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Social Costs of Inequality –

Heterogeneous Endowments in Public-Good Experiments[1]

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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; linear public good; income heterogeneity.

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[1] This study was previously titled "Rich man and Lazarus – Asymmetric Endowments in Public-Good Experiments".

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 there has been little attention to asymmetry.

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 super-rich 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.

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, Hofmeyer 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 Hofmeyer et al. and in our study in that it does not keep constant the sum of endowments across the homogeneous and heterogeneous treatments.

Hofmeyer 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 Hofmeyer et al. and by us. Altruism would simply predict higher absolute contributions by the wealthier participant; the results by Hofmeyer 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.

3. The experiment

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:

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

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.

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)[2] of the investment in the public account is constant and amounts to 0.5.

[2] 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 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 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 €.

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 Hofmeyer 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.

4.1 Group contribution

Figure 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 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.[3] 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.[4]

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.[5]

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 Hofmeyer 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.[6]

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

[4] 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.

[5] 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 $p^{(2)} = 0.6465$.

[6] 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 $p = 0.1438$.

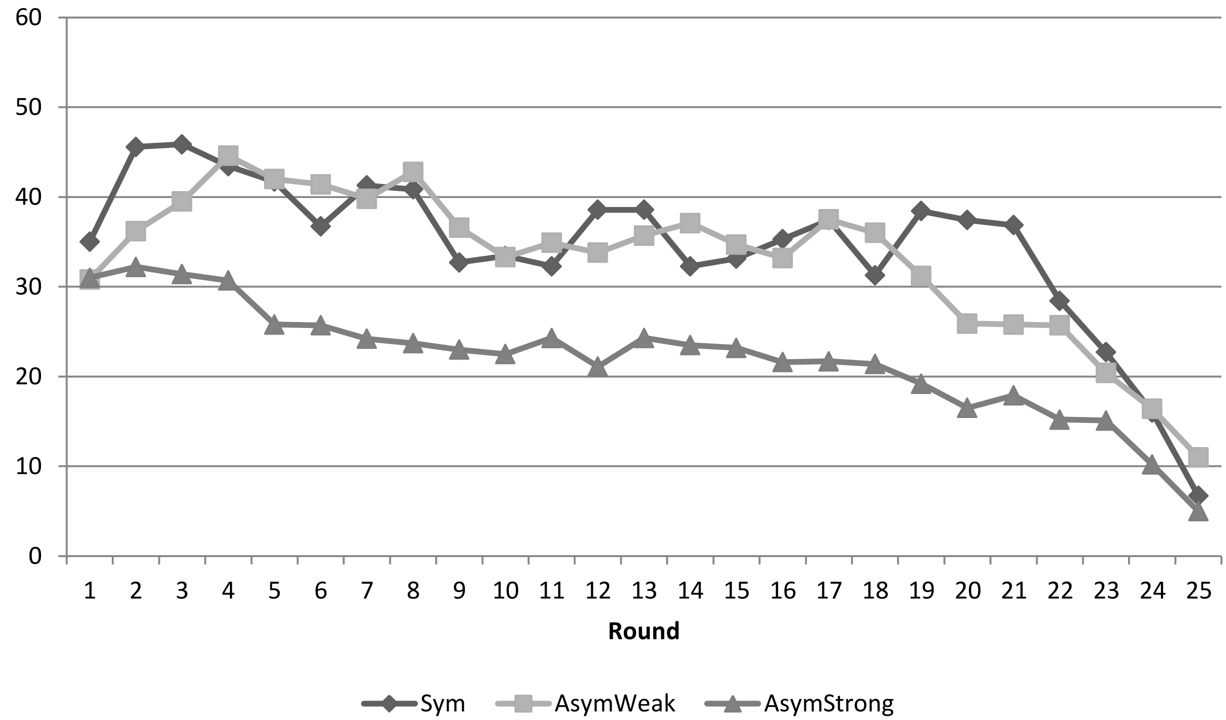

Figure 1: Group contribution to the public investment over the 25 rounds

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 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 Hofmeyer 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 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. 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 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.

