_t - 24}{36} & \text{otherwise} \end{cases} \qquad (2)$$

Y_t^{Net} captures, for round t, the group contribution above the sum of mandatory contributions (group contribution minus sum of mandatory contributions) relative to the net endowment of the group (group endowment minus sum of mandatory contributions). This measure ranges from zero to one. It is zero, when only the mandatory levies are contributed (which are zero in the case of NoMin) and one, when the entire net endowment is contributed.

This measure allows a more flawless comparison of the treatments in our study since it takes into account that players with different endowments and different minimum contribution requirements have different strategy sets. Based on this measure we define a "*motivational crowding-out* or *crowding-in*" of voluntary contributions, which is different from the classic definition of crowding-out by public policy (Andreoni, 1993). If we observe that in a MCS treatment groups contribute a lower (higher) percentage of their freely disposable endowments (net endowments) than the groups in the NoMin treatment, we interpret this observation as motivational crowding-out (crowding-in) of contributions by the minimum contribution requirements. Motivational crowding-out is, in contrast to the classic crowding-out, not measured token by token but in percent of the endowment that is at free disposal. While we define that net relative group contributions at the same level as in the NoMin treatment imply zero motivational crowding-out, full motivational crowding-out is defined by zero net relative group contributions. Both definitions are different from the classic definitions in Andreoni (1993).

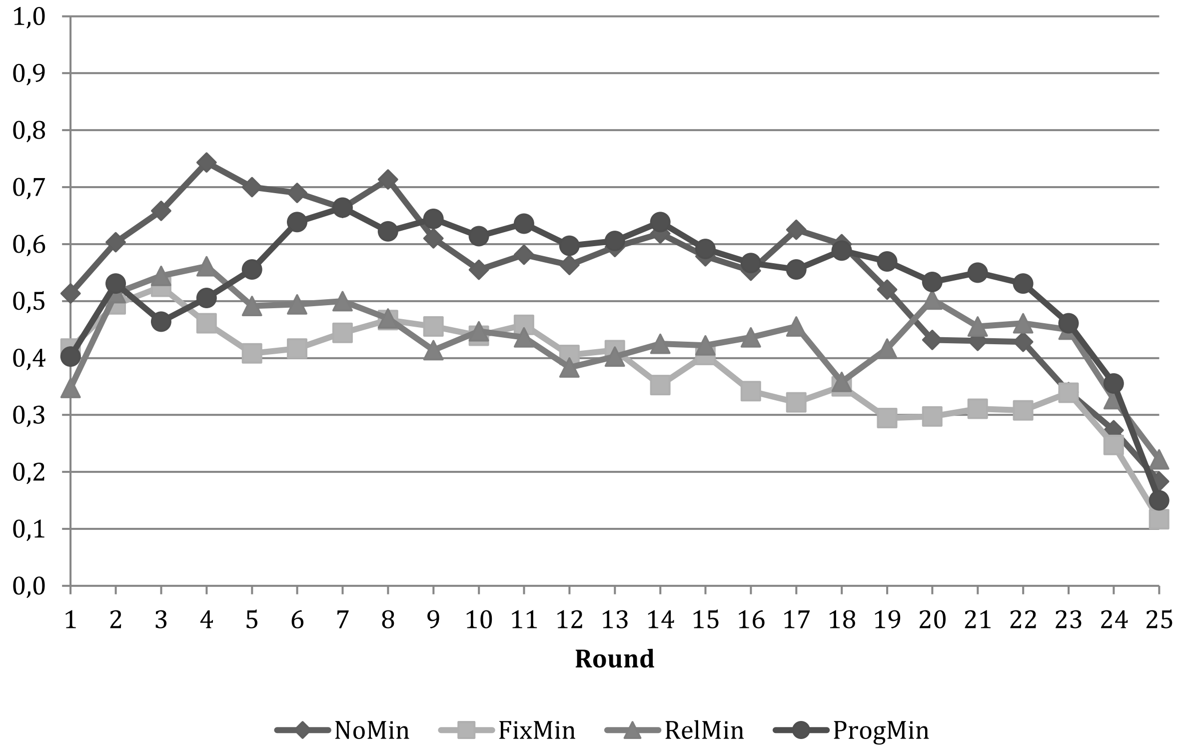
Figure 3-2 shows the development of the average net relative group contributions in the four treatments. Visual inspection suggests two distinct contribution levels over rounds 1 to 20: NoMin and ProgMin show average contributions of 60.6 percent and 57.6 percent, respectively, while FixMin and RelMin show average contributions of 40.8 percent and 45.1 percent, respectively.[23, 24] Pairwise comparisons, based on U tests, indicate significant differences between NoMin and FixMin as well as ProgMin and FixMin ($p = 0.0963$, for both comparisons). Thus, we find on average small and statistically insignificant motivational crowding-out of 4.9 percent in ProgMin and higher but still statistically insignificant motivational crowding-out of 25.5 percent in RelMin. Only the motivational crowding-out of 32.6 percent in FixMin is statistically significant.

Result 2: *Motivational crowding-out of group contribution is statistically significant in FixMin. There is no significant motivational crowding-out in ProgMin and RelMin.*

[23] The corresponding average standard deviations of Y_t^{Net} for rounds 1-20 are 0.1645, 0.1478, 0.1503, and 0.1885, for NoMin, FixMin, RelMin, and ProgMin respectively.

[24] The overall negative time trend is moderate and seems to be, except for the first periods, not different between the treatments.

Figure 3-2: Average net group contributions (by treatment)



3.4.2 Contributions by player types

3.4.2.1 Comparison within treatments

To compare the contributions of the different player types within each treatment, differences in the end-game effects for the player types play a minor role. We thus consider averages over rounds 1 to 25 in this analysis.

Figure 3-4 in 3.7 Appendix A presents the development of average contributions of the three player types (Type 10, Type 15, and Type 20) in the four treatments over the 25 rounds.[25] We find the non-surprising tendency for more abundantly endowed players to contribute more in absolute terms. Table 3-5 in Appendix A shows that, with the exception of two comparisons, all pairwise comparisons, based on signed-rank tests, show significant differences with $p \leq 0.0593$.

[25] For Type 10 (player 1) and Type 20 (player 4) the averages are based on ten players for each average, each. For Type 15 (players 2 and 3), the averages are based on twenty players.

Given the asymmetry in endowments, we consider two "relative contribution measures" to compare the contributions of the poor (Type 10), wealthy (Type15), and rich (Type 20) players. The first measure goes back to the fair-share rule in Hofmeyr et al. (2007) and Keser et al. (2014); it measures the absolute contributions of the player types relative to their individual endowment (relative contribution). Figure 3-5 in Appendix A presents the development of average relative contributions for the three player types in the four treatments. As can be seen, there are no significant differences in the average relative contributions between the player types both in NoMin (AsymWeak treatment of Keser et al. (2014)) and RelMin. For RelMin, where the mandatory contributions push contributions toward the "fair-share" rule with equal relative contributions, this result is highly plausible. In FixMin average relative contributions significantly differ between the player types such that relative contributions to the public good decrease with the endowment level. For ProgMin, on the other hand, the contribution hierarchy is reversed such that the wealthier players contribute relatively more. Table 3-6 in Appendix A provides the p-values of the pairwise comparisons of contributions by player type in the four treatments (signed-rank tests). These widely confirm the previous statement: all differences in NoMin and RelMin are insignificant, and (almost) all differences in FixMin and ProgMin are significant ($p \leq 0.0745$, the unique exception is the difference between Types 15 and 20 in ProgMin that is not statistically significant). We may conclude that the proportional mandatory contributions in RelMin, the regressive mandatory contributions in FixMin, and the progressive mandatory contributions in ProgMin, respectively, exert their "intended" influence. RelMin leads to equal relative contributions, FixMin to higher relative contributions by the less wealthy players, and ProgMin to higher relative contributions by the more wealthy players.

Result 3: *In RelMin players follow the simple "fair-share" rule of equal relative contributions of the endowment. However, this rule does not apply in FixMin and ProgMin: average relative contributions are higher for the less wealthy players in the regressive FixMin treatment and higher for the more wealthy players in the progressive ProgMin treatment. These results confirm Hypothesis 2.*

The second relative-contribution measure, y_{it}^{Net}, essentially calculates Y_t^{Net} on an "individual" basis for each player type $i \epsilon \{Type\ 10, Type\ 15, Type\ 20\}$:

$$y_{it}^{Net} = \frac{y_i - c_i}{e_i - c_i}, \qquad (3)$$

where c_i is treatment dependent. It captures for each player type i the average individual contribution net of the mandatory contribution (absolute contribution minus mandatory contribution) relative to the net endowment (individual endowment minus mandatory contribution).

Figure 3-6 in Appendix A presents the development of average y_{it}^{Net} for the three player types in the four treatments. Table 3-7 in Appendix A shows the p-values of the pairwise comparisons based on signed-rank tests. As can be seen, there is only one difference that is statistically significant ($p = 0.0745$, Type 10 players contribute significantly more than Type 20 players in FixMin). None of the remaining comparisons yields statistical significance. We conclude that players tend to follow a modified "net fair-share" rule of equal relative contributions of the disposable endowment in FixMin and ProgMin. The "net fair-share" rule also applies in NoMin and RelMin, since it coincides with the original "fair-share" rule.

Result 4: *Players follow in all treatments a "net fair-share" rule of equal contributions relative to the decision space.*

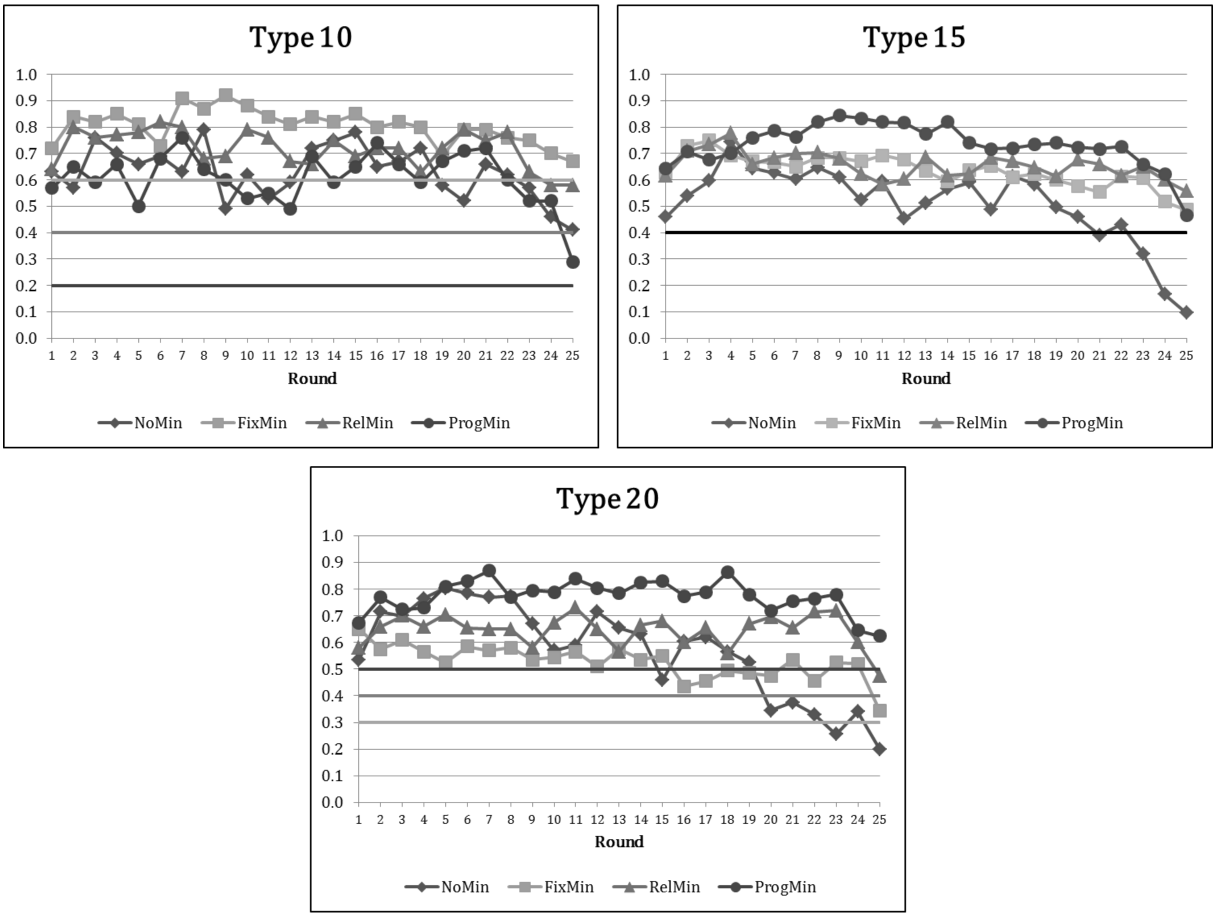
3.4.2.2 Comparison between treatments

So far, we have focused our analysis on the differences between the player types within each of the four treatments. For a deeper understanding of the mechanics that might be at work in the various treatments, i.e., how the norms might be set by the different MCS regimes, we compare the behavior of each player type across the four treatments. If we observe differences in behavior, these differences could ultimately lead to differences in group contributions between the treatments. Due to the strong end-game effect in NoMin, which is impeded by the minimum contribution requirements in the MCS treatments, we report only averages over rounds 1 to 20 in this analysis.

Figure 3-3 depicts that, on average, relative contributions (and thus also absolute contributions) of Type 10 are highest in FixMin, where also the mandatory minimum contribution relative to the endowment is highest for this player type. The trajectories in the other treatments are not clearly distinguishable. Contributions of Type 15 are clearly highest in ProgMin and lowest in NoMin; the trajectories in FixMin and RelMin lie in between. Contributions of Type 20 are highest in ProgMin and lowest in FixMin. NoMin shows a clear decline that, toward the end of the game, even undercuts the level of FixMin. Contributions in RelMin lie between those in FixMin and ProgMin.

Considering contributions in the first round, we find that, on average, Type 10 players contribute 6.3, 7.2, 6.4, and 5.7; Type 15 players 6.9, 9.4, 9.3, and 9.7; and Type 20 players 10.7, 13, 11.6, and 13.5 in NoMin, FixMin, RelMin, and ProgMin, respectively. For Types 10 and 20, the differences between the treatments are never statistically significant. For Type 15, differences are significant between NoMin and all three MCS treatments ($p \leq 0.0698$, U tests); comparisons between the MCS treatments yield no significant differences.

Figure 3-3: Average relative contributions (by treatment)



For contributions in rounds 1 to 20, Table 3-8 in Appendix A shows the p-values of the pairwise comparisons of average absolute [and net] contributions for the three player types (U tests). As can be seen, Type 10 players contribute on average most in FixMin and least in ProgMin and NoMin; contributions in RelMin lie in between. However, only the difference between ProgMin and FixMin is statistically significant ($p = 0.0257$). Type 15 players contribute in all MCS treatments on average more than in NoMin but only the difference between ProgMin and NoMin is significant ($p = 0.0232$). Although differences between the MCS treatments are not significant, the average figures indicate that contributions are highest in ProgMin, followed by RelMin, and then FixMin. Type 20 players contribute on average least in FixMin and most in ProgMin; contributions in NoMin and RelMin lie in between. Contributions in ProgMin are thereby significantly higher than in all other treatments ($p \leq 0.0696$), between which there is no statistically significant difference. For Type 20 we observe motivational crowding-out in FixMin and RelMin ($p \leq 0.0696$, for both). For no other player type do we observe motivational crowding-out. To conclude, for player types 15 and 20 but not for player type 10, ProgMin leads to the highest contributions to the public good. Given that Type 10 players have a lower leverage on group contributions than Type 15 and Type 20 players, this explains why we observe the highest group contribution level in ProgMin, which is significantly higher than in NoMin.

Result 5: *Type 10 and Type 20 players contribute most, when they are facing relatively high mandatory contributions (FixMin and ProgMin, respectively) and contribute least, when they are facing relatively low mandatory contributions (ProgMin and FixMin, respectively). Type 15 players contribute most in ProgMin and least in NoMin.*

One might argue that contributions in the MCS treatments increase merely due to the enforced increase in the contributions of uncooperative subjects, while the cooperative subjects' contributions might have remained the same. To test for this eventuality, we use a simple approach. For each player type and treatment, we order average contributions from the lowest to the highest, and divide this ordering by half. We can thus distinguish between more and less cooperative subjects and compare the behavior of the more cooperative subjects' in the various treatments. The average contributions are presented in Table 3-9 in Appendix A. Tests for differences across the treatments, based on U tests, confirm for both Type 15 and 20 players that the increase in contributions in ProgMin is not solely driven by the higher contributions of uncooperative subjects.[26]

Additionally, we find that in ProgMin lower-bound contributions of Type 15 players ($y_i = c_i = 6$), for which mandatory contributions are equal in all MCS treatments, exhibit with 19.8 percent the lowest proportion of all MCS treatments ($p \leq 0.0030$, U tests). In NoMin, we observe 38.3 percent of contributions of six or below. Furthermore, we also find that in ProgMin Type 15 and 20 players display the highest proportion of full contributions ($y_i = e_i = 15$ and $y_i = e_i = 20$, respectively) compared to all other treatments ($p \leq 0.0225$, U tests); for Type 10 players differences in the proportions of full contributions between the treatments are insignificant. The respective figures for lower-bound and full contributions are presented in Table 3-10 in Appendix A.

The results concerning contributions by cooperative players and concerning lower bound and full contributions indicate that the ProgMin treatment leads to a norm shift, not just to higher group contributions due to a higher constraint for the wealthier players.

[26] Cooperative Type 15 players significantly contribute more in ProgMin than in RelMin and FixMin (p ≤ .0413); all other differences are not significant. Cooperative Type 20 players contribute significantly more in ProgMin than in NoMin and FixMin (p = .0413, for both comparisons); all other differences are not significant. For Type 10 players, contributions of cooperative players are not significantly different between all treatments.

3.4.3 Reciprocity

As known from the literature (e.g., Keser and van Winden, 2000; Fischbacher et al., 2001), subjects behave reciprocally and make contributions that depend on the actions of others. Keser and van Winden (2000) argue that players, if they change their contribution from one round to the next, tend to increase (decrease) their contribution, if in the previous round their contribution was below (above) the average of the group. Given the different endowments of player types in our experiment, we examine reciprocity in terms of changes in relative contributions. In other words, we examine how players react if their own relative contribution has been lower (higher) than the average of the relative contributions of the other group members in the previous round.

Table 3-2 presents the results of a regression on the reaction of the individual relative contribution to the average relative contribution of the other group members in the previous round. The dependent variable is the individual change of the relative contribution to the public investment from the previous to the current round (Δy_{it}^{Rel}). The major explanatory variable is the lagged difference between the relative contribution of the player and the average relative contribution of the other group members ($L.Diff2MeanOthers$). Additionally, we control for player-type and treatment effects by using dummy variables (and interactions), considering Type 10 and NoMin as the respective reference group.

Table 3-2 indicates that $L.Diff2MeanOthers$ is significantly negative and thus provides clear evidence for reciprocity. Another important finding concerns the ProgMin treatment and potentially explains why it shows the highest group contribution level. On the one hand, we observe that Type 10 players behave most reciprocally (the interaction term *ProgMin × L.Diff2MeanOthers* is significantly negative) and, on the other hand, that Type 15 and Type 20 players behave least reciprocally (the interaction terms *Type 15 × ProgMin × L.Diff2MeanOthers* and *Type 20 × ProgMin × L.Diff2MeanOthers* are significantly positive). These findings are consistent with our previous results. As it seems, Type 15 and Type 20 players choose their contributions in this treatment "irrespective" of the contributions by Type 10 players. The two wealthier types seem to accept the low contributions by Type 10 players and "simply follow" the contribution norms set by the ProgMin schedule. This may, at least partially, explain why contributions of both player types in ProgMin are highest in this treatment, despite the fact that Type 10 players exhibit their lowest contributions of all treatments. Additionally, we find that the change in relative contributions is becoming more negative during the course of the game ($Round$ is significantly negative).

Result 6: *Players generally behave reciprocally. In ProgMin, Type 10 players behave more and Type 15 and 20 players less reciprocally.*

Table 3-2: Regression for comparisons of reciprocity

Dependent variable:	Δy_{it}^{Rel}	
Constant	.0378	(.0251)
L.Diff2MeanOthers	-.3268***	(.0552)
Round	-.0021***	(.0007)
Type 15	-.0390	(.0291)
Type 20	-.0043	(.0295)
FixMin	.0437	(.0288)
RelMin	.0201	(.0294)
ProgMin	-.0855**	(.0340)
Type 15 × FixMin	-.0267	(.0343)
Type 15 × RelMin	-.0001	(.0352)
Type 15 × ProgMin	.1312***	(.0389)
Type 20 × FixMin	-.1372***	(.0387)
Type 20 × RelMin	-.0417	(.0367)
Type 20 × ProgMin	.0981**	(.0398)
Type 15 × L.Diff2MeanOthers	-.1285*	(.0703)
Type 20 × L.Diff2MeanOthers	-.0313	(.0823)
FixMin × L.Diff2MeanOthers	.0601	(.0765)
RelMin × L.Diff2MeanOthers	-.0355	(.0800)
ProgMin × L.Diff2MeanOthers	-.2083**	(.0849)
Type 15 × FixMin × L.Diff2MeanOthers	.0072	(.0991)
Type 15 × RelMin × L.Diff2MeanOthers	-.0576	(.1030)
Type 15 × ProgMin × L.Diff2MeanOthers	.1995*	(.1078)
Type 20 × FixMin × L.Diff2MeanOthers	-.1446	(.1244)
Type 20 × RelMin × L.Diff2MeanOthers	-.0840	(.1183)
Type 20 × ProgMin × L.Diff2MeanOthers	.3226***	(.1151)
R^2	.2346	
N	3040	

Notes: OLS-regressions with robust variance estimates. Standard errors in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

3.4.4 Profits and Gini indices

Table 3-3 illustrates the average profits per round over rounds 1 to 20 for the three player types and the resulting average group profits in the four treatments. Pairwise comparisons, using U tests, show that solely the differences in average group profits between ProgMin and NoMin ($p = 0.0343$), and ProgMin and FixMin ($p = 0.0963$) are significant.

Table 3-3: Average profits per round

	NoMin	FixMin	RelMin	ProgMin
Type 10	43.30	42.30	45.60	52.23
Type 15	49.33	49.03	50.31	52.04
Type 20	50.75	57.07	54.27	53.19
Group profit	192.70	197.41	200.48	209.49

Notes: Averages for rounds 1 to 20. Social optimum sum of profits per round = 240. Equilibrium sum of profits per round = 120, 168, 168, 168. Equilibrium profit per round for Type 1 = 20, 32, 36, 40; equilibrium profit per round for Type 2 = 30, 42, 42, 42; equilibrium profit per round for Type 3 = 40, 52, 48, 44 (NoMin, FixMin, RelMin, ProgMin). Social optimum profit per round = 60 (for all types).

Comparisons for the player types between treatments based on U tests show that Type 10 players earn on average significantly more in ProgMin than in all other treatments, between which there are no significant differences ($p \leq 0.0343$). For Type 15 players, profits in ProgMin are significantly higher than in NoMin ($p = 0.0989$) and FixMin ($p = 0.0498$); for the other differences, we cannot reject the null hypothesis of no significant difference. For Type 20 players, profits in FixMin are significantly higher than in NoMin and ProgMin ($p \leq 0.0172$); all other differences are statistically insignificant.

Given that players in all four treatments start with different endowments, and that contributions to the public investment tend to result in an equalization of total profits through a redistribution of wealth, we analyze, based on the Gini index, the differences in inequality between the initial distribution of endowments, the distribution of total profits in equilibrium, and the actual distribution of total profits over rounds 1 to 20 in the four treatments. Table 3-4 displays the respective figures.

Average total profit Gini indices are smaller than Nash-equilibrium Gini indices for NoMin ($p = 0.0051$) and FixMin ($p = 0.0284$), using signed-rank tests; for RelMin the difference is almost significant ($p = 0.1141$). For ProgMin, on the other hand, total profit Gini indices are significantly higher than Gini indices in equilibrium ($p = 0.0218$).

Furthermore, the comparison of average total profit Gini indices discloses that ProgMin exhibits significantly smaller Gini indices than all other treatments. Based on U tests, we find significant differences between NoMin and ProgMin, and FixMin and RelMin ($p = 0.0284$, respectively), and also between FixMin and ProgMin, and RelMin and ProgMin ($p = 0.0065$, respectively).

Table 3-4: Gini indices

Treatment	Gini index for endowments [net of MCs] (1)	Gini index in Nash equillibrium (2)	Gini index for total profits (3)	Differences in percent (3)-(1)/ (2)-(1)/(3)-(2)
NoMin	.1250 [.1250]	.1250	.0561	-55.1/-0.0/-55.1
FixMin	.1250 [.2083]	.0893	.0674	-46.1/-28.6/-24.5
RelMin	.1250 [.1250]	.0536	.0471	-62.3/-57.1/-12.1
ProgMin	.1250 [.0417]	.0179	.0279	-77.7/-85.7/+55.9

Notes: Gini indices for total profits over rounds 1 to 20.

Result 7: *ProgMin leads to the lowest inequality in total profits of all treatments. Although, the inequality in total profits is larger than in equilibrium, the average group profit in ProgMin is the highest of all treatments.*

3.5 Conclusion

We investigate whether and how cooperation and the previously observed "fair-share" norm in public-good experiments with asymmetrically endowed players are influenced by enforced minimum-contribution schedules. We consider schedules, where all players face the same absolute minimum contribution irrespective of their endowment (FixMin), where all players face the same minimum contribution relative to the endowment (RelMin), and where a player with a higher endowment faces a higher minimum contribution relative to the endowment than a player with a lower endowment (ProgMin). Our mandatory minimum-contribution schedules relate to the literature on tax fairness or "vertical equity". In taxpayer surveys, Gerbing (1988) and Roberts and Hite (1994) find evidence of a preference for progressive tax rates. For upper-income taxpayers, however, Gerbing finds that they perceive flat tax rates as more fair. In the context of a public-good game, where participants can vote for several minimum contribution schemes, which are intended to provide a jointly agreed minimum group provision level, Gallier et al. (2014) find that the scheme which equalizes payoffs (similar to ProgMin) is mostly chosen by less wealthy players, while rich players mostly chose the scheme which equalizes contributions (similar to FixMin). Given this evidence and the pervasive calls for fairer tax systems implying tax breaks for lower and middle income classes together with tax increases for upper income classes, it is possible that an as fairer perceived distribution of mandatory minimum contributions (as, for example, in ProgMin) exerts a positive effect on individual and consequently total group contributions.

The results of our experiment suggest the potential of mandatory minimum contributions to exert expressive power. We observe them to exert a norm-giving character. They seem to communicate relations of fair contributions by the different player types and thus might increase group contributions relative to the situation without minimum-contribution requirements. It turns out that this is particularly true for our ProgMin treatment, which is likely perceived as the most fair among all mandatory contribution systems considered. ProgMin is the only treatment, where the crowding-out of voluntary contributions to the public good by mandatory contributions is significantly incomplete, when we use the measure by Andreoni (1993). For RelMin and FixMin the crowding-out is close to complete. When we consider motivational crowding-out as defined in this paper, it is statistically significant only in FixMin. ProgMin exhibits hardly any motivational crowding-out.

On the individual level, we find support for the “fair-share” rule in RelMin. This rule cannot be detected in FixMin and ProgMin due to the norms set through the (inverted) progressivity in both treatments. In the regressive FixMin treatment average relative contributions are higher for less wealthy players and in ProgMin average relative contributions are higher for more wealthy players. As we see, the “fair-share” norm can be eroded through a deliberate intervention. In particular, in ProgMin, the norm of what is a player’s fair share is adapted in the “intended” direction. Players in FixMin and ProgMin seem to coordinate on a modified fair-share rule of equal contributions relative to the decision space, which we call the “net fair-share” rule. Average relative contributions to the available decision space are equal for all player types in FixMin and in ProgMin.

Type 15 players, for which mandatory contributions are the same in all three MCS treatments, contribute most in ProgMin and least in NoMin. The other two player types contribute more, when they are facing relatively high mandatory contributions (FixMin for Type 10 and ProgMin for Type 20) and contribute less, when they are facing relatively low mandatory contributions (ProgMin for Type 10 and FixMin for Type 20). We also find Type 10 players to behave most and Type 15 and Type 20 players to behave least reciprocally in ProgMin. As it seems, Type 15 and Type 20 players choose their contributions in this treatment “irrespective” of the lower contributions by Type 10 players. This may, at least partially, explain why contributions of both player types in ProgMin are the highest of all treatments, despite the fact that Type 10 players exhibit their lowest contributions of all treatments. Thus, the observation that group contributions are significantly higher in ProgMin than in the other three treatments can potentially be explained by the acceptance of the norm of progressive contributions among the Type 15 and Type 20 players in this treatment, rendering their contributions unconditional on the contributions by Type 10 players. Furthermore, we find that ProgMin exhibits the lowest inequality in total profits of all our treatments in terms of the Gini index.

In spite of these strong results, we advise caution generalizing our findings, in particular with respect to public policy. The response of contributions in a public-good game with heterogeneous endowments to mandatory minimum contributions may not be the same as the response of real economic factors as, for example, labor supply on an intervention in this sphere (Lindsey, 1987). In our experiment, heterogeneous endowments were randomly allocated to all participants in a group. Thus, participants neither had to supply their endowments by themselves nor to work for them. Even though neither Clark (2002) nor Cherry et al. (2005) find that these origins of the endowments, compared to cases where participants are provided with windfall endowments, have an effect in their public-good experiments, we believe that at least some caution is advised concerning possible effects of the endowment origin. This might be particularly true, when the asymmetry in the endowment distribution becomes more important. For example, Cherry et al. (2002) find an effect of endowment origin on behavior in a dictator-game setting. If endowments had to be earned, our mandatory contributions could likely exert similar effects as taxes and lead to a decline in the work effort, which would be in keeping with the Laffer curve hypothesis. Note, however, that for almost all types (with the exception of Type 10 in FixMin and Type 20 in ProgMin) our tax rates are well below the empirically observed tax-revenue-maximizing rates of 50 to 60 percent (e.g., Sutter and Weck-Hannemann, 2003). Although our study is able to show that the progressive minimum-contribution schedule performed best in our public-good setting in terms of overall contribution rates, we are not able to predict, which degree of progression would work best in a public-good environment, where endowments must be earned.

With respect to our initial example of public institutions, which rely on two-tier financing models based on mandatory admission charges plus voluntarily charitable donations and/or employ third degree price discrimination by setting admission fees that vary by status (e.g., regular tickets and reduced tickets for children, students, retirees, unemployed etc.), the increase in average group contributions in ProgMin compared to NoMin and FixMin suggests that progressive tariff structures can indeed be used to improve the financing of such institutions.

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3.7 Appendix A - Additional Tables and Figures

Figure 3-4: Average absolute contributions by player type

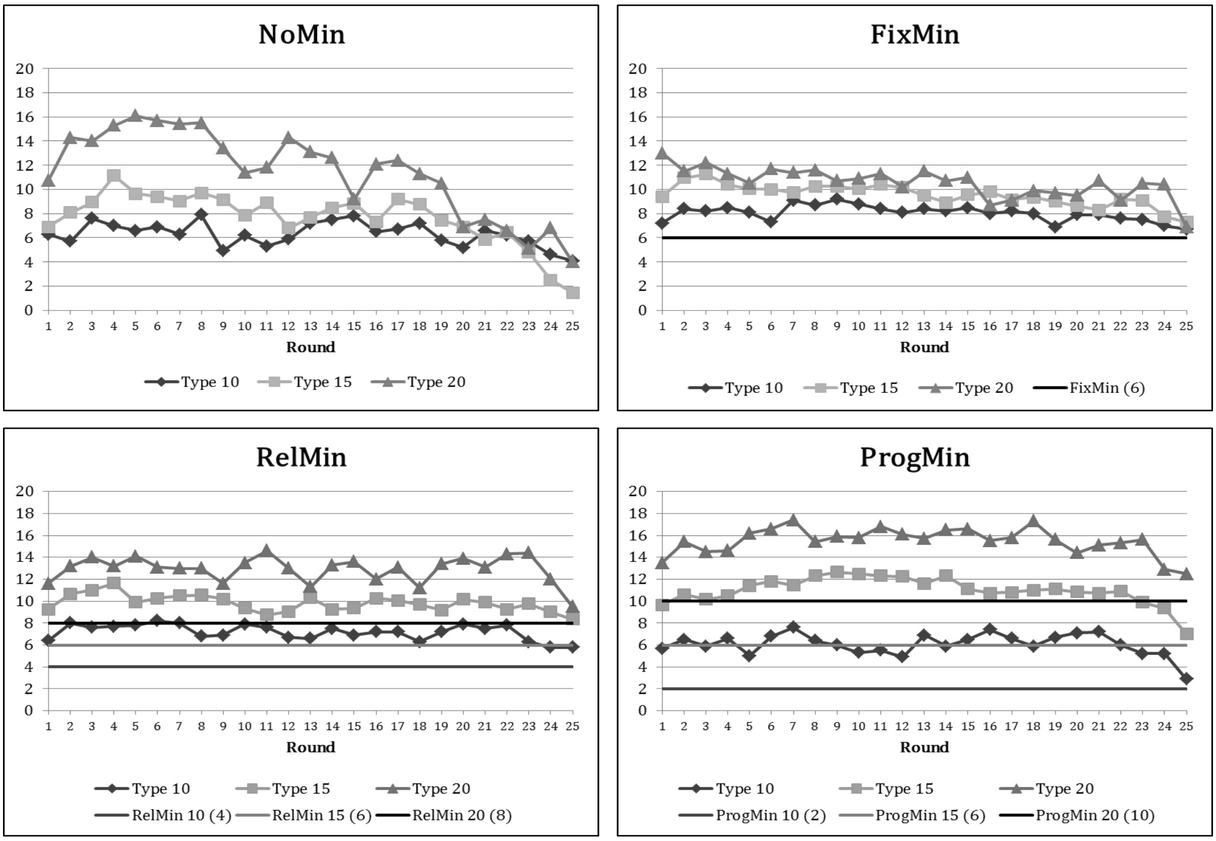


Table 3-5: Comparisons of average absolute contributions between player types (p-values of two-sided signed-rank tests)

	NoMin				**FixMin**		
	Type 10 (6.31)	Type 15 (7.65)	Type 20 (11.44)		Type 10 (8.03)	Type 15 (9.54)	Type 20 (10.56)
Type 10 (6.31)	-	.2845	**.0218**	Type 10 (8.03)	-	**.0593**	**.0284**
Type 15 (7.65)	-	-	**.0051**	Type 15 (9.54)	-	-	.2411
Type 20 (11.44)	-	-	-	Type 20 (10.56)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (7.18)	Type 15 (9.82)	Type 20 (12.92)		Type 10 (6.07)	Type 15 (11.00)	Type 20 (15.48)
Type 10 (7.18)	-	**.0166**	**.0069**	Type 10 (6.07)	-	**.0051**	**.0051**
Type 15 (9.82)	-	-	**.0069**	Type 15 (11.00)	-	-	**.0051**
Type 20 (12.92)	-	-	-	Type 20 (15.48)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player type are given in parentheses.

Figure 3-5: Average relative contributions by player type

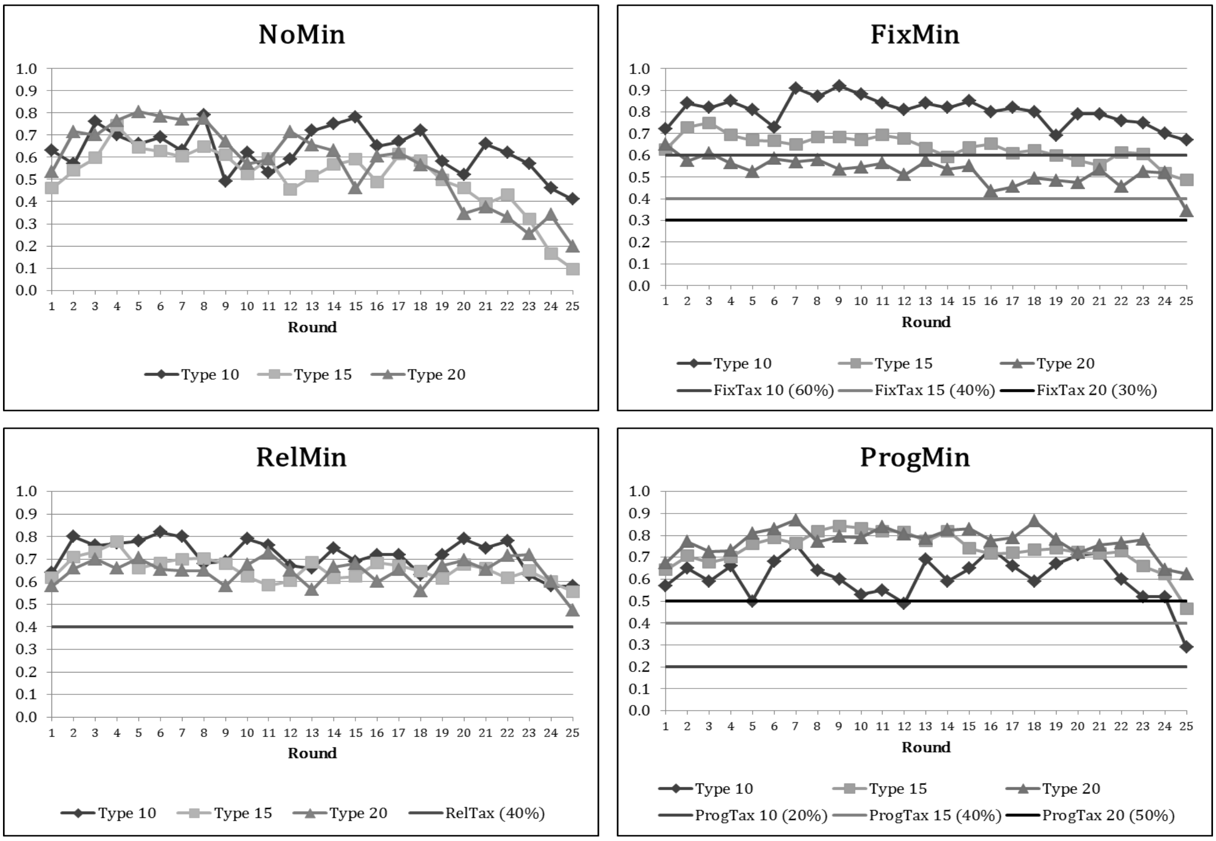


Table 3-6: Comparisons of average relative contributions between player types (p-values of two-sided signed-rank tests)

	NoMin				**FixMin**		
	Type 10 (.6308)	Type 15 (.5101)	Type 20 (.5720)		Type 10 (.8032)	Type 15 (.6359)	Type 20 (.5280)
Type 10 (.6308)	-	.2411	.6465	Type 10 (.8032)	-	**.0166**	**.0093**
Type 15 (.5101)	-	-	.1394	Type 15 (.6359)	-	-	**.0593**
Type 20 (.5720)	-	-	-	Type 20 (.5280)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (.7184)	Type 15 (.6549)	Type 20 (.6460)		Type 10 (.6068)	Type 15 (.7332)	Type 20 (.7740)
Type 10 (.7184)	-	.1394	.2845	Type 10 (.6068)	-	**.0593**	**.0745**
Type 15 (.6549)	-	-	.2411	Type 15 (.7332)	-	-	.3329
Type 20 (.6460)	-	-	-	Type 20 (.7740)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player type are given in parentheses.