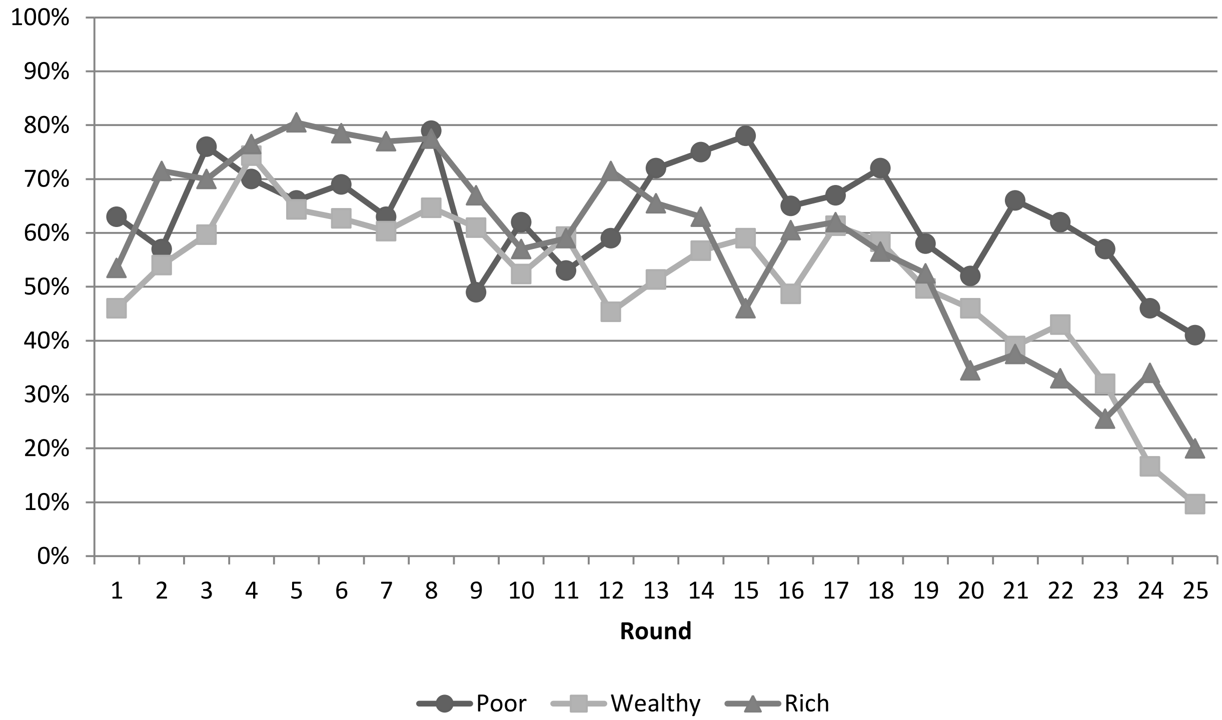

Figure 2: Proportion of endowment contributed in AsymWeak

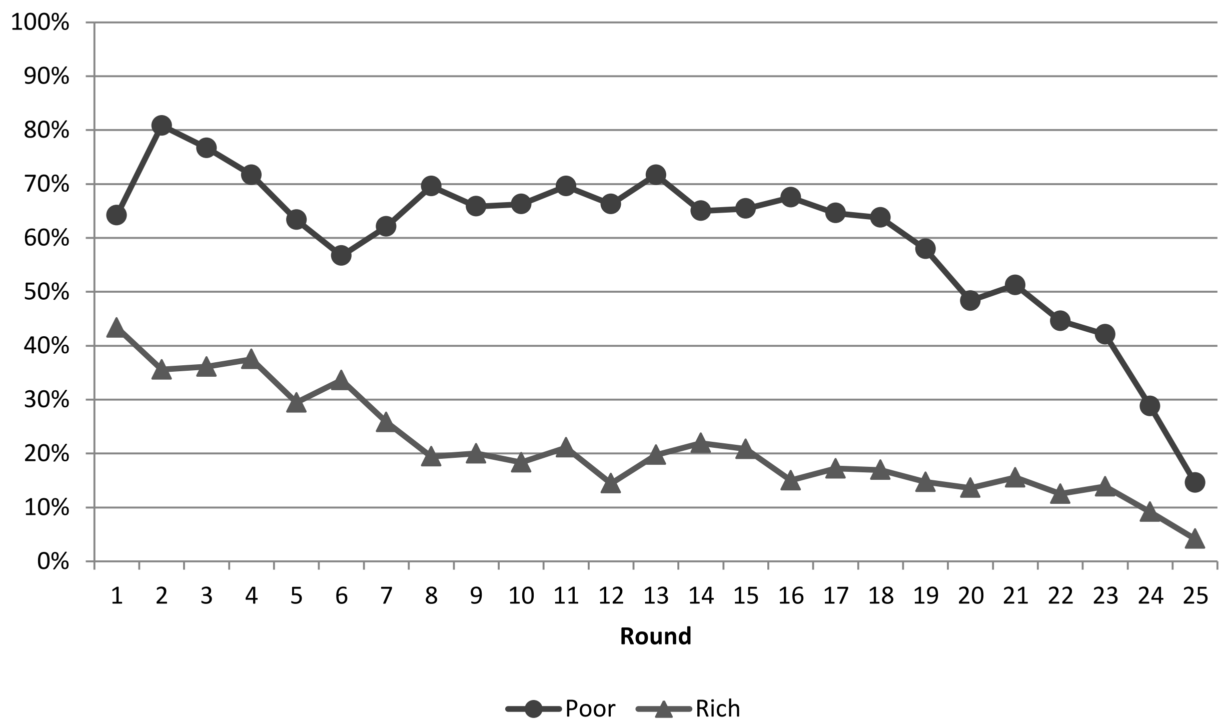

Figure 3: Proportion of endowment contributed in AsymStrong

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

	Model 1 AsymWeak	Model 2 AsymStrong
Period	-0.0067***	-0.0089***
Last5Periods	-0.1717***	-0.1422***
Rich	0.6919	-0.3873***
Poor	0.1207	
Intercept	0.6317***	0.7438***
σ_u	0.223	0.123
σ_e	0.300	0.324
R^2	0.095	0.254
N	1000	1000

*** 1-percent significance

Table 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**

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 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 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

4.4 Profits and Gini coefficients

Table 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.[7]

Table 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.*

[7] 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 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 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

5. Conclusion

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 Hofmeyer 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 Hofmeyer 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 that, while moderate asymmetry has little to no effect on public-good provision, extreme asymmetry has a detrimental effect surely could be taken into account in the discussions and evaluations of global and national endeavors on public-good provision. It might 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.

References

Andreoni, J., 1988. Why free ride?: Strategies and Learning in Public Goods Experiments. Journal of Public Economics 37, 291-304.