Figure 3-6: Average net contributions by player type

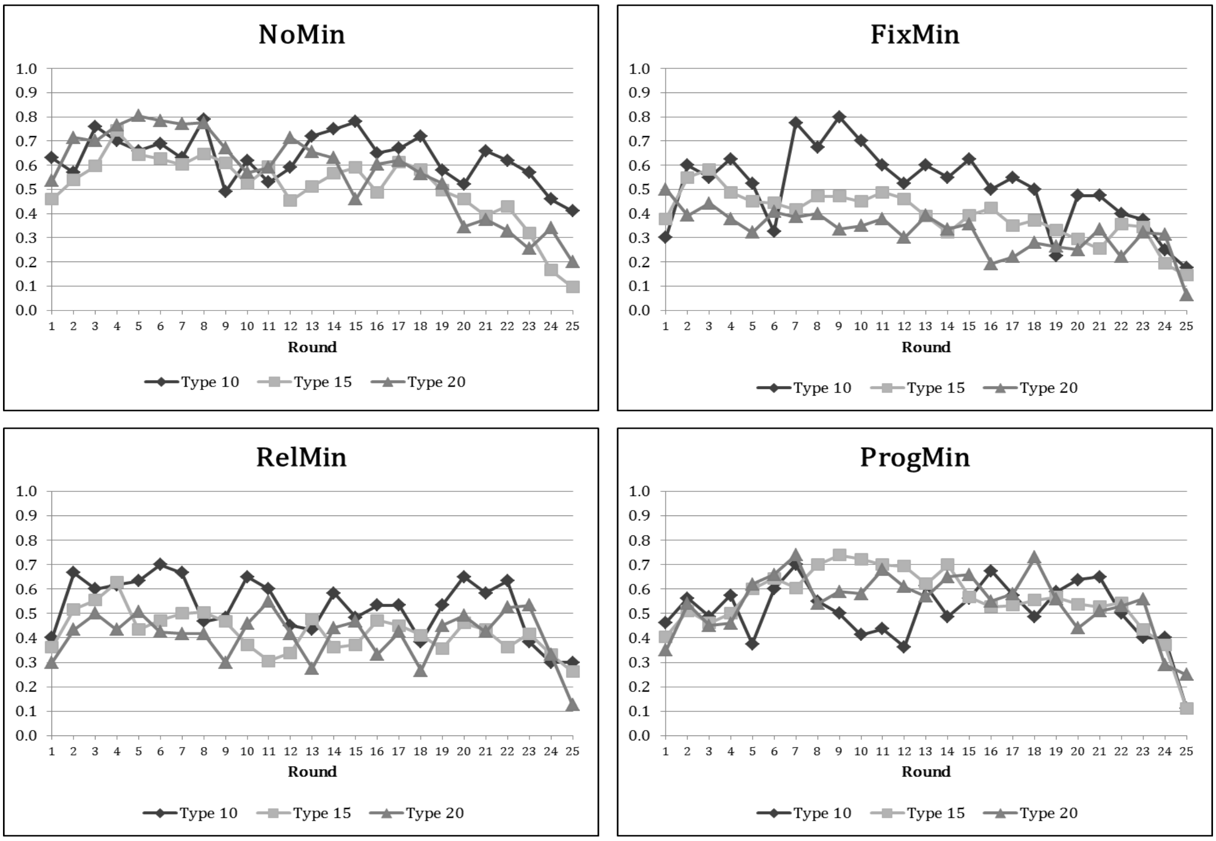


Table 3-7: Comparisons of average net contributions between player types (p-values of two-sided signed-rank tests)

	NoMin				**FixMin**		
	Type 10 (.6308)	Type 15 (.5101)	Type 20 (.5720)		Type 10 (.5080)	Type 15 (.3931)	Type 20 (.3257)
Type 10 (.6308)	-	.2411	.6465	Type 10 (.5080)	-	.1394	**.0745**
Type 15 (.5101)	-	-	.1394	Type 15 (.3931)	-	-	.5076
Type 20 (.5720)	-	-	-	Type 20 (.3257)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (.5307)	Type 15 (.4249)	Type 20 (.4100)		Type 10 (.5085)	Type 15 (.5553)	Type 20 (.5480)
Type 10 (.5307)	-	.1394	.2845	Type 10 (.5085)	-	.5076	.7213
Type 15 (.4249)	-	-	.2411	Type 15 (.5553)	-	-	.9594
Type 20 (.4100)	-	-	-	Type 20 (.5480)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player type are given in parentheses.

Table 3-8: By Type: Comparisons of average absolute [and average net] contributions between treatments (p-values of two-sided U tests)

Type 10				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.1211 [.5453]	.5453 [.4963]	.7624 [.4057]
FixMin	-	-	.3445 [1.000]	**.0257** [.8205]
RelMin	-	-	-	.2725 [.9097]
ProgMin	-	-	-	-
Type 15				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.1617 [.1988	.1508 [.2265]	**.0232** [.8798]
FixMin	-	-	.8798 [.8798]	.1304 [.1306]
RelMin	-	-	-	.1123 [.1124]
ProgMin	-	-	-	-
Type 20				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.2265 [**.0191**]	.9698 [**.0696**]	**.0639** [.5706]
FixMin	-	-	.1509 [.4057]	**.0082** [**.0963**]
RelMin	-	-	-	**.0696** [.1988]
ProgMin	-	-	-	-

Note: Average contributions over rounds 1 to 20 in NoMin, FixMin, RelMin, ProgMin: Type10: $\bar{y}_i$: 6.53, 8.21, 7.32, 6.26; $\bar{y}_i^{Net}$: .6525, .5513, .5533, .5325. Type 15: $\bar{y}_i$: 8.51, 9.84, 9.97, 11.35; $\bar{y}_i^{Net}$: .5675, .4267, .4408, .5947. Type 20: $\bar{y}_i$: 12.80, 10.82, 12.99, 15.78; $\bar{y}_i^{Net}$: .6400, .3443, .4154, .5780.

Table 3-9: Comparisons of contributions by cooperative and uncooperative players within treatments

		NoMin	FixMin	RelMin	ProgMin
Type 10	U	4.4	7.4	6.0	4.6
	C	8.6	9.0	8.7	7.9
Type 15	U	5.6	7.7	8.1	9.5
	C	11.4	12.0	11.8	13.2
Type 20	U	10.0	7.7	10.3	13.5
	C	15.6	13.9	15.6	18.1

Notes: Average contribution figures involve rounds 1 to 20. U = Uncooperative players, C = Cooperative players. For Type 10 and 20 there are per definition respectively 5 U and 5 C players per treatment and for Type 15 respectively 10 U and 10 C players per treatment.

Table 3-10: Relative frequency of individual decisions at the lower bound or full contribution to the public investment

	Lower-bound contributions (in percent)	Full contributions (in percent)
NoMin – Type 10	15.0 [39.5; 25.0; 17.5]	41.5
NoMin – Type 15	14.3 [38.3; 38.3; 38.3]	32.3
NoMin – Type 20	10.0 [19.0; 23.0; 27.0]	32.0
FixMin – Type 10	32.0	44.0
FixMin – Type 15	33.3	24.8
FixMin – Type 20	28.0	17.5
RelMin – Type 10	20.5	37.0
RelMin – Type 15	28.8	18.8
RelMin – Type 20	18.0	17.5
ProgMin – Type 10	25.5	36.5
ProgMin – Type 15	19.8	40.0
ProgMin – Type 20	25.0	43.5

Notes: All figures involve rounds 1 to 20. Lower bound contributions are 0 in NoMin for all player types; 6 in FixMin for all player types; 4, 6, and 8 in RelMin; and 2, 6, and 10 in ProgMin for Type 10, Type 15, and Type 20 players, respectively. Figures in [] respectively show the percentage of contributions that were below the minimum contributions in FixMin, RelMin, and ProgMin for the three player types.

3.8 Appendix B - Experiment Instructions (ProgMin)

You participate in an economic decision experiment, in which you can earn money. How much each of you will earn depends on your personal decisions and those of other participants in the experiment. Each participant makes his decisions at a computer, isolated from the others. We ask you not to talk to other participants.

The experiment consists of 25 rounds. In the beginning of the experiment you will be randomly matched with three other persons to build a group of four. You will remain in this group during the entire experiment. You will not know the identity of your group members at any time, though.

Each group member is endowed in each round with a certain amount of tokens. Player 1 is endowed with 10 tokens per round. Players 2 and 3 are endowed with an amount of 15 tokens each. Player 4 is endowed with 20 tokens per round. The individual player numbers (and thus the individual endowments) will be randomly assigned and announced at the beginning of the experiment.

DECISIONS

In each of the 25 rounds, all group members each group member has to decide on how to allocate her/his tokens between two alternatives, called X and Y. The return of a token, in experimental currency units (ECU), is different for the two alternatives. The return of the allocation decision is determined as follows:

Each token that you contribute to X yields a return of 2 ECU. If you contribute nothing to X, your return from X is zero.

Each token that you contribute to Y, yields to you and to each of the other group members a return of 1 ECU. You may thus have a positive return from Y even if you yourself don’t contribute anything to Y.

During the allocation of your tokens, you must note that you are required to contribute a minimum contribution to Y. This minimum contribution is 2 tokens for Player 1, 6 tokens for Players 2 and 3 each, and 10 tokens for Player 4.

Group Member	Endowment (tokens)	Mandatory Contribution to Y
Player 1	10	2
Player 2	15	6
Player 3	15	6
Player 4	20	10

You may allocate your tokens, above the minimum contribution to Y, to X or to Y only, but you may also allocate them among both alternatives. However, only entire tokens may be contributed. In the decision box on your screen you need to enter, for each alternative, the number of tokens that you want to allocate. If you do not want to contribute anything to X or Y, you need to type in a zero. The sum of the tokens contributed to X and Y must be always equal to your endowment. This means that the entire token endowment has to be allocated among X and Y. With the <Tab> key you can switch among the entry fields. The entries have to be confirmed by clicking on <OK>.

Your individual return per round is the sum of your returns from X and Y and is calculated as follows:

Return = 2 × (your contribution to X) + (sum of tokens contributed to Y in your group).

PAYMENT

At the end of the experiment, you will be paid based on your individual total profit over all 25 rounds. Your individual total profit in ECU will be converted into € (1 ECU = 0.01 €) and paid to you in cash. You are paid at the end of the experiment. The payment is carried out individually and anonymously.

AVAILABLE INFORMATION

In each round, you will see an overview table on your screen which provides you with the results of all previous rounds that you have played. The results include the following information for each round:

Your endowment, your mandatory minimum contribution to Y, your contribution to X, your contribution to Y, the individual contributions to Y of each of the other group members, your return from X, your return from Y, your round profit, and your total profit.

If you want to see the results of earlier rounds, which are no longer visible in the table, please use the scroll function on the right side of the table.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. You then will be given on your screen a number of questions regarding these instructions. If you have any questions please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

4. Two + One: Cooperation and Punishment

with Claudia Keser

Abstract: We investigate the role of punishment in a repeated three-player public-good experiment with heterogeneous endowments. In a 2x2 treatment design we study two different endowment distributions (rich majority vs. poor majority) and a scenario with punishment option vs. one without. We observe that the option to punish individual others increases group contributions but not profits. Punishment tends to decrease over time but increases again in the very last repetition. While the punishment option distorts the "fair-share rule" of contributing the same percentage of one's endowment towards a higher relative contribution by the low-endowment player in the rich-majority scenario, we observe that the low-endowment players in the poor-majority scenario, that contribute a higher share of their endowment when there is no punishment mechanism, tend to contribute the same share when a punishment mechanism is in place. In support of this, we observe no difference in punishment on an overall level. Focusing on the player type in majority, we find in the rich-majority scenario the high-endowment players to punish each other on average significantly more than the low-endowment player and in the poor-majority scenario the low-endowment players to punish the high endowment player more. Overall, about one quarter of punishment is anti-social, implying that a player gets punished who has contributed a higher percentage of her or his endowment than the punisher.

JEL classification: C92; D63; H41

Keywords: Experimental economics; public goods; heterogeneous endowments; punishment; norms

4.1 Introduction

It is a well-known observation in experimental economics that the opportunity for peer punishment can foster cooperation. In their seminal paper, Ostrom et al. (1992) find that in a common-pool-resource game cooperation can be increased by punishment, in particular when combined with the possibility to communicate and to self-determine the punishment rule within the group. Fehr and Gächter (2000) show in a symmetric linear public-good setting that people do make use of a punishment option even when it is costly. The introduction of a peer-punishment mechanism increases and stabilizes the average provision of the public good. Due to the costs of punishing, however, the average profit over all rounds is not increased. Gächter et al. (2008) show, punishment can increase profits given a long time horizon of repeated interactions (50 rounds). The punishment mechanism introduced by Fehr and Gächter (2000) has been implemented in many subsequent studies on public-good provision and their results have often been replicated.

The majority of studies on punishment in linear public-good games have investigated symmetric settings, where all players have the same endowment and the same return from the public good. Thus, in our study we investigate the role of punishment in a linear public-good game with heterogeneous endowments. Specifically, we consider two different endowment distributions, rich majority with two high-endowment plus one low-endowment players, and poor majority with two low-endowment plus one high-endowment players. The focus of our study revolves around the question whether rich and poor players display different punishment behavior and whether being a majority- or minority-player plays a role.

Warr (1983) and Bergstrom et al. (1986) developed a neutrality theorem, stating small redistributions of income have no effect on the public good provision. In a linear public good game Chan et al. (1996) discuss the effect of endowment asymmetries in a three player public-good game. Chan et al. (1996) change in five treatments the degree of asymmetry; starting with symmetry and increasing in the four remaining treatments the endowment of one player, while symmetrically decreasing the endowment of the two other players. They find in the symmetric treatment the group contributions to reflect the results from the theoretical Bergstrom et al. model as well as confirming the neutrality theorem. Furthermore the low endowment players under strong asymmetry contribute more than the Bergstrom et al. (1986) prediction, while the high endowment player contributes less.

We are aware of a few studies that investigate punishment in heterogeneous public goods. Anderson and Putterman (2006), on the other hand, use a “one-shot” VCM games with punishment, but symmetric endowment. Participants would encounter in five rounds punishment costs drawn from a known distribution. Each value could appear with the same probability. The levels of those values were change between the treatments. The allocation of punishment positively scales with the level of free-riding behavior. Additionally the authors find a negative correlation between the costs of punishing and the punishment frequency. Egas and Riedl (2008) use a similar approach to Anderson and Putterman (2006). Based on a symmetric three players public-good game with a MPCR of 0.5, they change in five treatments the ratio of costs for punishing and being punished, starting with a baseline without punishment. They find that punishment is only effective if the costs for the punisher are relatively low compared to the punished. In the experiment this was reflected in a 1:3 ratio. The overall focus in both studies is on variant of punishment efficiency.

Reuben and Riedl (2013) compare treatments with and without a punishment mechanism of three-player public-good games that are characterized by asymmetries in endowment or MPCR: one of the players is characterized either by a higher endowment or MPCR than the remaining two players with the same lower endowment or MPCR. The group members and roles within a group were randomly assigned and stayed like that for the remainder of the experiment. In contrast to our experiment the group endowment may vary over treatments. Furthermore, some treatments contain restrictions for the maximum contributions, limiting contributions by the high endowment player to the maximum of the low endowment players. The treatment most similar to our experiment corresponds to the high endowment being endowed with twice as much as the low endowment players and contributions are unrestricted. Still the framework tackles a different problem and focuses on different punishment regimes, while it is not build to distinguish whether a majority of high or low endowment players exhibit structural differences in the punishment behavior. They find that the punishment mechanism increases the public-good contributions of both player types. The average profit level over all 10 periods remains unaffected, but the average profits in the second half are significantly higher in the treatment with punishment than in the similar setting without punishment. Furthermore they find that the two player types show no differences in punishment behavior. Additionally, a questionnaire with neutral participants was conducted to analyze a third party view on fair contributions. The results indicate that under asymmetric endowment most participants consider an equal contribution as a proportion of the endowment as fair.

Based on our treatments we find a similar contribution behavior as in previous studies, exhibiting declining group contributions over the course of the game, which are independent of the endowment distribution. The implementation of the punishment mechanism stabilizes group contributions and reaches higher group profits than in the according no-punishment treatments in the second half of the experiment. In general, group members tend to punish players that contributed a smaller share of their endowment than themselves. The focus and mayor contribution to the research lays in the analysis of the differences in the type punishment. We find indications that more punishment is pointed towards the high endowment players, so that high endowment players educate each other or low endowment player push the single high endowment player to higher contributions. On the downside we also observe anti-social punishment, which shows structural differences between the two punishment treatments, letting high endowment players in a rich majority punish each other more than the low endowment player. In the case of two low endowment players and one high endowment player there appear to be no punishment differences.

The remainder of this paper is structured as follows. Chapter 4.2 presents the experimental design and procedure. In Chapter 4.3 we derive hypotheses. Chapter 4.4 presents the experimental results and Chapter 4.5 concludes the paper.

4.2 Experimental Design

4.2.1 The Model

Our experiment is based on a linear three-player public-good game. Subjects are randomly assigned to groups of three and stay in these groups for the entire experiment, which comprises 25 rounds of decision making (partners design). In each round, each group member i $(i = 1,2,3)$ is endowed with a fix number of tokens, e_i. These tokens have to be allocated between two alternatives, called X and Y. Participants are free to invest in just one or split the investment between the two alternatives. The alternative X is private and involves private returns to the investing player, exclusively. The alternative Y is public and implies returns to all players in the group. Any token allocate to the private alternative X yields a private return of two Experimental Currency Units (ECU). Any token invested in the public alternative Y yields a return of one ECU to every group member.

We use a 2x2 treatment design. In the first dimension, we consider two endowment distributions, “rich majority” or “2R1P” with two rich and one poor and “poor majority” or “1R2P” with one rich and two poor. The endowments of 8, 26 and 26 in rich majority or 17, 17 and 26 in poor majority are randomly allocated to the participants. Both distributions involve two levels of endowment among the three players, low and high, and a total endowment of 60 tokens. In the following, we shall distinguish player types by their endowments (T8, T17 and T26). In the second dimension of our 2x2 treatment design, we consider a scenario with punishment option (“Pun”) and one without. Table 4-1 provides an overview of all treatments.

In the two (baseline) treatments without punishment, the participants are asked to simultaneously make their investment decisions in each round. After all group members have made their decisions, the profits are determined. The individual profit of each player i, π_i, is calculated as follows:

$$\pi_i = 2 \cdot (e_i - y_i) + \sum_{j=1}^{3} y_j,$$

where x_i is the amount allocated by player i to the private alternative X and y_i is the player's amount allocated to the public alternative Y. At the end of the round, each player is informed of the contribution to Y of each other group member.

The one-shot game has a Nash equilibrium in dominant strategies. Independently of the decisions by the other two group members, a player's individual profit is maximized by investing everything into the private good. The subgame perfect equilibrium for the repeated game is determined by backward induction: in each of the twenty-five rounds, all group members invest their entire endowment into their respective private alternative X. In contrast, the social optimum would require that all players invest their whole endowment in the public good, in every period.

The punishment treatments resemble the baseline treatments, but are extended by a punishment stage, which directly follows the investment decision. The punishment mechanism employed is based on Fehr and Gächter (2002). In the beginning of the punishment stage, each group member is informed of each group member's individual contribution to Y and invited to allocate up to a maximum of eight punishment points to any of the two other group members. The allocation of each punishment point costs one ECU to the punishing player (p_{ij} are the punishment points allocated by player i to player j, with $i \neq j$). The punished player has to pay four times the number of punishment points received (p_{ji} are the punishment points received by player i from player j, with $i \neq j$). The total number of punishment points that a player may allocate is limited (in addition to the maximum of eight points per person) by the profit realized prior to the punishment stage in the current round.

The profit of player i in the punishment treatments thus calculates as:

$$\pi_i = 2 \cdot (e_i - y_i) + \sum_{j=1}^{3} y_j - \sum_{j \neq i}^{3} p_{ij} - 4 \cdot \sum_{j \neq i}^{3} p_{ji}.$$

At the end of the round, each player is informed about the total number of punishment points received. However, no information on the donor or donors of those punishment points is provided.

The subgame perfect equilibrium prescribes again, for each player, to invest everything in the private good. The opportunity to punish individual others has no impact on the equilibrium investment since no rational player would engage in costly punishment. Therefore no player will ever punish. In the social optimum, all group members, similarly to the treatments without punishment, contribute the complete endowment to the public good and no group member ever engages in punishment.

Table 4-1: Treatment overview

Treatment	Acronym	Endowment		# Players		Punishment	# Observations
		Low	High	Low	High		
Rich majority	2R1P	8	26	1	2	No	11
Rich majority + Pun	2R1PPun	8	26	1	2	Yes	18
Poor majority	1R2P	17	26	2	1	No	14
Poor majority + Pun	1R2PPun	17	26	2	1	Yes	16

4.2.2 Procedure

The experiment was conducted at the Göttingen Laboratory of Behavioral Economics using z-Tree (Fischbacher (2007)). We invited students from various fields of study using ORSEE (Greiner (2004)). We conducted two sessions in each, the 2R1P and 1R2P treatment, allowing a total of 11 and 14 independent observations. The respective punishment treatments, 2R1PPun and 1R2PPun, were conducted in three sessions each, with a total of 18 and 16 independent observations. An overview of the treatments can be found in Table 4-1. In total 177 students participated in the experiments. Participation was allowed only once. The majority (63 percent) of the participants were undergraduate students; 48 percent of the participants were female.

The experiment was structured as follows. Participants were welcomed in a separate room. The written instructions were handed out and read aloud by the same experimenter in each session. Subsequently, the participants were escorted to randomly assigned cubicles. Before the experiment started, every participant had to answer to a computerized series of questions to assuring the understanding of the instructions. Should a participant have a question, it was individually answered. After everybody had finished the questionnaire the experiment started. All subjects received their cash payoff individually, at the end of the experiment. The average payoff was 14.86 €. An experimental session took 75 minutes on average.

4.3 Hypotheses

Hypothesis 1: *Players will contribute the same share of their endowment ("fair-share rule").*

Experimental evidence by Hofmeyr, Burns and Visser (2007), Keser et al. (2014) and Reuben and Riedl (2013) suggests that in an environment with heterogeneous endowments players tend to contribute the same fraction of their respective endowments rather can contributing the same absolute amount. Sugden (1984) refers to this as "fair-share rule". The reciprocity principle, which is an important component of conditional cooperation (as defined in Keser and van Winden (2000) for homogeneously endowed players), implies an increase in one's own contribution if in the previous period one's contribution level below the one of the other players, while contributions tend to be decreased after having contributed more than others. In the case of endowment heterogeneity, the fair-share-rule implies that reciprocity relates to contributions relative to the contributor's endowment.

Hypothesis 2a: *The availability of the punishment mechanism will increase the cooperation level and keep it more stable.*

This hypothesis follows from the experimental results presented in the seminal paper by Fehr and Gächter (2000), on which our punishment mechanism is grounded. They observe that in a linear public-good game with the costly opportunity to punish individual others contributions can be maintained on a very high level, both in a partners and a strangers setting. Among many replications of their punishment mechanism, Xu et al. (2013), for example, find an increase in group contributions in various public-good treatments that differ in size, marginal per capita return (MPCR) and marginal per group return (MGR). Nikiforakis & Normann (2005) show that effectiveness of punishment is influenced by the ratio between costs for punishing and being punished (fee-to-fine ratio). They show the necessity of a ratio of at least 1:3 to achieve an increase in contribution. This is satisfied in our experiment.

Hypothesis 2b: *Punishment will have no effect on the (overall) profit level.*

While the provision of punishment helps to increase the players' contributions, punishment is as well costly. Depending on the number of allocated punishment points and the corresponding costs to both, the punishing and the punished player, payoff gains from higher contributions might be consumed by punishment expenditures. Several authors find that there is no significant difference in public-good games with and without punishment mechanism (e.g., Bochet, Page and Putterman (2006); Reuben and Riedl (2009)). Fehr and Gächter (2000) as well as Masclet et al. (2003) state a slight (but insignificant) increase in profits, though. These observations have been made in studies based on public good games that have been repeated a relatively small number of times (10 to 30 times). Gächter et al. (2008) show that the impact of punishment on the overall profit level depends on the number of repetitions. Specifically, they find that in public-good games that are repeated as many as fifty times the profit level in the punishment treatment exceeds the one in a similar no-punishment treatment. The experiment in our study will be based on twenty-five repetitions, which is closer to the previous studies with a small number of interactions than to Gächter et al. (2008).

Hypothesis 3: *Punishment will be made use of but it will decline over the course of the game.*

Fehr and Gächter (2000) observe that people are willing to punish others even if punishment is costly to the punisher as well. Reuben and Riedl (2009) and Sefton, Shupp and Walker (2007) find declining punishment expenditures.

Hypothesis 4: *We will observe both pro- and anti-social punishment.*

Punishment can be used by cooperative players to motivate less cooperative players to contribute more. This is considered as pro-social punishment. Previous studies (e.g., Bochet, Page and Putterman 2006; Fehr and Gächter 2000; Gächter and Herrmann 2011; Herrmann, Thöni and Gächter 2008; Masclet et al. 2003, Sefton, Shupp and Walker 2007) have shown that players sometimes also punish others that have contributed a higher percentage of the endowment than the punisher self. In this case we speak of anti-social punishment.

Hypothesis 5: *Punishment does not differ between players with different endowments.*

Reuben and Riedl (2009) find that different player types, in particular players that are differently rich in endowment, punish to the same extent and with the same frequency for a given situation. Two opposite effects may be considered that seem to cancel each other out. On the one hand, although punishment costs per punishment point are in absolute terms the same to the different player types, punishment is relatively more expensive for low-endowment players. On the other hand, low endowment players do profit the most from group contributions, the increase of which being usually the motivation for punishment.

Hypothesis 6: *In "poor majority", a poor player will punish the rich more than the other poor, while in "rich majority", a rich player will punish the other rich player more than the poor player.*

Our experiment is designed such that in each treatment there are always two of the three players of one type and the third player of a different type. In the 2R1PPun treatment, we have a majority of rich players, while the 1R2PPun has a majority of poor players. These constellations may lead to different effects on punishment behavior. Fehr and Schmidt (1999, p. 842) argue that punishment can be used by inequality-avers conditional cooperators to reduce differences in profits. While Masclet and Villeval (2008) observe that people punish even when punishment has no effect on the distribution of profits between the punisher and the punished person, Raihani and McAuliffe (2012) claim to "show that humans punish cheats only when cheating produces disadvantageous inequity, while there is no evidence for reciprocity." Assuming inequality aversion to play some role in our experiment, we can expect that punishment takes place and is influenced by the degree of inequality as follows. In the case of 2R1PPun it is reasonable to assume that more punishment should be used against the same type. A cooperative high-endowment player should see less motivation in punishing a free-riding low-endowment player that usually faces a lower round profit anyway, than in punishing a free-riding high-endowment player. Punishing the latter reduces the profit advantage that this same-type player had created for herself by contributing a lower amount to the public. In the case of 1R2PPun, a low-endowment player can be expected to punish free-riding behavior by the other low-endowment player, but he might punish the high-endowment player more severely, since this player already has a profit advantage by his endowment.

4.4 Results

4.4.1 Group Contributions

Figure 4-1: Average group contribution

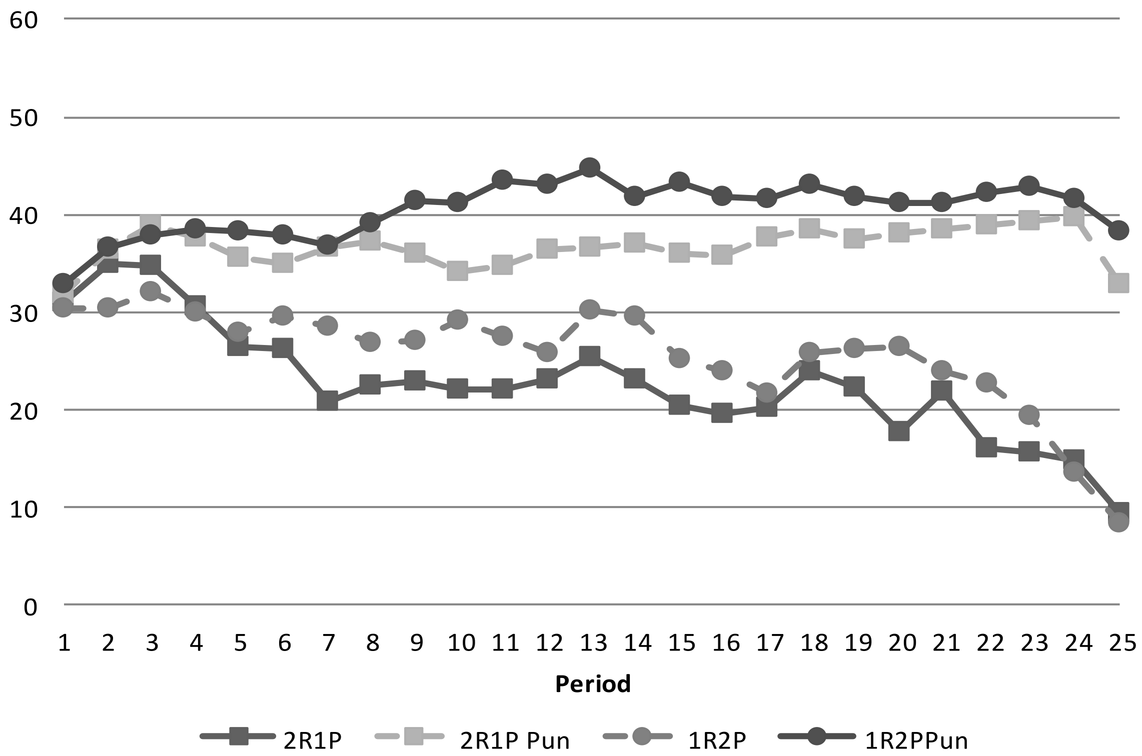


Figure 4-1 exhibits the mean group contribution per treatment over the course of the twenty-five periods. It shows clearly higher contributions in the punishment treatments relative to the non-punishment treatments. Over all periods, the average group contribution is 22.66 and 25.63 for 2R1P and 1R2P, respectively, and 36.64 and 40.45 for 2R1PPun and 1R2PPun, respectively. The differences between 2R1P and 2R1PPun as well as between 1R2P and 1R2PPun are statistically significant at $p = 0.059$ and $p = 0.0018$, respectively (two-sided Wilcoxon-Mann-Whitney U test (U test)). Although Figure 4-1 suggests higher contribution levels in 1R2P than in 2R1P and in 1R2PPun and 2R1PPun, the differences are statistically insignificant (requiring significance at the ten-percent level).[27]

[27] Standard deviations in the group contributions are 11.22 and 11.46 in 2R1P and 1R2P, respectively, and 8.53 and 5.05 in 2R1PPun and 1R2PPun, respectively. They are significantly lower in the two punishment treatments than in the respective no-punishment treatments ($p = 0.004$ for the rich-majority and $p = 0.0002$ for the poor-majority treatments). Between the two endowment distributions we find no significant differences, neither with nor without punishment.

Figure 4-1 also reveals that the contributions in the no-punishment treatments follow a downward trend, while the contributions in punishment treatments are more or less constant at a constant level or even slightly increasing over the course of the game. The possibility to punish thus stabilizes the contribution behavior. Pairwise comparison of average contributions during periods 1 to 12 and periods 13 to 24 based on two-sided sign-rank tests yields a significant downward trends for 2R1P ($p = 0.0754$) and 1R2P ($p = 0.048$). For 2R1PPun we observe no significant trend ($p = 0.2484$), while group contributions even increase in 1R2PPun ($p = 0.0298$). To focus on a potential end-game effect we compare periods 21 to 24 and period 25. All treatments, with exception of 1R2PPun, show a significant decline in the average contributions ($p = 0.0033$ in 2R1P, $p = 0.0501$ in 2R1PPun, and $p = 0.0131$ in 1R2P and $p = 0.21$ in 1R2PPun).

Result 1: *The option to punish individual others significantly increases group contributions. While the typical downward trend can be observed in the no-punishment treatments, the two punishment treatments show mostly constant or increasing levels of contribution (Hypothesis 2a). We find no significant differences in the contribution levels between "rich majority" and "poor majority", neither with nor without the punishment mechanism.*

Figure 4-2: 2R1P: Relative Contribution by Type

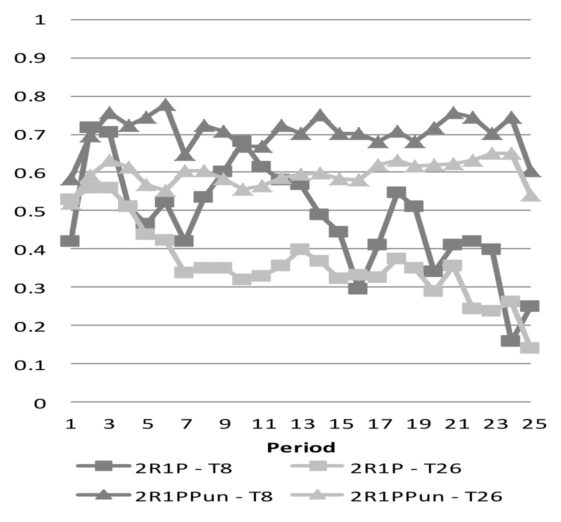
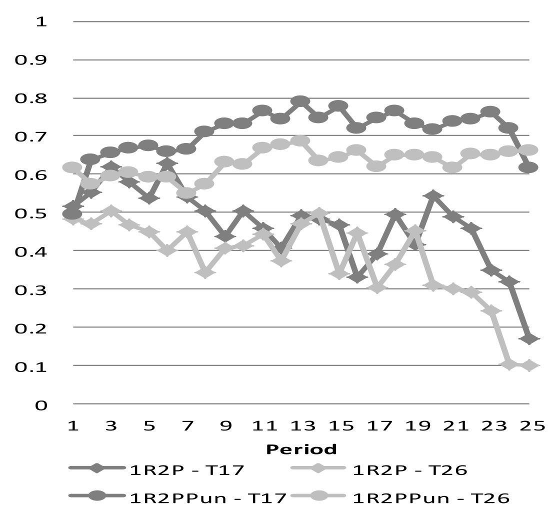


Figure 4-3: 1R2P: Relative Contribution by Type



4.4.2 Contributions by type

In each of the four treatments, we label each player as either the low- or high-endowment player. T8 in the rich-majority and T17 in the poor-majority treatments are the low-endowment players. T26 is the high-endowment player in all treatments. The comparison between the rich-majority treatments 2R1P and 2R1PPun shows for both, low- and high-endowment player, significantly higher contributions in the punishment treatment ($p = 0.0714$ for T8 and $p = 0.0796$ for T26). For the poor-majority treatments 1R2P and 1R2PPun the results are similar ($p = 0.0041$ for T17 and $p = 0.0141$ for T26).

Comparisons within the treatments, using the Wilcoxon-Signed-Rank Test, show a significantly higher absolute contribution by the high-endowment relative to the low-endowment players. Figure 4-2 and Figure 4-3 exhibit the relative contributions of low- and high-endowment players in the rich-majority and the poor-majority treatments, respectively. The comparisons of the relative contributions based on Wilcoxon-Signed-Rank tests show no differences between low- and high-endowment players in 2R1P and 1R2PPun. This is in line with the assumption of the "fair-share rule". For 1R2P and 2R1PPun we find significantly higher relative contributions by the low-endowment players ($p = 0.0186$ for 1R2P and $p = 0.0936$ for 2R1PPun). Note that inequality aversion (Fehr and Schmidt (1999) and Bolton and Ockenfels (2000)) would imply the opposite, i.e. the high-endowment player(s) to contribute the higher share of endowment. This contradicts findings by e.g. Buckley and Croson (2006) and Cherry et al. (2005), where the low endowment player contributes the bigger share of her endowment. Based on Reuben and Riedl (2013) we repeat the tests restricted to groups not reaching the group optimum more than 1/3 of the periods. The results for 2R1P, 1R2P and 1R2PPun stay unchanged. Only the test results for 2R1PPun change and become insignificant at the 10 percent level ($p = 0.1159$). This is additional support for the fair share hypothesis. Table 4-2 gives an overview how many groups have been dropped for the comparison. The high number of groups dropped in the punishment treatments is an additional indicator of the cooperation inducing effect of a punishment mechanism.

Result 2: *2R1PPun and 1R2P show significantly higher relative contributions by the low-endowment players than by the high-endowment players. This finding for 2R1PPun becomes insignificant if we exclude groups with mostly full cooperation. In the remaining treatments we find support for the "fair-share rule" (Hypothesis 1).*

Table 4-2: Number of groups with 2/3 of the periods full contributions

Treatment	Groups without mostly full contributions	Groups with mostly full contributions	Total number of groups
2R1P	11	0	11
2R1PPun	13	5	18
1R2P	13	1	14
1R2PPun	12	4	16

4.4.3 Profits

Figure 4-4: Average group profit

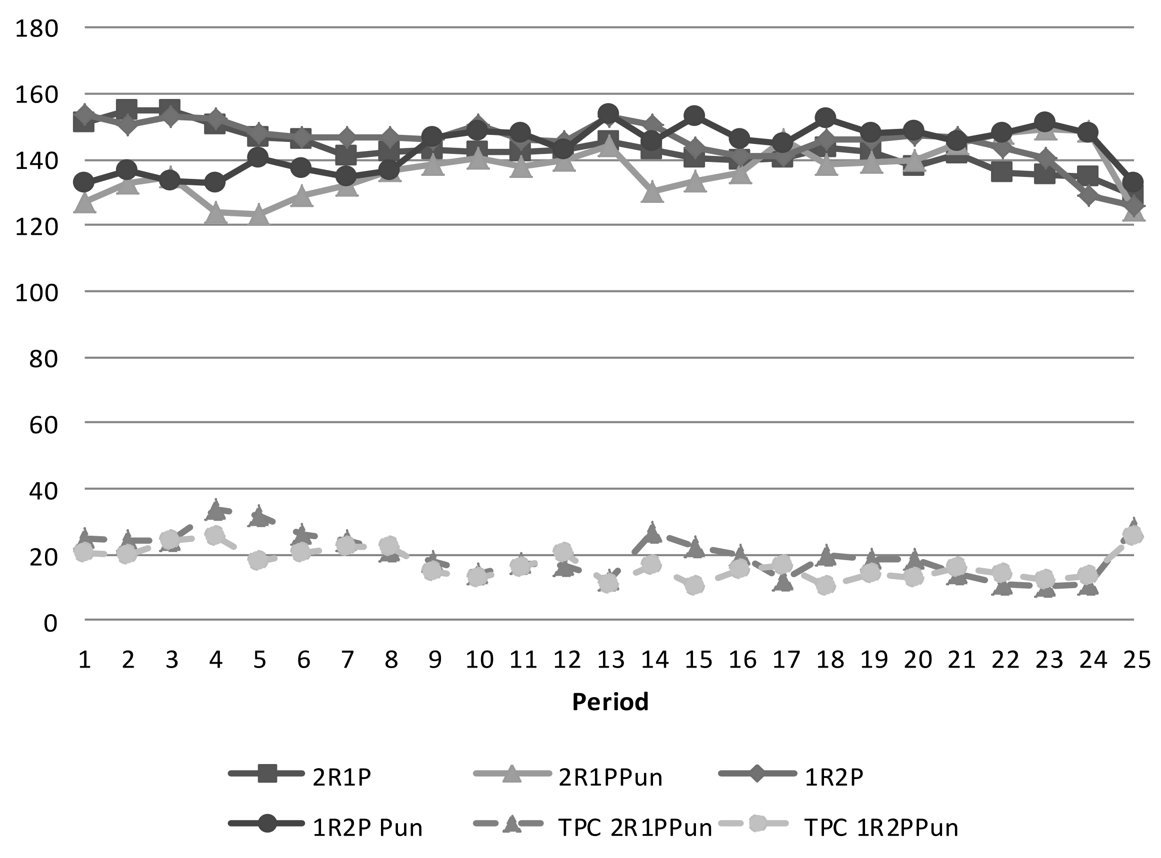


Figure 4-4 depicts, for all treatments, the average group profits over the 25 periods. In addition, it exhibits the corresponding average group punishment expenditures. The four profit curves run most of the periods very closely but differ in the initial phase for the treatments with punishment. The average group profits are 142.66 for 2R1P, 136.73 for 2R1PPun, 145.63 for 1P2R and 143.51 for 1R2PPun. None of the pair-wise comparisons with U tests indicates significant difference at the ten-percent level. For the with-and-without-punishment comparison (for a given endowment distribution) this lack of an increase in profits reflects the kick in of punishment costs: profit gains from higher contributions in the punishment treatments are consumed by costs of sanctioning. Distinguishing again between periods 1 to 12 and periods 13 to 24, we find no significantly differences in the average profits between the treatments. Although the signs indicate a tendency of lower (higher) profits in the first (second) half for the punishment treatments, the p-values are far from being significant.

Investigating profits of the different endowment types, we observe that both in 2R1PPun and 1R2PPun the low-endowment player, on average, gains a profit that is not significantly different from the profit of the respective treatment without punishment. However, the high-endowment player gains a significantly lower profit in periods 1 to 12 if a punishment mechanism is in place, both in 2R1P ($p = 0.0651$) and in 1R2P ($p = 0.0026$). The second half of the games shows no profit between the treatments.