Becker, G.S., 1974. A Theory of Social Interactions. The Journal of Political Economy 82, 1063-1093.

Bergstrom, T., Blume, L., Varian, H., 1986. On the Private Provision of Public Goods. Journal of Public Economics 29, 25-49.

Bolton, G.E., Ockenfels, A., 2000. ERC: A Theory of Equity, Reciprocity, and Competition. The American Economic Review 90, 166-193.

Buckley, E., Croson, R., 2006. Income and Wealth Heterogeneity in the Voluntary Provision of Linear Public Goods. Journal of Public Economics 90, 935-955.

Cardenas, J.C., 2003. Real Wealth and Experimental Cooperation: Evidence from Field Experiments. Journal of Development Economics 70, 263-289.

Cardenas, J.C., Carpenter, J., 2004. An Inter-Cultural Examination of Cooperation in the Commons. Working Paper, Department of Economics, Middlebury College.

Cardenas, J.C., Carpenter, J., 2008. Behavioral Development Economics: Lessons from Field Labs in the Developing World, Journal of Development Studies 44, 311-338.

Cherry, T.L., Kroll, S., Shogren, J.F., 2005. The Impact of Endowment Heterogeneity and Origin on Public Good Contributions: Evidence from the Lab. Journal of Economic Behavior & Organization 57, 357–365.

Cherry, T.L., Frykblom, P., Shogren, J.F., 2002. Hardnose the Dictator. American Economic Review, 92, 1218-1221.

Fehr, E., Schmidt, K.M., 1999. A Theory of Fairness, Competition, and Cooperation. The Quarterly Journal of Economics 114, 817-868.

Fisher J., Isaac, R.M., Schatzberg J. W., Walker, J.M., 1995. Heterogeneous Demand for Public Goods: Behavior in the Voluntary Contributions Mechanism. Public Choice 85, 249-266.