Result 3: *Profits on the group level are uninfluenced by the option to punish (Hypothesis 2b). High-endowment players earn a significantly lower profit in the first half in the punishment treatments than in the respective treatment without punishment mechanism.*

Figure 4-5: Total punishment per period

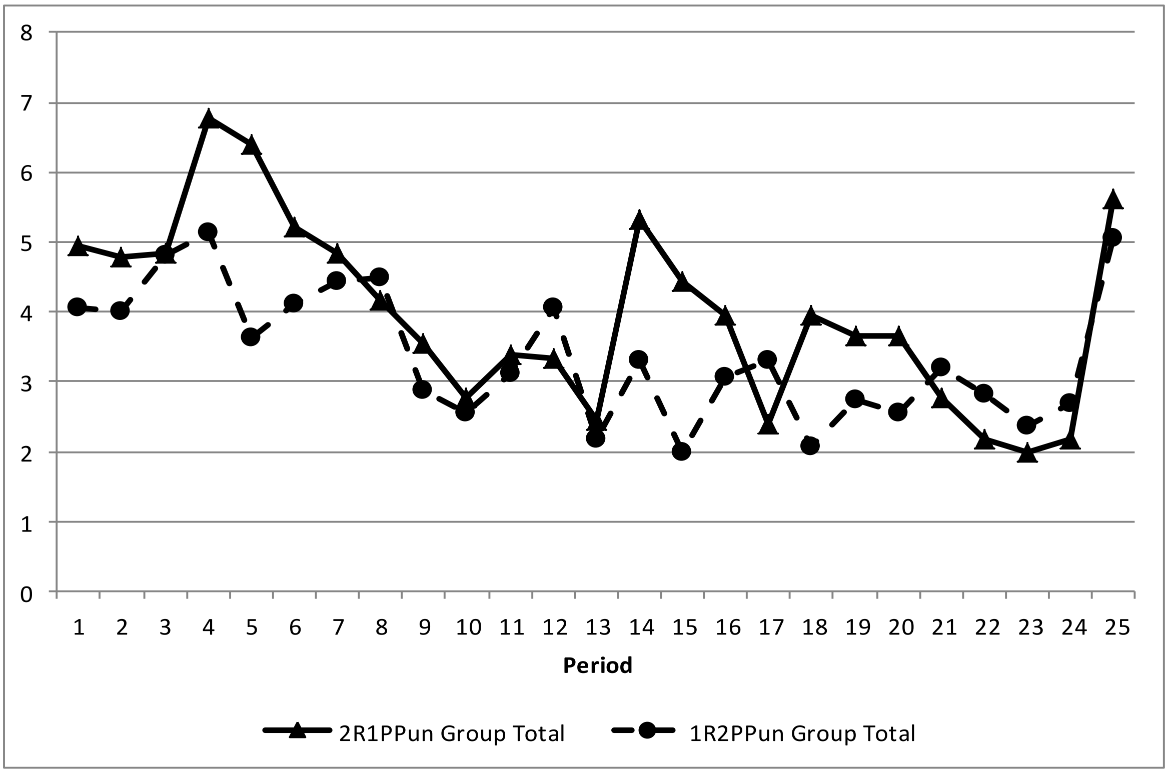


Figure 4-6: Punishment points allocated per period

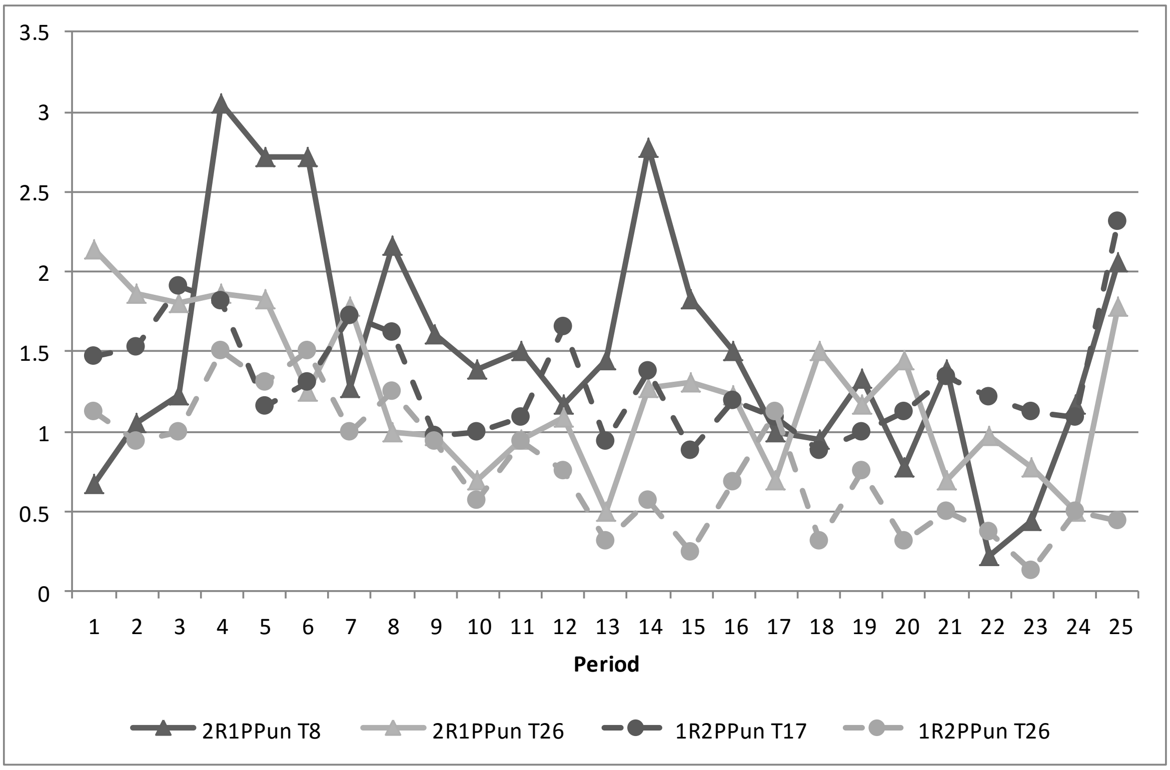
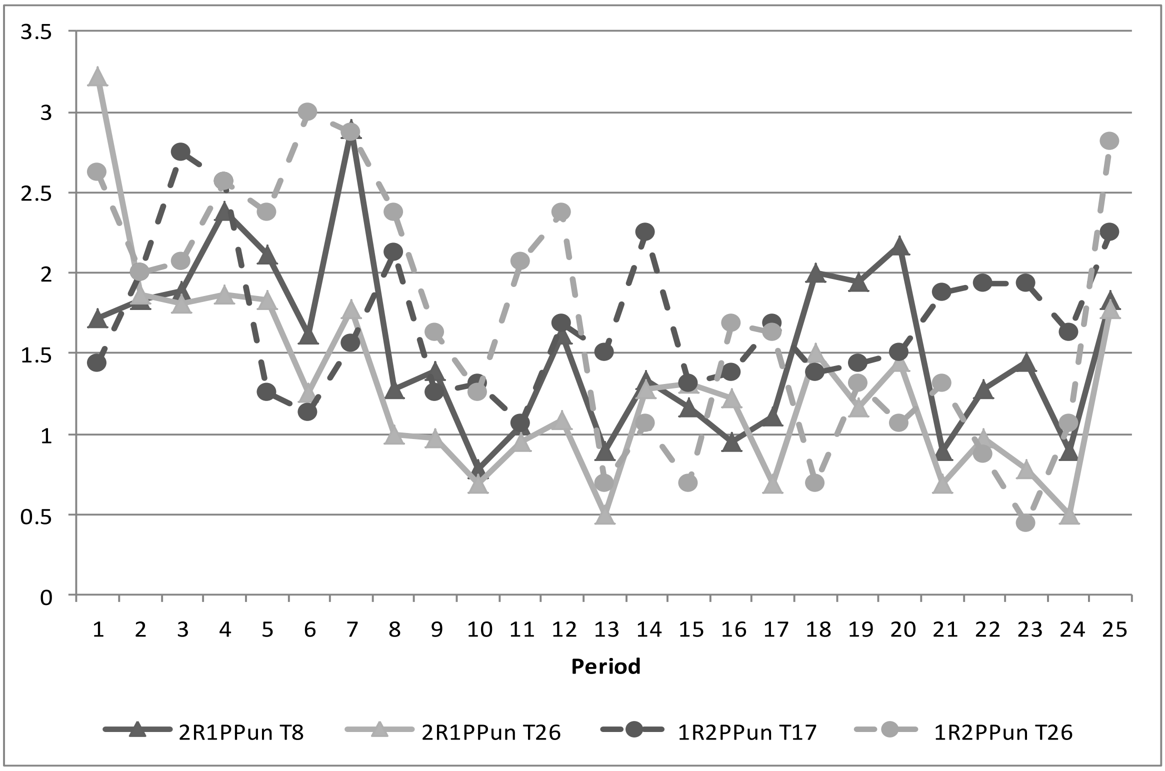


Figure 4-7: Punishment points received per period



4.4.4 Punishment behavior

After discussing the contribution behavior in the previous chapter, we now turn toward the punishment behavior. Figure 4-5 exhibits for each of the twenty-five periods the average sum of punishment points by treatment. Additionally, Figure 4-6 shows the average punishment per player type and Figure 4-7 the average number of punishment points received per player type. A first look at Figure 4-5 suggests that punishment in both treatments decreases over the course of the game. The 2R1PPun treatment exhibits higher amplitudes. In the last period we observe a peak in both treatments, which is in line with, for example, Bochet, Page & Putterman (2006): although there is no future interaction, punishment is used. One possible explanation is a combination of educational intentions and revenge. Although there is no further interaction in the lab, participants may punish in the last period to teach a lesson (on generally expected behavior).

To control for potential differences we use U tests. We observe no significant difference in the group punishment points between treatments, neither on average over all periods, nor if we split the period into two blocks for periods 1 to 12 and periods 13 to 24. The same holds true for the punishment frequency and average number of allocated punishment points per punishment action. The most frequent numbers of punishment points allocated are one, two and eight punishment points. They account for approximately 70 percent of all punishment cases in both endowment distributions. One and two punishment points account for 46 percent of all punishment in 2R1PPun and 59 percent in 1R2PPun. Eight punishment points are chosen in 24 and 14 percent of all cases in 2R1PPun and 1R2PPun, respectively. Table 4-3 presents average punishment points allocated over all periods, as well as periods 1 to 12 and 13 to 24. We distinguish between treatment and type. Furthermore, we disentangle the data for punishment between and within types. Among others, it suggests that the single (low-endowment) player type in 2R1PPun is punishing on average more than the twin type players (high endowment), while the single (high-endowment) player type in 1R2PPun is punishing on average less than the twin type players (low endowment). Looking at the punishment toward the same player type, there is indication that T17 and T26 punish on average the same way. Furthermore, the split of the data into the average of periods 1 to 12 and 13 to 24 indicates a decline in punishment as suggested by Figure 4-5.

Table 4-3: Overview of average punishment points per period

	Average punishment over all periods and groups		
	1 to 25	1 to 12	13 to 24
2R1PPun Group	3.98	4.58	3.25
2R1PPun T8	1.5	1.71	1.24
2R1PPun T26	1.24	1.44	1
2R1PPun T8ToT26	1.5	1.71	1.24
2R1PPun T26ToT8	1.54	1.71	1.34
2R1PPun T26ToT26	0.95	1.16	0.67
1R2PPun Group	3.39	3.94	2.69
1R2PPun T17	1.31	1.44	1.10
1R2PPun T26	0.76	1.07	0.48
1R2PPun T17ToT26	1.69	1.68	1.65
1R2PPun T26ToT17	0.76	1.07	0.48
1R2PPun T17ToT17	0.94	1.2	0.56

To analyze the allocation of punishment points over the course of the game, we use the previously introduced grouped periods 1-12 and 13-24. Period 25 is excluded due to its remarkable increase in punishment that appears to be a clear break in the trend. Both in1R2PPun and 2R1PPun, we observe a significant decrease in punishment from the first to the second half ($p = 0.034$) and ($p = 0.0577$), respectively. The comparison of phase 12-24 and period 25 shows only for 2R1PPun a significant increase of punishment in the last period ($p = 0.0775$). On the type level, we cannot find significantly different punishment behavior between phases 1-12 and 13-24 for T8 in 2R1PPun ($p = 0.3273$). It is worth mentioning, that the average punishment for this player type exhibits large spikes in punishment activity in periods 4 to 6 and 14 to 16, while appearing to be balanced in the rest of the periods. For T17 in 1R2PPun ($p = 0.0437$) as well as for T26 in both treatments (2R1PPun ($p = 0.0292$) and 1R2PPun ($p = 0.0309$)) punishment is significantly lower in the second half of the game. The observed increase of punishment in the last period for 2R1PPun is on the type level not observable.

The direct comparison of player types shows for 2R1PPun that both types punish in total over all rounds as well as in terms of frequency equally much. For the 1R2PPun treatment we find higher punishment for T17. This is valid for the full game as well as for phase 1-12 and 13-24. This reflects the average behavior observed in Figure 4-6.

To complement the non-parametric tests, Table 4-4 presents Tobit regressions on the punishment level chosen. The two separate regressions in (1) (2R1PPun) and (3) (1R2PPun) show fairly similar results. The main driving factor for punishment seems to be the difference between the punisher's and the punished player's relative contribution to the public good ("Deviation from avg. Contri. Others (rel)").[28] For both treatments the time trend ("Period") is negative, but disrupted by a significant last-period increase (significantly positive coefficient of the "Last Period" dummy), as suggested in Figure 4-6 and the non-parametric results posted above. Furthermore, we observe in both treatments a positive effect of received punishment in the last period. A significantly positive coefficient here indicates some kind of retribution behavior. We will emphasize this question in chapter 4.4.5.

Result 4: *Punishment significantly decreases over the game. In the last period we observe an increase in punishment.*

We now focus on the punishment behavior by twin type players. The results are posted in Table 4-4, columns (2) and (4) for 2R1PPun and 1R2PPun, respectively. With our asymmetry in the number of type members, two + one, we implemented the potential to treat the same type (twin) in a different way than the single type, while minimizing the noise that might be created by more than one other player per type. This difference is reflected in the coefficients of "Deviation Single Type (rel)" and

[28] One might argue whether to use absolute or relative contributions. Since we find a significant effect of contributing more than the average share of the others, but no type effect ("Low Endowment Player" is a dummy variable equal to one in the case of a low-endowment player), it seems justified to base our argumentation on deviation of the relative contributions. At the same time, using the average of the others in absolute terms may lead to blurry results, since in 2R1PPun the average absolute contributions of T8 are significantly below those of T26, as shown in 4.4.2.

"Deviation Twin Type (rel)".[29] We observe a harsher punishment between the T26 players in 2R1PPun (if the punisher contributed a larger share of her endowment than the respective other group member) than the punishment allocated the T8 player. The difference in the punishment points given to a T8 or T26 recipient is almost significant at the ten percent level ($p = 0.109$). This finding might be driven by the lower endowment of the single type. High-endowment players might find a lower punishment level for the low-endowment player as effective as a higher punishment level for the high-endowment player. In 1R2PPun, we find the low-endowment players T17 to punish negative deviations from the own relative contributions by the high-endowment player T26 more severely than those by their twin types ($p = 0.038$). This is also reflected in the punishment frequency with 190 times for T26 versus 139 times for T17.

These findings indicate that in their punishment the twin high-endowment T26 players in rich majority focus more on each other than on the low-endowment player. This is plausible since the contribution of their twin is more payoff relevant and at the same time contributions can be directly compared at the absolute level. The low-endowment T17 players in poor majority, on the other hand, seem to team up against the high-endowment group member and try to force her contribution. Recalling the results in Section 4.4.2 above, this behavior is successful, since 1R2PPun not only achieves a higher group contribution than 1R2P, but also results in T17 and T26 contributing the same share of their endowment, in contrast to 1R2P where T17 contributed significantly more.

Result 5: *The twin-type player's behavior depends on whether they are in a low- or high-endowment situation. High-endowment twins respond stronger on low cooperation by their type, while low-endowment twins punish low contributions by the high endowment player stronger.*[30]

[29] The single (twin) player type is the low (high) endowment player in 2R1PPun and the high (low) endowment player in 1R2PPun.

[30] This result is in line with findings by Reuben and Riedl (2013), showing that low and high endowment players sanction so that the high endowment players contribute more in absolute terms than the low endowment players. This pushes group members in the direction of a fair-share contribution.

Table 4-4: Tobit panel regression of allocated punishment points. Columns (2) and (4) include only punishment by the twin-type players.

	2R1PPun	2R1PPun T26	1R2PPun	1R2PPun T17
	(1)	(2)	(3)	(4)
Period	$-.1879^{***}$	$-.0904^{**}$	$-.1315^{***}$	$-.0581^{**}$
	$(.0344)$	$(.0388)$	$(.0252)$	$(.0267)$
Last Period	4.216^{***}	2.0357^{*}	3.6683^{***}	3.4486^{***}
	(1.096)	(1.2319)	$(.7852)$	$(.8306)$
Low Endowment Player	-1.3972		$.9885$	
	(2.1037)		(1.3915)	
Total Pun. Received in $t-1$	$.2763^{***}$	$.0943$	$.3489^{***}$	$.3916^{***}$
	$(.086)$	$(.1001)$	$(.0766)$	$(.0917)$
Deviation from avg. Contri. Others (rel)	8.7039^{***}		4.2887^{***}	
	$(.9475)$		$(.6809)$	
Deviation Single Type (rel)		7.3215^{***}		6.6389^{***}
		(1.4394)		(1.0461)
Deviation Twin Type (rel)		10.7535^{***}		3.5772^{***}
		(1.4276)		$(.8434)$
Intercept	-3.5297^{***}	-5.2624^{***}	-2.7723^{**}	-3.449^{***}
	(1.3132)	(1.0845)	(1.1976)	$(.8507)$
DYRelSingleType = DYRelTwinType		$(p = 0.109)$		$(p = 0.038)$
sigma_u	6.7678^{***}	4.7152^{***}	4.2522^{***}	3.7861^{***}
	$(.9431)$	$(.814)$	$(.5757)$	$(.6317)$
sigma_e	5.0286^{***}	4.6232^{***}	3.7983^{***}	3.3693^{***}
	$(.2237)$	$(.251)$	$(.1654)$	$(.1651)$
rho	$.6443$	$.5099$	$.5562$	$.5581$
	$(.0632)$	$(.0855)$	$(.0664)$	$(.082)$
N	1296	864	1152	768

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

4.4.5 Anti-social punishment

So far we discussed the general effects of punishment. In this section we focus on distinguishing punishment into socially desirable and undesirable. The latter is subsumed as anti-social punishment and defined as, for example, "punishments of individuals who contribute more than the average of their peers. Anti-social punishments can be attributed to the anticipation by some free riders of the forthcoming punishment by cooperators and their willingness to retaliate these sanctions or the desire to avenge sanctions that took place in previous periods." (Nikiforakis (2008), pp. 102) On the basis of this definition, we classify a punishment action as anti-social if a player is punished even though she contributed relatively more or the same as the punisher. We include also punishment in the case of the equal relative contributions since in that case there is no reason to punish. Furthermore, based on our discussion on relative and absolute contributions in the previous chapters, we take that differences between the relative contributions are a good benchmark to distinguish anti-social from normal punishment.

Table 4-5 gives an overview on the frequency of punishment taking place, sorted by different categories. The main statement reflects in the notable amount of anti-social punishment allocated. Overall, between 26.12 percent (2R1PPun) and 28.41 percent (1R2PPun) of all punishment actions are considered as anti-social punishment. This is slightly above the values found by Nikiforakis (2008). Again, this difference may be explained by diverging opinions about the contribution norm due to the endowment asymmetry, which might not be captured by the selection rule we employ. Low endowment players might expect relatively higher contributions by high endowment players. The same, vice versa, is true from the high endowment player's perspective. Since low endowment players gain more from a high level of cooperation, their contributions could be expected to be higher. To compare the anti-social punishment and pro-social behavior, we first focus on the times a player type contributes relative more, equal or less than a player type and punishes.[31] In detail we compare punishment from low to high, high to low and between the twin type (T26 to T26 in 2R1PPun and T17 to T17 in 1R2PPun).

[31] We find a significant higher frequency for T8 to contribute relative more than T26 ($p = 0.0936$), as well as the T26 types between each other($p = 0.0103$). In 1R2PPun treatment we find no differences in the frequency of relatively higher contributions.

Table 4-5: Overview of the frequency of punishment actions per total times punishing occurred, as well as divided by the relative performance to the other player

	Total	Low endow.	High endow.	Low to high endow.	High to low endow.	Between same endow.
2R1PPun total times pun.	467	191	138	191	157	119
1R2PPun total times pun.	447	164.5	118	190	118	139
2R1PPun avg. times pun. of one player	4.32	5.31	3.83	5.31	4.36	3.31
1R2PPun avg. times pun. of one player	4.66	5.14	3.69	5.94	3.69	4.34
2R1PPun social pun. / total pun. freq.	345/467 73.88%	137/191 71.73%	208/276 75.36%	137/191 71.73%	114/157 72.61%	94/119 78.99%
1R2PPun social pun. / total pun. freq.	320/447 71.59%	246/329 74.77%	74/118 62.71%	149/190 78.42%	74/118 62.71%	97/139 69.78%
2R1PPun anti-social pun. / total pun. freq.	122/467 26.12%	54/191 28.27%	68/276 24.64%	54/191 28.27%	43/157 27.39%	25/119 21.01%
1R2PPun anti-social pun. / total pun. freq.	127/447 28.41%	83/329 25.23%	44/118 37.29%	41/190 21.58%	44/118 37.29%	42/139 30.22%
2R1PPun social pun. / rel. more contri	345/804 42.91%	137/405 33.83%	104/199.5 52.13%	137/405 33.83%	114/193 59.07%	94/206 45.63%
1R2PPun social pun. / rel. more contri	320/789 40.56%	123/278.5 44.17%	74/232 31.9%	149/349 42.69%	74/232 31.9%	97/208 46.63%
2R1PPun rel. equal and pun.	36/1092 3.3%	12/302 3.97%	12/395 3.04%	12/302 3.97%	13/302 4.3%	11/488 2.25%
1R2PPun rel. equal and pun.	14/822 1.7%	6.5/301.5 2.16%	1/219 0.46%	0/219 0%	1/219 0.46%	13/384 3.39%
2R1PPun rel. less and pun.	86/804 10.7%	42/193 21.76%	22/305.5 7.2%	42/193 21.76%	30/405 7.44%	14/206 6.8%
1R2PPun rel. less and pun	113/789 14.32%	35/220 15.91%	43/349 12.32%	41/232 17.67%	43/349 12.32%	29/208 13.94%
2R1PPun anti-social pun. / rel. equal and less contri.	122/1896 6.43%	54/495 11.00%	68/1401 4.85%	54/495 11.00%	43/707 6.08%	25/694 3.60%
1R2PPun anti-social pun. / rel. equal and less contri.	127/1611 7.88%	83/1043 7.96%	44/568 7.75%	41/451 10.00%	44/568 7.75%	42/592 7.09%

We start with the comparison of anti-social punishment for relatively the same or lower contributions. Afterwards we have a look at the general number of anti-social punishment. For equal relative contributions all players punish with same frequency in 2R1PPun. For 1R2PPun we find that T17 players use more often anti-social punishment against each other than against T26 ($p = 0.015$) or T26 against T17 ($p = 0.047$). This result has to be evaluated with caution, since 0 and 100 percent relative contributions are the only two values that can occur for both player types. In case of relatively lower contributions we find no differences in any comparison in the 1R2PPun treatment. For 2R1PPun the only significant differences is between punishment from T26 to T8 and T26 to T26. We find that T26 punishes T8 more often than the other T26 ($p = 0.0282$). A possible explanation is the frequency by which a T26 player is contributing relatively less. In the previous paragraph we showed that T8 contributes more often relatively more than T26. This situation delivers more opportunity to T26 to punish anti-socially. This means, if this result is only due to a higher frequency of lower contributions by T26 compared to T8, the punishment frequency in case of lower contributions divided by the total number of lower contributions should be the same for both types. In total we observe 405 times a relatively lower contribution by T26 than by T8. 30 of these observations took place in the same period as punishment by the low contributor. Between T26 players we observe 206 times relatively lower contributions, while 14 times punishment was applied. In the former case this implies a ratio of 0.074, in the latter case a ratio of 0.068. The observed difference seems to stem from the more frequently occurring low contributions of T26 compared to T8. The tests of the total number of anti-social punishment by types, results presented in Table 4-6, and between treatments, results presented in Table 4-7, show no significant differences.

Table 4-6: Wilcoxon-Signed-Rank test of anti-social punishment between types by treatment

Comparison of frequency of anti-social punishment	2R1PPun	1R2PPun
LowEndow = HighEndow	-0.177 (0.8598)	0.52 (0.6032)
LowToHigh = HighToLow	-0.045 (0.964)	0.262 (0.7935)
LowToHigh = SameToSame	0.513 (0.6081)	-0.052 (0.9582)
HightToLow = SameToSame	0.829 (0.4073)	-0.237 (0.8124)

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Table 4-7: Wilcoxon-Mann-Whitney U Test of anti-social punishment by type between treatments

Comparison of frequency of anti-social punishment	1R2PPun = 2R1PPun
LowEndow	0.68 (0.4963)
HighEndow	-0.329 (0.7423)
LowToHigh	0.561 (0.5751)
HighToLow	0.133 (0.8941)
SameToSame	1.011 (0.3118)

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Table 4-8: Effects of over and under contribution of the punishment target on punishment. Columns (2) and (4) include only punishment by the twin type players.

	2R1PPun		1R2PPun	
	(1)	(2)	(3)	(4)
Contributed rel. less than the punisher	8.0029^{***} (1.4362)	15.3018^{***} (3.5857)	5.9604^{***} (1.3962)	2.9115 (2.0577)
Contributed rel. less than the punisher and the same type		−2.8705 (4.5549)		7.7602^{**} (3.3784)
Contributed rel. more than the punisher	6.3763^{***} (2.0582)	−2.6176 (4.2305)	6.866^{***} (1.2747)	5.5641^{***} (1.9003)
Contributed rel. more than the punisher and same type		14.6241^{**} (6.3058)		5.0668 (3.2974)
Contributed rel. less than the avg. of group members	7.4884^{***} (1.7333)	−2.4347 (3.8251)	6.3088^{***} (1.4885)	10.3144^{***} (2.2546)
Contributed rel. less than the avg. of group members and the same type		14.2133^{***} (4.9154)		-9.881^{**} (3.8336)
Contributed rel. more than the avg. of group members	-13.6048^{***} (2.6376)	-7.6902^{*} (4.6306)	-8.3456^{***} (1.8854)	−5.1392 (3.3137)
Contributed rel. more than the avg. of group members and the same type		-20.1653^{**} (8.9433)		−7.1169 (5.0528)
Punishing the same type		-2.9217^{*} (1.6156)		.0176 (1.0341)
Social	.0907 (.2594)	.09946 (.2854)	.3186 (.2227)	.4731 (.3417)
Tense	$-.7157^{*}$ (.366)	−.4938 (.4427)	−.1662 (.2259)	.0081 (.2793)
Negative reciprocity	$.9277^{**}$ (.4642)	1.5492^{***} (.5522)	$.3998^{**}$ (.1869)	$.5504^{*}$ (.2936)
Intercept	-9.2501^{***} (.8089)	-8.0557^{***} (1.2775)	-5.8452^{***} (.4859)	-5.9124^{***} (.8096)
sigma_u	5.6414^{***} (.6251)	5.2969^{***} (.7529)	3.1939^{***} (.3387)	3.3789^{***} (.4418)
sigma_e	4.9149^{***} (.2209)	5.2503^{***} (.3173)	3.4277^{***} (.1452)	3.4436^{***} (.1722)
rho	.5685 (.0526)	.5044 (.0688)	.4647 (.0514)	.4905 (.0638)
N	2700	1800	2400	1600

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Table 4-9: Effects of over and under contribution of the punishment target on punishment. Columns (2) and (4) include only punishment by the twin type players. Only groups with less than 2/3 of the rounds full contribution.

	2R1PPun		1R2PPun	
	(1)	(2)	(3)	(4)
Contributed rel. less than the punisher	7.7915^{***} (1.4532)	15.6781^{***} (3.6485)	5.2707^{***} (1.2759)	2.1498 (1.7911)
Contributed rel. less than the punisher and the same type		−3.3524 (4.5565)		7.7591^{***} (2.945)
Contributed rel. more than the punisher	4.9328^{**} (2.1423)	−2.7251 (4.2064)	6.1648^{***} (1.1881)	4.6338^{***} (1.7175)
Contributed rel. more than the punisher and same type		12.5115^{**} (6.3168)		5.8307^{**} (2.9621)
Contributed rel. less than the avg. of group members	5.7758^{***} (1.7908)	−4.1649 (3.9761)	5.5672^{***} (1.3716)	9.1637^{***} (1.9568)
Contributed rel. less than the avg. of group members and the same type		11.7553^{**} (5.0724)		-10.3236^{***} (3.3916)
Contributed rel. more than the avg. of group members	-13.5413^{***} (2.6583)	-8.7187^{*} (4.6067)	-8.082^{***} (1.7312)	-5.1294^{*} (2.9495)
Contributed rel. more than the avg. of group members and the same type		-18.3662^{**} (8.7436)		−7.3109 (4.4851)
Punishing the same type		-3.2918^{**} (1.645)		−.3814 (.9563)
Social	−.2557 (.3281)	−.5405 (.345)	.332 (.2045)	.3811 (.2781)
Tense	−.571 (.3886)	.0177 (.4613)	.1597 (.2285)	.3339 (.2575)
Negative reciprocity	.691 (.517)	1.7087^{***} (.6278)	.1735 (.1935)	.4434 (.2718)
Intercept	-7.2914^{***} (.8476)	-5.2304^{***} (1.25)	-4.4432^{***} (.4538)	-3.8828^{***} (.7133)
sigma_u	5.4422^{***} (.644)	4.4121^{***} (.6918)	2.7923^{***} (.3124)	2.7075^{***} (.37)
sigma_e	4.9295^{***} (.228)	5.2521^{***} (.3253)	3.1583^{***} (.1358)	3.0187^{***} (.1508)
rho	.5493 (.0569)	.4137 (.0746)	.4387 (.0544)	.4458 (.0668)
N	1950	1300	1800	1200

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

In order to focus on potential dynamics in the data that could not be captured in the above describe non-parametric tests we present in Table 4-8 the results of Tobit regressions based on the approach by Masclet et al. (2003), investigating the effects of differences in relative contributions between the punisher and her target on punishment. Columns (1) and (3) include the data from all player types.

The results confirm our previous findings in Table 4-4 and are similar for both treatments. Players that contribute less than the average of the other group members, as well as the punisher, get punished significantly more. The effects on group members outperforming the punisher or the group average, we find mixed results. On a bilateral level we find still significant and positive punishment taking place. This is in support of Hypothesis 4. In contrast, a contribution above the average lowers the punishment significantly. The coefficients in the first row are significant and positive, indicating that relatively lower contributions by group members are punished. The finding of punishment against cooperators is in line with earlier findings by Masclet et al. (2003) and Fehr and Gächter (2000). Additionally we use characteristics derived from a principal component analysis of our ex-post questionnaire. Detailed information about the composition of the factors can be found in Appendix B, in Table 4-12. The factors are labeled: "social", "tense" and "negative reciprocity". We find that "negative reciprocity" increases the punishment for all four regressions, while "tense" only seems to have a punishment reducing effect in 2R1PPun. Columns (2) and (4) focus exclusively on the punishment behavior by the twin type players. The results for T26 in column (2) indicates that in general the other T26 is punished less than T8. This is in line with one of our non-parametric results. In the case of higher contributions by the punisher, we find a significant positive effect on punishment. Whether the target is a low or high endowment player seems to be irrelevant. Deviations from the average relative contributions lead only for the other T26 to an increase in punishment. Anti-social punishment is only significant between T26 players on the bilateral level. This holds as long as the punished player does not contribute at the same time more than the group average. The effect for the latter case shows a significantly negative coefficient of similar magnitude. The results for T17 players in column (4) display that the dummy for punishing the same type has no effect. Underperformance on the bilateral level is only punished between T17 players. On the other hand, deviations of T17 from the group average have a significantly negative effect. Therefore underperforming on the bilateral level, while outperforming on the group level avoids punishment. T26 is punished if her contributions to the public good are equivalent to free riding on both poor. Again, we find significant punishment of players contributing relatively more than the punisher. The effect shows no differences between the target's types. Positive deviations from the average of the group members have no effects.

The estimates of the punishment coefficients in Table 4-8 include all groups. To avoid potential distorting effects of groups with full contributions on our punishment analysis, we reduce the number of groups as in Section 4.4.2. This is done because groups with full cooperation are expected to punish less over the course of the game.[32] The results are displayed in Table 4-9. Qualitatively the results for

[32] Reuben and Riedl (2013) exclude groups with very high cooperation levels to avoid potential distortions on the analysis of the punishment behavior.

columns (1) to (3) stay unchanged. The major difference arises in column (4), focusing on the low endowment players in 1R2PPun. The bilateral punishment for the peer is now significantly higher than for the high endowment player. This indicates that also low endowment players use higher anti-social punishment against same player type, similar to T26 in 2R1PPun. The second difference shows a negative coefficient for anti-social punishment for players contributing more than the average of the other group members. This way the positive anti-social punishment from the bilateral level and the negative anti-social punishment from the group comparison might cancel each other out. The interaction term for the same type indicated an even stronger negative effect for the other T17, but just misses the ten percent level ($p = 0.104$). The effect of "negative reciprocity" becomes insignificant in all columns besides (2).[33] The focus on groups without full contribution indicates that anti-social punishment is preferably used against the same type, at the same time contributing more than the average tends to nullify the effect.

Table 4-10: Times of anti-social punishment if the player got punished in the previous period

	LowToHigh	HighToLow	SameToSame	Total
2R1PPun after not being punished	7	26	12	45
2R1PPun after being punished	47	17	13	77
2R1PPun Revenge	18	3.5	3.5	25
1R2PPun after not being punished	15	23	17	55
1R2PPun after being punished	26	24	25	75
1R2PPun Revenge	8.5	8	8.5	25

The twin type players show for revenge to the other and the same type the same entry. This is due to the fact that revenge action cannot distinguish between player types.

To conclude this hypothesis we have a look at anti-social punishment and its link to previously received punishment. Table 4-10 gives an overview of anti-social punishment frequencies for both treatments and conditions. The numbers are sorted by punishment between and within the types. For 2R1PPun we see that the entries are very similar. The anti-social punishment by T8 after being punished is a clear exception and is very high compared to the rest of the observations. This result is mostly driven by two groups in which anti-social punishment is only used by T8. In numbers those two groups account for 61.7 percent (12 and 17 times) of those in total 47 observations and are characterized by high cooperation levels of on average 50.8 and 51.28 points to the public good. Both T26 players are high contributors in those groups with an average of approximately 95 percent and 92 percent group

[33] The p-value for "negative reciprocity in column (4) is 0.103.

contribution, while T8 contributes on average 17.0 percent and 45.5 percent. These situations lead to severe punishment against T8 with an average contribution of 17 percent and in response to anti-social punishment. In the second case the punishment is not as intense as in the first case but the likely cause of the observed level of anti-social punishment. In the 1R2PPun treatment both player types seem to act similar. Using the Wilcoxon-Signed-Rank test we find almost no significant differences in any treatment between the types as well as between both setups. Only for the comparison of the anti-social punishment of T8 after not being punished is significantly smaller ($p = 0.0483$) than after being punished. This is little surprising considered Table 4-10.

In addition we consider anti-social punishment as revenge, if a player uses anti-social punishment on both group members. Since a player is mostly unable to determine whether punishment was committed by one or both team members, it is necessary to punish both in order to be certain to take revenge on the right player. Therefore we speak of revenge if both group members are subject to the same amount of anti-social punishment. From Table 4-10 we see that those cases are fairly even spread between both types in 1R2PPun. This is also confirmed by our tests indicating no differences. For 2R1PPun it appears that revenge behavior may be more frequently used by T8, but we cannot find significant difference either.

Result 6: *Anti-social punishment is committed by all player types. We find indications that anti-social punishment is mostly based on direct comparison of the punisher with the punished. Especially T26 players show increased anti-social punishment against each other.*

4.5 Conclusion

The focus of our analysis is on the punishment behavior in groups with asymmetric player types. We use a linear public good experiment. In a 2x2 design we vary endowment distributions or the possibility to punish. The endowments are designed to create so the members of one player type outnumber the other. Additionally, in the punishment treatments, group members are given the opportunity to punish after they learned about the group members individual investments. This gives us the opportunity to analyze behavioral differences of within and between type punishments.

We find a contribution increasing effect of punishment. Contributions in all treatments tend towards a "fair-share" norm. This is in accordance with the existing literature. The results show, that contributions start in all treatments at similar levels, but groups without punishment display a downward trend. Groups with punishment, on the other hand, maintain their initial contribution level and therefore outperform no-punishment groups. At the same time we observe the typical end-game behavior. Especially in the last period group contributions break down. In terms of profits we cannot find any significant differences between punishment and no-punishment groups. Analog to the contributions, groups without punishment show the typical downward trend, while punishment groups tend to increase their profits over the course of the game. This effect is mostly driven by decreasing expenditures on punishment. At this point the existing literature diverges. While some paper find significant increases in profits, in accordance with increasing contributions, other studies, including ours, find no significant effects. This result is partially driven by the high expenditures of punishment, where one punishment point means a total cost of 5 to group earning. Towards the end of the game we find indications that the punishment treatments outperform the no-punishment treatments. Gächter et al. (2008) find support for a positive long run effect of punishment on profits.

The main contribution of this paper is on the punishment behavior of players of a type in a minority or majority role in the group. In line with previous studies punishment is mostly allocated based on lower contributions by the other group members. Players compare their group members' contributions both directly with their own contributions, but also compared to the groups average contribution. In general, lower contributions are punished and no player type is excluded from punishment, but we find indications that the high endowment player type is target of more punishment by twin player types. In the case of two T26 players punishment against the other T26 is harder than against the single T8. The same is true in 1R2PPun. T17 players punish the single T26 harder than each other. Furthermore, in a more detailed analysis of the twin type players, we show that in 2R1PPun T26 punishment against the same type is harder if the punished player contributes less than the group average. For T8 only the direct comparison of relative contributions is relevant. In 1R2PPun the same is true. T17 punishes the other T17 based on the direct comparison, while the high endowment player is mostly punished based on her under contribution compared to the group average. We also observe anti-social punishment. In the case of the twin type players it appears to be based on direct comparison and directed at the same type. The focus of future research should be put on the punishment mechanism. The uncoordinated allocation of punishment bares costs to the group that needs to be avoided to achieve a clear profit enhancement. In this context the reduction or complete prevention of anti-social punishment should be an additional target.

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4.7 Appendix A: Introduction for 2R1PPun

You participate in an economic decision experiment, in which you can earn money. How much each of you will earn depends on your personal decisions and those of other participants in the experiment. Each participant makes his decisions at a computer, isolated from the others.

The experiment consists of **25 rounds**. In the beginning of the experiment you will be randomly matched with **two** other persons to build a group of **three**. You will remain in this group during the entire experiment. You will not know the identity of your group members, though.

Each group member is endowed **in each round** with a certain amount of tokens. Player 1 is endowed with **8** tokens per round. Players 2 and 3 are endowed with an amount of **26** tokens each. The individual player numbers (and thus the individual endowments) will be randomly assigned and announced at the beginning of the experiment.

Group member	Endowment (# tokens)
Player 1	8
Player 2	26
Player 3	26

Decisions

In each of the 25 rounds, all group members make their decisions simultaneously, though independently from each other. Each of the 25 rounds consists of two decision stages.

In **Stage 1**, each group member has to decide on how to allocate his tokens between two alternatives, called X und Y. The return of a token, in experimental currency units (ECU), is different for the two alternatives. The return of the allocation decision is determined as follows:

Each token that you contribute to X yields a return of **2 ECU**. If you contribute nothing to X, your return from X is zero.

Each token that you contribute to Y, yields to you and to each of the other group members a return of **1 ECU**. You may thus have a positive return from Y even if you yourself don’t contribute anything to Y.

You may allocate your tokens to X or to Y only, but you may also allocate them among both alternatives. However, only entire tokens may be contributed. In the decision box on your screen you need to enter, for each alternative, the number of tokens that you want to allocate. If you do not want to contribute anything to X or Y, you need to type in a zero. The sum of the tokens contributed to X and Y must be always equal to your endowment of tokens. This means that the entire token endowment has to be allocated among X and Y. With the <Tab> key you can switch among the entry fields. The entries have to be confirmed by clicking on <OK>.

Your individual return in the first stage of a round is the sum of your returns from X and Y and is calculated as follows:

Return = 2 × (your contribution to X) + (sum of tokens contributed to Y in your group).

In the beginning of Stage 2, each group member is informed of the results of Stage 1. This information includes your contribution to X, your contribution to Y, the contributions to Y of each of the other group members, your return from X, your return from Y and your total return in this round.

With this information, you are given in Stage 2 the opportunity to punish, and thus reduce the Stage 1 return, of any of the two other players in your group. To do this, we ask you to allocate penalty points. We ask you to decide for each other player, if you want to punish this player and if yes, how many penalty points you want to allocate to this player. If you don't want to punish a player, you need to type zero. If you want to punish a player, you may, for each player, choose a number of one, two, three… or a maximum of eight penalty points. Only integer numbers may be chosen.

Each penalty point that you allocate to any of the other players cost you 1 ECU and thus reduces your own return from Stage 1 by punishment costs of 1 ECU.

In total, your punishment costs may not exceed your Stage 1 return of the current round.

The return of the other player will be reduced by <u>four</u> times the number of penalty points that you allocate to this player. Their penalty costs per penalty point received are thus 4 ECU.

In Stage 2 likewise all players in the group make simultaneous decisions. Please note that you yourself might receive penalty points from other group members.

At the end of Stage 2 you will be informed of the total number of penalty points allocated to you. You will not know how many points each individual group member allocated to you.

Your individual profit in ECU at the end of each round will be determined by your Stage 1 return minus your punishment costs and minus the penalty costs imposed on you by others in Stage 2 of the round:

Profit = Stage 1 return – (sum of penalty points that you allocate to others)

– 4 × (sum of penalty points that you receive from others)

Payment

At the end of the experiment, you will be paid based on your individual total profit over all **25 rounds**. Your individual total profit in ECU will be converted into € (1ECU=0.01€) and paid to you in cash. You are paid at the end of the experiment. The payment is carried out individually and anonymously.

Available Information

In each round, you will see an overview table on your screen which provides you with the results of all previous rounds that you have played. The results include the following information for each round:

your return from X, your return from Y, your return in stage 1, your punishment costs (1x penalty points allocated), the penalty costs imposed on you by others (4 x penalty points received), your profit, your total profit, your contribution to Y, the penalty points received by you, the individual contributions to Y of each of the other group members and the penalty points allocated by you to the respective group member.