Hoffman, E., Spitzer, M., 1985. Entitlements, Rights, and Fairness: An Experimental Examination of Subjects' Concepts of Distributive Justice. Journal of Legal Studies 15, 254–297.

Fischbacher, U., 2007. z-Tree: Zurich Toolbox for Ready-made Economic Experiments. Experimental Economics 10, 171-178.

Hofmeyer, A., Burns, J., Visser, M., 2007. Income Inequality, Reciprocity and Public Good Provision: An Experimental Analysis. South African Journal of Economics 75, 508-520.

Isaac, R.M., Walker, J. M., Thomas, S. H., 1984. Divergent Evidence on Free Riding: An Experimental Examination of Possible Explanations. Public Choice 43, 113-149.

Isaac, R.M., Walker, J. M., 1988. Group Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism. Quarterly Journal of Economics 103, 179–199.

Keser, C., 2000. Cooperation in Symmetric Duopolies with Demand Inertia. International Journal of Industrial Organization 18, 23-38.

Keser, C., 2002. Cooperation in Public Goods Experiments. In: Bolle F., Lehmann-Waffenschmidt M. (Eds.), Surveys in Experimental Economics: Bargaining, Cooperation, and Election Stock Markets. Heidelberg: Physica-Verlag.

Keser, C., van Winden, F., 2000. Conditional Cooperation and Voluntary Contributions to Public Goods. Scandinavian Journal of Economics 102, 23-39.

Ledyard, J., 1995. Public Goods: A Survey of Experimental Research, in: J. H. Kagel and A. E. Roth (eds.), The Handbook of Experimental Economics, Princeton University Press.

Loomes, G., Burrows, P., 1994. The Impact of Fairness on Bargaining Behaviour, Empirical Economics 19, 201-221.

Marwell, G., Ames, R.E., 1979. Experiments on the Provision of Public Goods. I. Resources, Interest, Group Size, and the Free-Rider Problem. The American Journal of Sociology 84, 1335-1360.

Mason, C.F., Phillips, O.R., Nowell, C., 1992. Duopoly Behavior in Asymmetric Markets: An Experimental Evaluation. Review of Economics and Statistics 74, 662-669.

Maurice, J., Rouaix, A., Willinger, M., 2013. Income Redistribution and Public Good Provision: An Experiment. International Economic Review 54, 957-975.

OECD, 2011. Divided We Stand: Why Inequality Keeps Rising. OECD Publishing. http://dx.doi.org/10.1787/9789264119536-en.

Olson, M., 1965. The Logic of Collective Action: Public Goods and the Theory of Groups, Cambridge, MA: Harvard University Press.

Ostrom, E., Gardner, R., Walker, J., 1994. Rules, Games, and Common-Pool Resources. The University of Michigan Press.

Sadrieh, A., Verbon, H.A.A., 2006. Inequality, Trust, and Growth: An Experimental Study. European Economic Review 50, 1197-1222.

Selten, R., Mitzkewitz, M., Uhlich, G.R., 1997. Duopoly Strategies Programmed by Experienced Players. Econometrica 65, 517-555.

Selten, R., Stoecker, R., 1986. End Behavior in Sequences of Finite Prisoner's Dilemma Supergames: A Learning Theory Approach, Journal of Economic Behavior & Organization 7, 47-70.

UNDP, 2011. Human Development Report 2011: Sustainability and Equity: A Better Future for All. New York: Palgrave Macmillan. (http://hdr.undp.org/en/media/HDR_2011_EN_Complete.pdf)

Van Dijk, E., Wilke, H., 1994. Asymmetry of Wealth and Public Good Provision. Social Psychology Quarterly 57, 352-359.

Warr, P. G., 1983. The Private Provision of a Public Good is Independent of the Distribution of Income. Economics Letters 13, 207-211.

Weimann, J., Brosig-Koch, J., Heinrich, T., Hennig-Schmidt, H., Keser, C, Stahr, C., 2014. MPCR distance to explain (first-round) contributions in public goods: A laboratory test with large groups. Mimeo.

Appendix: Additional Data Tables

Table A.1: 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 A.2: 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 A.3: 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 A.4: 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