If you want to see the results of earlier rounds, which are no longer visible in the table, please use the scroll function on the right side of the table.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. You then will be given on your screen a number of questions regarding these instructions. If you have any questions please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

4.8 Appendix B: Ex-post questions

Table 4-11: Overview of ex-post questions and variable names (scaled 1 to 7)

Question	Variable name
I see myself as someone who work thorough.	Thorough
I see myself as someone who is communicative.	Communicative
I see myself as someone who can sometimes be rude to others.	Occasionally impolite
I see myself as someone who is inventive, has new ideas.	Inventive
I see myself as someone who often worries.	Worried
I see myself as someone who is conciliatory.	Conciliatory
I see myself as someone who tends to be lazy.	Lazy
I see myself as someone who is outgoing, sociable.	Sociable
I see myself as someone who is artistically minded.	Artistic
I see myself as someone who gets easily nervous.	Easy to irritate
I see myself as someone who proceeds efficient and effective.	Efficient
I see myself as someone who is cautious.	Reserved
I see myself as someone who is attentive and nice to others.	Thoughtful/kind
I see myself as someone who is imaginative.	Imaginative
I see myself as someone who is relaxed, can handle stress.	Relaxed
If someone does me a favor, I am most likely to return it.	Return favor
If I suffer from great injustice, I will take revenge at any cost and at the first occasion.	Injustice revenge
If someone puts me in a difficult position, I will do the same to her.	Caused difficulties returned
I am particularly committed to help people who helped me in the past.	Motivated help return
If someone insults me, I will be insulting toward this person.	Insult return
I am ready to incur cost in order to help someone who helped me in the past.	Costly help return
If someone hurts me emotionally, I overcome it rather easily.	Easy emotional healing
If someone has done me wrong, I do think about it for a long time.	Experienced injustice reflection
I tend to be resentful.	Resentful
When someone does me wrong, I try to forgive and forget.	Injustice forgiving
I have a positive opinion of myself.	Positive self-esteem

Table 4-12: Factor loadings of the principal component analysis

Variables	Factor 1 *Social*	Factor 2 *tense*	Factor 3 *negative reciprocity*
Thorough			
Communicative	0.317		
Occasionally impolite			
Inventive	0.3137		
Worried		0.3925	
Conciliatory			
Lazy			
Sociable	0.3165		
Artistic			
Easy to irritate		0.388	
Efficient			
Reserved			
Thoughtful/kind	0.3518		
Imaginative			
Relaxed		-0.3841	
Return favor			
Injustice revenge			0.437
Caused difficulties returned			0.4496
Motivated help return	0.3191		
Insult return			0.3604
Costly help return			
Easy emotional healing		-0.3374	
Experienced injustice reflection		0.3982	
Resentful			0.324
Injustice forgiving			
Positive self-esteem		-0.3132	
Proportion explained	0.179	0.1221	0.1196

Only components larger than 0.3 are displayed.

5. Absolute is the easier Fair-Share

with Claudia Keser and Jörn Kroll

Abstract: In our study we focus on the impact of inequality in the context of a potential fair-share norm. We use a linear public good game and implement an additional stage where participants are asked to choose between two presentation methods for their investment decision, either in absolute values or as shares of the individual's endowment. Inequalities are induced by endowment differences between the subjects. The focus is on two player groups with either symmetric, weakly asymmetric or strongly asymmetric endowments. We find that the majority of participants prefer to contribute in absolute terms, while contributions, in general, roughly reflect a fair-share behavior. Latter effect seems to be driven by groups which most of the rounds fully cooperate or defect. Whether the participants chose the absolute or relative interface has no effect on the contribution level. Furthermore, the players in the symmetric treatment choose significantly more often the absolute mechanism relative to both other two player treatments.

JEL classification: C92; D63; H41

Keywords: Experimental economics; public goods; heterogeneous endowments; norms

5.1 Introduction

The provision of public goods has attracted the interest of experimental economists since more than 30 years (see e.g. Ledyard (1995) for a review of this early work). The surprising discovery shows that people are willing to contribute to the public good although the game theoretical analysis of a rational player would predict no contribution at all.

In the last years the research focus shifted to the provision of a public good by players who face heterogeneity in income and possible heterogeneity effects on the contribution to the public good.

The documentation of such an effect is however mixed. Some studies find a negative influence of endowment heterogeneity on the contribution (e.g. Cherry et al. (2005), Cardenas and Carpenter (2008), Cardenas (2003)) others in contrast do not find any significant influence (e.g. Hofmeyr et al. (2007), Sadrieh and Verbon (2006) and Keser et al. (2014).

On the individual level in the presence of an inequality in endowments the contribution behavior seems different to experiments with homogenous players. A few studies report that the lower endowed player contributes a bigger share of his endowment than the richer player (e.g. Cherry et al. (2005), Buckley and Croson (2006), Reuben and Riedl (2013)) whereas Hofmeyr et al. (2007) could not reproduce such findings. They find that the contribution follows a "fair-share"- rule, i.e. every player contributes the same share of his endowment. Keser et al. (2014) gives support to both observations depending on the degree on inequality.

The implication of such a fair share rule is in contrast to findings of previous studies in the field of psychology. Multiple studies (see e.g. Kruger and Vargas (2008), Mix et al. (1999), Chen and Rao (2007), Parker and Leinhart (1995) and more references therein) have shown that people struggle when it comes to working with percentages.

Therefore we study public good provision under an income inequality with special focus on the question whether people use a method which allows an easy calculation of percentages, and how this influences the contribution behavior, especially in terms of a fair share rule.

Our experiment is a linear VCM-game with three treatments each played by two person groups. The first treatment is a baseline treatment with a symmetric endowment structure, the second treatment covers a weakly inequality in endowments while our third treatments covers a situation which has been nearly unstudied in the literature. So far Keser et al. (2014) is – to the best of our knowledge –

the only one with such a scenario. Here the inequality is so strong, that the rich player does not benefit in the social optimum, i.e. there is no classical social dilemma.

Within our experiment we study groups of two to better understand the processes at work in a direct confrontation between low and high endowment players.

The public good literature finds to varying degrees a “fair-share” rule for contributions in asymmetric groups. Previous studies e.g. by Keser et al. (2014) found that a “fair-share” rule is as long as asymmetries are not too big. In those previous studies, contributions were done in absolute terms. The concept of a contributing a “fair share” is in its concept very intuitive, but becomes more complicated as soon as a situation becomes asymmetric. We assume that giving participants the possibility to choose the contribution method reduces their computation costs for the “fair share” and will lead to more cooperation.

Apart from the potential increase in cooperation we want to focus on possible reasons for participants to change between contribution methods. We assume groups where everybody contributes the same absolute amount will choose more often the absolute contribution norm, while groups that target everybody to contribute the same share of their endowment to choose more often the relative contribution method.

*The rest of the paper is structured as follows: Section 5.2 describes the ex*perimental design, Section 5.3 reviews the experimental results and Section 5.4 concludes.

5.2 Experimental Design

5.2.1 Treatments

To tackle our question we conducted a series of standard voluntary contribution mechanism experiments, where players have the choice to invest in option X, the private good, or option Y the public good. We use a four and a two player framework. In the four players treatment we distinguish three player types (low, middle and high), where as in the two players case two player types (low and high). The endowments of the types and the according treatments are given in Table 5-1. In treatment 2Strong we chose the high endowment to be high enough to render the social optimum uninteresting for the high endowment player.

Players in the four players treatment have the choice to invest in X and receive a return twice as high as their investment or invest in Y and everybody in the group receives exactly what the player invested. This translates into a MPCR (marginal per capita return) of 0.5. The two players treatments yield a return of 1 from X and a return of 2/3 for all group members from Y. In both treatments the individual profit maximizer invests everything to X, which is equivalent to a MPCR of 2/3. We employ two different MPCRs to account for the different group sizes.

Table 5-1: Treatment Overview

Treatment	Endowment			# Observations
	Low	Mid	High	
4Weak	10	15	20	15
2Sym	30		30	21
2Weak	24		36	19
2Strong	10		50	20

The experiments were programmed and conducted with zTree (Fischbacher (2007)). At total of 180 students participated in this experiment and all were recruited using the ORSEE (Greiner (2004)) software to ensure nobody was familiar with VCM experiments. The instructions were read aloud and their understanding checked in an instruction questionnaire.

At the end of the experiment the earnings were paid to the students privately and in cash. The payoff was approximately 14€ for a session lasting about 75 minutes.

All players had to reach two decisions per round. First, all group members had to decide on their contribution method, whether to contribute in absolute or relative terms. In the second stage the players had been asked to split their endowment between the public and the private good. If a player chooses absolute contributions, the allocation is done in numbers between zero and their endowment. In case the player decides to contribute in relative terms, the contribution stage will allow to contribute everything between 0 percent and 100 percent of the endowment. Furthermore players receive at the end of each round an overview with the contributions by all players in absolute and relative terms. During all stages a history table is displayed, including the on past choices of absolute and relative, all group members contributions in relative and absolute terms as well as own payoffs.

5.2.2 Predictions

Based on the VCM and public good literature we expect positive contributions, declining over the course of the game, rather than the game theoretical solution of zero contributions to the public good (pure free riding). In addition we expect the following observations:

Hypothesis 1: *In treatments 4Weak and 2Weak players choose more often to contribute in relative terms. 2Strong leads to more choices of the absolute contribution scheme. In 2Sym all players choose the absolute contribution scheme, due to its lower cognitive complexity.*

Hypothesis 2: *Players contribute all treatments with no or weak asymmetry the same share of their endowment (fair-share rule). In 2Strong, the players tend to contribute absolute the same.*

5.3 Results

5.3.1 Choice of contribution method

First, we want to investigate whether the choice of the method suggests fair-share thinking. Figure 5-1 shows by treatment the frequency of relative and absolute contributions. We assume treatments with a weak asymmetry, like 4Weak and 2Weak to exhibit more choices of the relative contribution scheme then 2Strong. This is based on previous observations that under weak asymmetry players tend to contribute all the same in relative terms of their endowment. Once the endowment differences become too large, so the rich player is not interested in the public good anymore, the observed behavior changes from "relative the same" to "absolute the same".

However, we find that between 64 percent (2Strong) and 86 percent (2Sym) of all choices have been "absolute". This contradicts the expectation that players, preferring a fair-share contribution would choose relative contribution method. Despite our expectations this is in line with findings in the psychology literature discussed under 5.1, indicating that people prefer to decide in absolute terms, due to its lower complexity. We find in the symmetric treatment the most frequent choice of the absolute method. At the same time players in 2Strong exhibit the lowest frequency of the absolute method. This is in contrast to our expectations based on the findings in Keser et al. (2014) where high endowment asymmetry leads to the same absolute contributions by all players. We use the Wilcoxon-Mann-Whitney U test (U test) to compare the frequency of absolute contributions between the two player treatments. The results are posted in Table 5-11, the columns "# rel.". We find the symmetric treatment to have significantly more absolute contributions than 2Weak ($p = 0.0364$) and 2Strong ($p = 0.0025$). Between the asymmetric treatments we find no differences ($p = 0.3249$). Comparisons on the type level show no significant differences for any treatment and player type. The results are reported in Table 5-2.

Furthermore we are also interested in how often players tend to change between the contribution methods. Figure 5-7 gives an overview for all types and treatments. The figures indicate no differences between the treatments, which is supported by the U test conducted between the two player treatments. This is true on the group and type level. The test statistic is displayed in Table 5-11. Within the two players treatments we find again no differences between the types, using the Wilcoxon-Signed-Rank test. The only difference in 4Weak is between the low and high endowment types with the low endowment players switching significantly less often ($p = 0.0818$). Given the fact that contributions by this type are between 0 and 10, this is not to surprising given the simple translation between absolute and relative values. Results are reported in Table 5-2.

Figure 5-1: Share of absolute and relative contributions by treatment

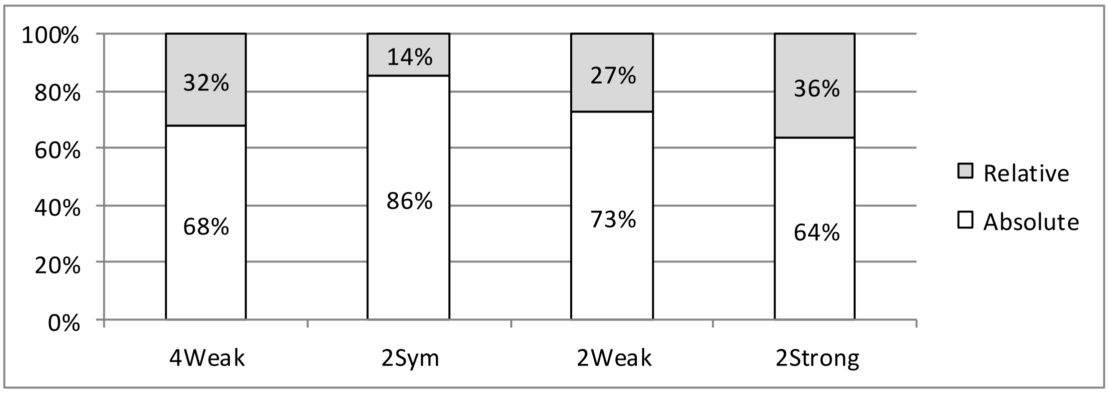


Figure 5-2: Average times the contribution method is changed by type and treatment

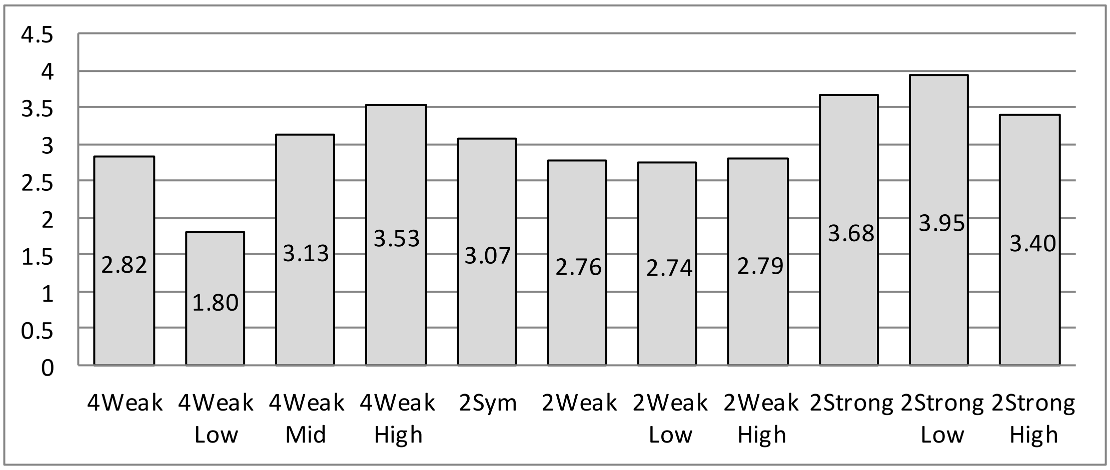
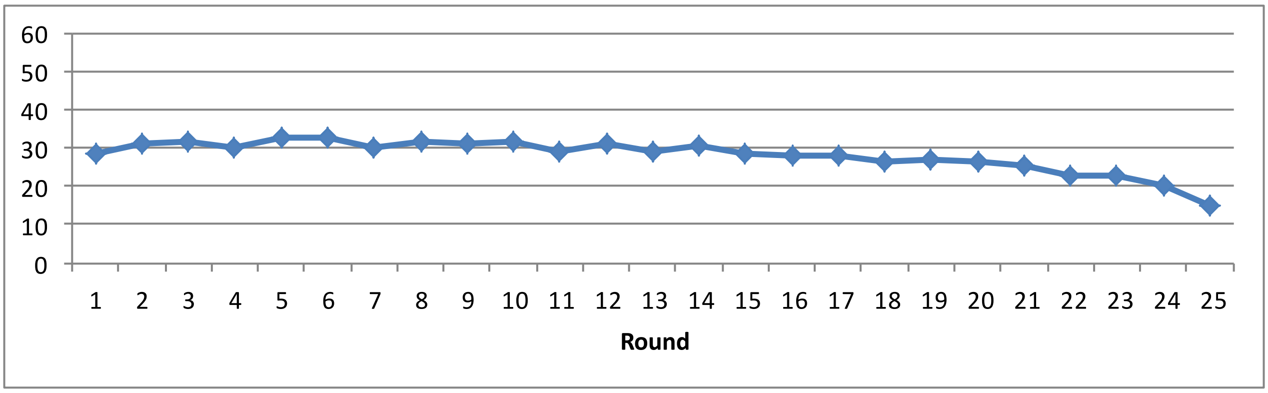


Table 5-2: Wilcoxon Signed Rank Test of frequency of absolute method chosen between types

	Low = Mid		Low = High		Mid = High	
	Freq.	# Change	Freq.	# Change	Freq.	# Change
4Weak	−0.881 (0.3784)	−1.112 (0.2662)	−0.512 (0.6085)	−1.740* (0.0818)	0.114 (0.9095)	−0.711 (0.4769)
2Sym						
2Weak			−0.423 (0.6722)	0.040 (0.9678)		
2Strong			−0.655 (0.5123)	0.586 (0.5578)		

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Figure 5-3: Group contribution to the public good in 4Weak



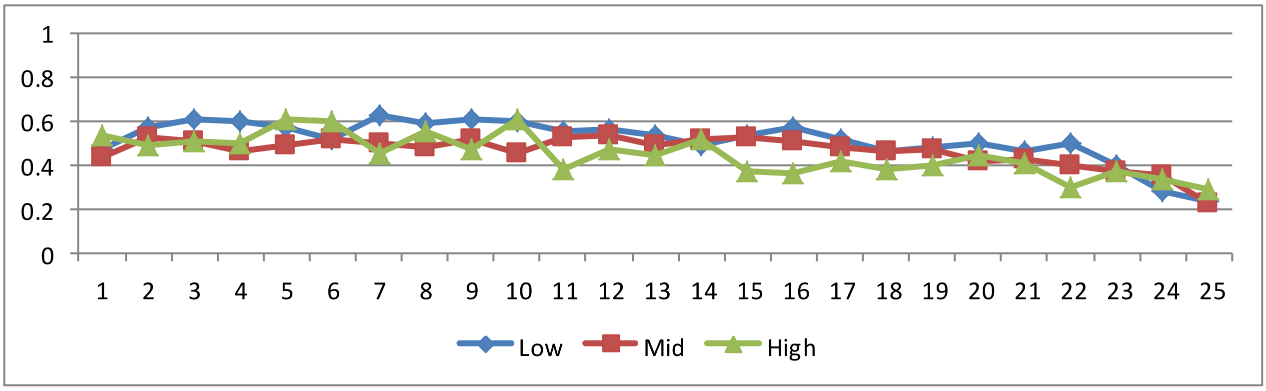
5.3.2 Contributions in the four player treatment

After the surprising results from 5.3.1 we now turn to the contribution behavior in the treatments. We start in this subchapter with the 4 player treatment. Although we did not find significant differences in the choice of "absolute" between the asymmetric treatments, contribution behavior of single players might still be influenced by their choice. Figure 5-3 depicts the average group contribution. The chart displays the typical downward trend of a public good game. The group contribution starts at approximatively 50 percent of the theoretical maximum and decreases over the course of the game. Table 5-3 gives additional descriptive statistics on the group and type level. It shows the high endowment players contribute absolute more. The contributions as share of the endowment show mixed results. Here the contribution levels seem to be quit equal, with the low endowment player tending to contribute slightly more to the public good. The type level contributions are displayed in Figure 5-4.

Table 5-3: Absolute (relative) contribution to the public good in 4Weak

Treatment		Type level			Group level contributions
		Low	Mid	High	
4Weak	1st Period	4.7393 (0.4739)	6.5365 (0.4358)	10.8286 (0.5414)	28.6409 (0.4773)
	25 periods average	5.1592 (0.5159)	6.9915 (0.4661)	9.0199 (0.451)	28.1621 (0.4694)

Figure 5-4: Contributions to the public good by type in 4Weak



To test our assumptions statistically we ran Tobit regressions, to test for potential influences of time (Period), contribution method (ContriByAbs), lagged average contributions by the other group members (L.AvgContriOthers) and type effects (MidType and HighType). We use the aforementioned parameters in model (1) to analyze the effects of on (absolute) contributions and in model (2) for the effects relative contributions.

$$y_i = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot \frac{1}{3} \cdot \sum_{j \neq i} y_j + \beta_4 \cdot \text{Type}_{\text{Mid}} + \beta_5 \cdot \text{Type}_{\text{High}} + \epsilon \qquad (1)$$

$$\frac{y_i}{e_i} = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot \frac{1}{3} \cdot \sum_{j \neq i} \frac{y_j}{e_j} + \beta_4 \cdot \text{Type}_{\text{Mid}} + \beta_5 \cdot \text{Type}_{\text{High}} + \epsilon \qquad (2)$$

The results are presented in Table 5-4. Column (1) presents the results for equation (1) and column (2) for equation (2). We find a negative time trend, supporting the previous findings of the public good literature. The same holds true for our reciprocity parameter. We find a positive effect of higher contributions by the other group members on the own contribution level. Indicating players willingness to increase contributions if the own contribution is below the group level and reducing contributions if above group level. In addition, we find no significant effect of our newly implemented decision on the relative or absolute contribution method. This rules out any effect based on the representation of contribution methods.[34] However, we find a significant type effect. Low endowment players contribute significantly less than the other group member, in absolute terms. This is in contrast to our findings in column (2), where we do not find any significant differences between the player types. This supports our Hypothesis 1. The other coefficients show qualitatively the same effects as in column (1). Replicating the effects of previous studies, we find support for a fair-share rule as in e.g. Hofmeyr et al. (2007) and Keser et al. (2014).[35]

$$\frac{y_{i,t} - y_{i,t-1}}{e_i} = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot max\left(0; y_i - \frac{1}{3} \cdot \sum_{j \neq i} y_j\right) + \beta_4 \cdot max\left(0; \frac{1}{3} \cdot \sum_{j \neq i} y_j - y_i\right) + \epsilon \quad (3)$$

To focus on potential reciprocal behavior we use a panel regression with fixed effects. The model is represented by equation (3) and depicts the change in relative contributions between the rounds. In contrast to models (1) and (2) we include the difference in contributions between a player and the remaining group member's average relative contribution in the last round, which is considered by "Contri. more than other (lagged)" for players contributing more than the average and "Contri. less than other (lagged)" for players contributing less than the average. We find the reciprocity observed as in e.g. Keser and van Winden (2000), where relative over contribution in the last period leads to a reduction in the present period and vice versa.

[34] In an additional test, which is not presented in this paper, we compared the group contributions between a basic version of our 4Weak treatment, where contributions were allocated by typing the integer numbers for the investments to the private and the public good. We find no significant differences. An overview and test results can be found in Table 5-9.

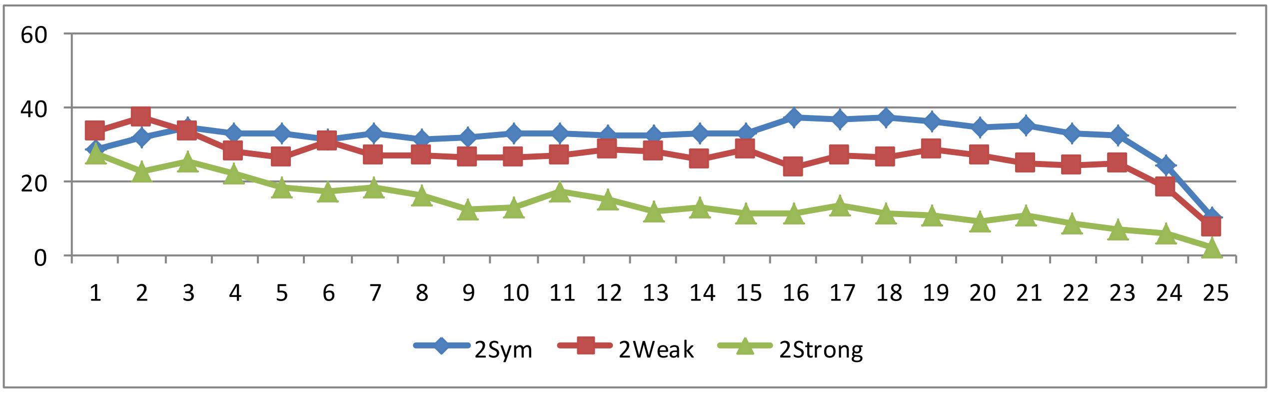
[35] In two additional regressions Tobit regressions we only included groups which perform in less than 2/3 of the rounds in the social optimum or Nash equilibrium. Two high contribution groups were excluded, based on this rule. The results for equation (1) only change for type Mid, which becomes insignificant. The regression results for the equation (2) stay qualitatively unchanged.

Table 5-4: Tobit regression of absolute and relative contributions, as well as the change in relative contributions

	(1) Abs	(2) Rel	(3) Diff. Rel
Period	$-.1166^{***}$	$-.0084^{***}$	$-.0026^{***}$
	(.0169)	(.0015)	(.0009)
ContriByAbs	$-.0536$	.0119	.0044
	(.3919)	(.0345)	(.0221)
L.AvgContriOthers	$.5003^{***}$	$.6858^{***}$	
	(.0446)	(.0592)	
MidType	2.0902^{*}	$-.0965$	
	(1.2267)	(.1112)	
HighType	4.4053^{***}	$-.1095$	
	(1.4162)	(.1286)	
Contri. more than other (lagged)			$-.6167^{***}$
			(.041)
Contri. less than other (lagged)			$.4873^{***}$
			(.0432)
_cons	2.4052^{**}	$.3623^{***}$	$.0387^{*}$
	(1.1227)	(.1002)	(.0228)
Type Mid – Type High	-2.3151^{*}	.0131	
	(1.2253)	(.1114)	
sigma_u	3.7735^{***}	$.3419^{***}$	.1152
	(.3704)	(.0356)	
sigma_e	4.1535^{***}	$.3398^{***}$	.23
	(.0897)	(.0089)	
rho	.4522	.5031	.2005
	(.0497)	(.0527)	

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Figure 5-5: Group contributions to the public good by treatment



5.3.3 Contributions in the two player treatment

Based on our replication of the results of previous studies, presented in chapter 5.3.2, we strive to test the fair-share rule in a two players public good. By doing so we put the results from the often used four player framework to the test. A two player setting allows us to see a direct effect of asymmetry, without the potential blurriness induced by multiple players per type. In the following chapter we will focus on three remaining treatments from Table 5-1.

$$y_i = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot y_{-i} + \beta_4 \cdot \text{Type}_{\text{Low}} + \epsilon \quad (4)$$

$$\frac{y_i}{e_i} = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot \frac{y_{-i}}{e_{-i}} + \beta_4 \cdot \text{Type}_{\text{Low}} + \epsilon \quad (5)$$

$$\frac{y_{i,t} - y_{i,t-1}}{e_i} = \beta_0 + \beta_1 \cdot \text{Period} + \beta_2 \cdot \text{AbsRel} + \beta_3 \cdot max(0; y_i - y_{-i}) \quad (6)$$

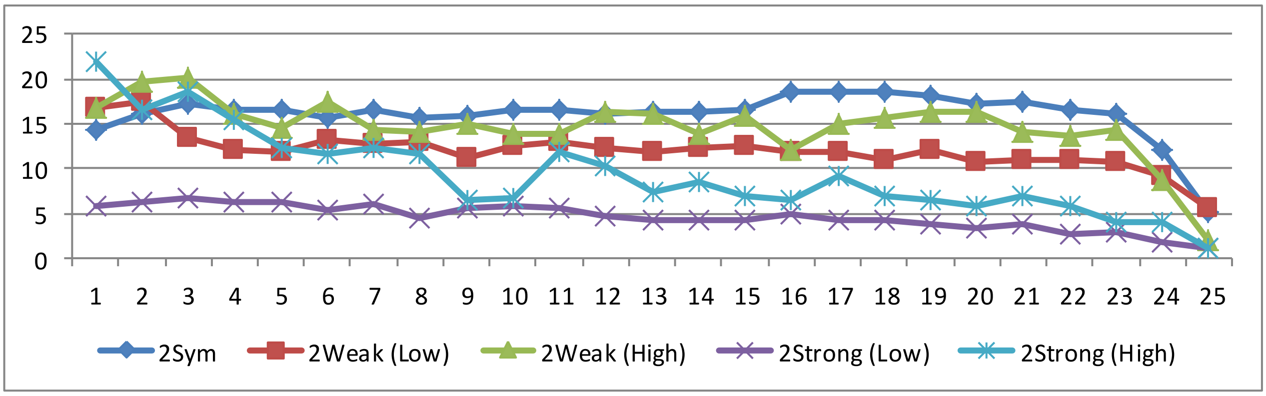
$$+\beta_4 \cdot max(0; y_{-i} - y_i) + \epsilon$$

The group contributions are depicted in Figure 5-5. We employ the U test to control for differences between the treatments. We find group contributions in 2Strong to be significantly lower than in 2Sym ($p = 0.0016$) and 2Weak ($p = 0.0678$), but no significant difference between the latter two ($p = 0.3787$). We use a Tobit regression, based on equations (4) and (5), for a more detailed analysis. The results are presented in Table 5-6 for absolute and Table 5-7 for relative contributions, in the columns “all”. All treatments display a decreasing contribution level over time and the individual contribution depend positively on the contributions of the other player in the group. In line with our results in chapter 5.3.2, we find no significant effect of the choice on the contribution method. However, there is a difference related to the type variable. Both asymmetric treatments show lower contributions (absolute) by the low endowment players. In the case of relative contributions this finding changes significantly. Similar to 4Weak, 2Weak exhibits a fair-share rule where as in 2Strong the low endowment player contributes a by far larger share of her endowment than the high endowment group member. The latter finding is in line with e.g. Buckley and Croson (2006), Cherry et al. (2005) as well as Reuben and Riedl (2013), finding lower absolute, but higher relative contributions of the low endowment players. The difference in absolute contributions is in contrast to findings by Keser et al. (2014), and might be due to the fact that in their setup three low endowment players were grouped with one very high endowed player. This special framework seems to induce a norm of contributing absolutely the same.

Table 5-5: Frequency of groups with mostly zero or full contributions by all players

	2Sym	2Weak	2Strong
Mostly zero	1	2	1
Mostly full	4	3	0
others	16	14	19

Figure 5-6: Contributions to the public good by player type and treatment



However, the observed fair-share contribution in 2Weak can be also a result of groups with a majority of either zero or full contributions. It can be argued whether zero contributions by all group members reflect the same share of contribution since de facto no contributions take place. Full contributions on the other hand depict the other. Table 5-5 presents the number of groups that show mostly full or zero contributions, as well as the remaining groups per treatment. The results are presented in Table 5-6 and Table 5-7 in the columns "reduced" and only include groups where both players contribute less than 2/3 of the time zero or everything. Table 5-5 gives an overview of how many groups have been qualified as zero or full contributors. The results in both tables are qualitatively the same between for "all" and "reduced", with one important exception. We find the low and high endowment players in 2Weak to contribute the same in absolute terms, and low endowment players to contribute more in relative terms. This is the opposite of the findings in column "all". Furthermore, this finding seems to imply that the fair-share norm might be an artifact induced by groups with extreme free-riding or cooperation. Based on equation (6) we performed a panel data regressions with fixed effects for the two player treatments. The results are posted in Table 5-8, confirming the same reciprocal behavior as observed in the four player case. Additionally we find in 2Sym a significant negative effect of choosing the absolute contribution option on the change in contributions.

Table 5-6: Tobit regression of absolute contributions

Absolute Contributions	2Weak all	2Weak reduced	2Strong all	2Strong reduced
Period	$-.2696^{***}$	$-.2259^{***}$	$-.564^{***}$	$-.5499^{***}$
	$(.0461)$	$(.0532)$	$(.0509)$	$(.0518)$
ContriByAbs	-1.2402	$-.9247$	$.2736$	$.1791$
	(1.0311)	(1.1108)	(1.0138)	(1.032)
LAvgContriOther	$.5775^{***}$	$.6106^{***}$	$.2145^{***}$	$.2097^{***}$
	$(.042)$	$(.0447)$	$(.044)$	$(.0443)$
LowType	-6.0204^{**}	-2.575	-5.6328^{**}	-5.9948^{***}
	(2.8714)	(2.3129)	(2.6779)	(2.6373)
_cons	10.2711^{***}	7.3652^{***}	11.9975^{***}	12.729^{***}
	(2.3072)	(2.0341)	(2.1284)	(2.1249)
sigma_u	8.5861^{***}	5.8094^{***}	8.1571^{***}	7.8085^{***}
	(1.1305)	$(.8859)$	$(.9899)$	$(.973)$
sigma_e	8.7952^{***}	8.8523^{***}	9.0898^{***}	9.1564^{***}
	$(.2601)$	$(.2977)$	$(.2761)$	$(.2805)$
rho	$.488$	$.301$	$.4461$	$.421$
	$(.0673)$	$(.0658)$	$(.061)$	$(.0618)$

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Table 5-7: Tobit regression of relative contributions

Relative Contributions	2Weak all	2Weak reduced	2Strong all	2Strong reduced
Period	$-.0125^{***}$	$-.0095^{***}$	$-.0232^{***}$	$-.0222^{***}$
	$(.0026)$	$(.0025)$	$(.0023)$	$(.0023)$
ContriByAbs	$-.0661$	$-.0507$	$.0127$	$.01113$
	$(.0568)$	$(.0515)$	$(.0441)$	$(.0441)$
LAvgContriOther	$.8247^{***}$	$.7725^{***}$	$.5882^{***}$	$.587^{***}$
	$(.07)$	$(.0627)$	$(.0633)$	$(.0638)$
LowType	$.1703$	$.2576^{**}$	$.6588^{***}$	$.666^{***}$
	$(.164)$	$(.1002)$	$(.1448)$	$(.1448)$
_cons	$.2256^{*}$	$.0898$	$.0178$	$.0306$
	$(.1335)$	$(.0921)$	$(.1158)$	$(.1165)$
sigma_u	$.4881^{***}$	$.2477^{***}$	$.4398^{***}$	$.4289^{***}$
	$(.0697)$	$(.0394)$	$(.0569)$	$(.057)$
sigma_e	$.4452^{***}$	$.3994^{***}$	$.3744^{***}$	$.371^{***}$
	$(.0185)$	$(.0165)$	$(.0138)$	$(.0138)$
rho	$.5459$	$.2777$	$.5798$	$.572$
	$(.0709)$	$(.0646)$	$(.0633)$	$(.0654)$

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

Table 5-8: Panel regression with fixed effects

Diff. in Relative Contributions	2Sym all	2Sym reduced	2Weak all	2Weak reduced	2Strong all	2Strong Reduced
Period	$-.0053^{***}$	$-.0046^{***}$	$-.0035^{***}$	$-.0023^{*}$	$-.0026^{**}$	$-.0026^{**}$
	$(.0011)$	$(.0013)$	$(.0011)$	$(.0013)$	$(.0011)$	$(.0011)$
ContriByAbs	$-.0621^{**}$	$-.0922^{**}$	$-.0353$	$-.0284$	$.0282$	$.0275$
	$(.0296)$	$(.0364)$	$(.0248)$	$(.0288)$	$(.0233)$	$(.0245)$
Contri. more than	$-.6018^{***}$	$-.6097^{***}$	$-.6162^{***}$	$-.6053^{***}$	$-.6032^{***}$	$-.615^{***}$
other (lagged)	$(.0418)$	$(.048)$	$(.0399)$	$(.0464)$	$(.0357)$	$(.0373)$
Contri. less than	$.4315^{***}$	$.3878^{***}$	$.2321^{***}$	$.2798^{***}$	$.2033^{***}$	$.2164^{***}$
other (lagged)	$(.0418)$	$(.048)$	$(.0399)$	$(.0464)$	$(.0357)$	$(.0373)$
_cons	$.1259^{***}$	$.1522^{***}$	$.0932^{***}$	$.0723^{**}$	$.0653^{***}$	$.0683^{**}$
	$(.0308)$	$(.0389)$	$(.0255)$	$(.0306)$	$(.0249)$	$(.0266)$
sigma_u	$.0468$	$.0519$	$.08$	$.0918$	$.1538$	$.1621$
sigma_e	$.2223$	$.2353$	$.2184$	$.2312$	$.2201$	$.2237$
rho	$.0423$	$.0464$	$.1184$	$.1361$	$.3281$	$.3444$

(*) symbol indicates the level of significance from (*) - 10%, (**) - 5% and (***) - 1%.

5.4 Conclusion

In our study we focused on the impact of inequality in the context of a potential fair-share norm. We used a linear public good game and implemented an additional stage where participants are asked to choose between two presentation methods for their investment decision. The first option displays all contributions in absolute terms from zero to the player's endowment. The second option presents all values as shares of the individual endowment, from zero percent to 100 percent. Inequalities were induced by endowment differences between the subjects. The focus is on two player groups with endowments ranking from symmetry, over weak asymmetry up to high asymmetries, where the high endowment player has no interest in the social optimum. Additionally we presented results from a four player experiment to check for contribution differences created by the choice mechanism, in contrast to previous studies.

We found that most participants prefer to contribute in absolute terms. With more endowment inequality an increasing number of subjects choose the relative contribution option, while the majority still uses absolute contributions. The choice has no significant effect on the contribution level. While regressions results show a negative influence on group contributions, this is far from being significant. The group contributions in the weak symmetry treatments indicate all players to contribute the same share of their endowment. These results changes when excluding groups operating most of the rounds at the group optimum or at zero contributions, indicating that low endowment player contribute more in relative terms. In the strong asymmetry treatment group contributions are lower than in the symmetric and weakly asymmetric treatments. Furthermore, low endowment players contribute less in absolute, but more in relative terms.

Our findings show that the contribution method has no effect on contribution, but that people adapt their preferred contribution method depending on the complexity of the situation, with asymmetric treatments showing clearly more relative contribution choices.

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5.6 Appendix

Table 5-9: Comparison 4Weak and 4PBasic

Treatment	Type level			Group level contributions
	Low	Mid	High	
4Weak	5.1592 (0.5159)	6.9915 (0.4661)	9.0199 (0.451)	28.1621 (0.4694)
4PBasic	6.308 (0.6308)	7.652 (0.5101)	11.44 (0.572)	33.052 (0.5509)
4PBasic = 4Weak z-value (p-value)	0.943 (0.3457)	0.436 (0.6631)	1.442 (0.1492)	1.332 (0.1830)

Table 5-10: Average frequency of absolute method chosen within 25 periods

	Low	Mid	High	Total
4Weak	14.4	18.13	17.27	16.98
2Sym				21.45
2Weak	18		18.47	18.24
2Strong	15.9		16.05	15.98

Figure 5-7: Share of absolute and relative contributions by type in 4Weak

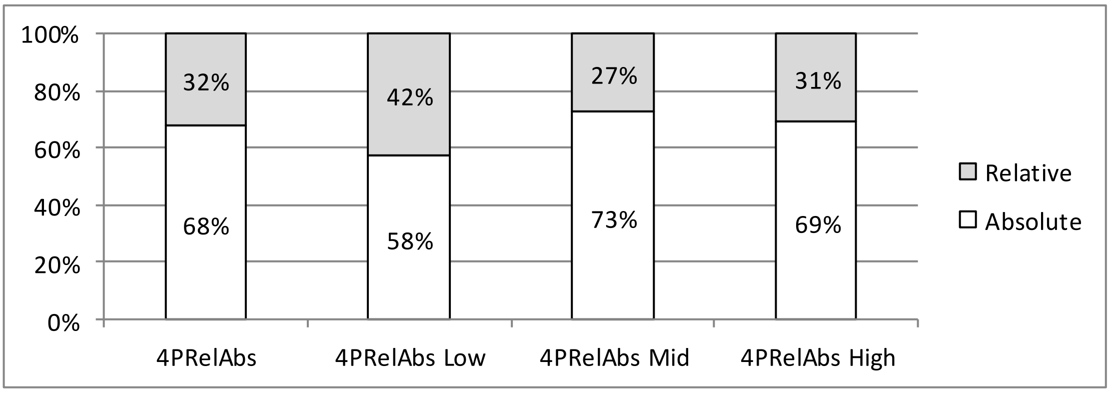

Figure 5-8: Share of absolute and relative contributions by treatment (reduced)

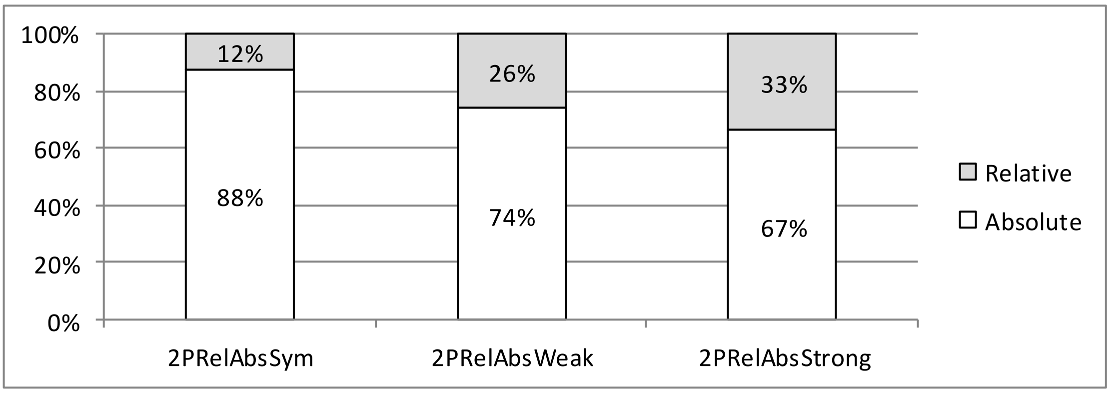

Table 5-11: Wilcoxon-Mann-Whitney U test of frequency of absolute contributions between treatments and the frequency of changes in the contribution method between treatments

	Group		Low		High	
	# rel.	# switched	# rel.	# switched	# rel.	# switched
2Sym = 2Weak	2.092^{**} (0.0364)	−0.586 (0.5581)	1.064 (0.2871)	−0.137 (0.8908)	0.467 (0.6407)	0.318 (0.7505)
2Sym = 2Strong	3.021^{***} (0.0025)	−1.222 (0.2218)	1.982^{**} (0.0475)	−0.952 (0.3411)	1.67^{*} (0.0949)	−0.555 (0.5786)
2Weak = 2Strong	0.984 (0.3249)	−1.130 (0.2584)	0.75 (0.4531)	−0.615 (0.5384)	1.111 (0.2666)	−0.805 (0.421)