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Asymmetric Endowments in Public-Good Experiments

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Résumé/abstract

We compare voluntary contributions to a public good in a symmetric setting to those in a weakly and a strongly asymmetric setting, where the players have different, randomly allocated endowments. We observe that the group-contribution levels are not significantly different between the symmetric and the weakly asymmetric setting. In both situations, participants tend to contribute the same proportion of their respective endowment. In the strongly asymmetric situation, where one of the players has a higher endowment than the three other players together, we observe a significantly lower group contribution than in the other situations. The rich player in this situation does not contribute significantly more than the average contribution of the poor players and thus contributes a significantly lower proportion of the endowment. This player is not as greedy as the rich man in the parable but leaves not more than breadcrumbs to the poor players.

Mots clés/keywords : Experimental economics, public goods, asymmetries.

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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). In the interaction of industrialized, emerging and development countries it is not clear, whether the inequality of wealth has a positive, negative or null effect on the provision of public goods.

For example, Warr's neutrality theorem states that the provision of a single public good is unaffected by a redistribution of wealth (Warr 1983). Bergstrom, Blume & Varian (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. 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) to finance a public good, in which they investigate 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 this paper, we examine whether and how differences in endowments affect contribution levels, without making reference to redistributions of endowments. We present a (linear) VCM experiment, in which we compare, in a between-subject design, contributions under a symmetric, a weakly asymmetric and a strongly asymmetric allocation of endowments among four players. 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.

There exists an extensive literature on VCM experiments. The bulk of it is based on the simple linear game introduced by Marwell & Ames (1979) and Isaac, Walker & Thomas (1884) 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, participants in the experiment typically contribute between 40 and 60 percent of their endowment (Ledyard 1995). The actual level depends on various factors, including 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, the number of interaction rounds and many others.

An often neglected factor to potentially impact the contribution level is the degree of asymmetry in the game. 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 more easily determined in the symmetric case, where equal contribution is an obvious requirement. It is not so clear, where players in asymmetric situations are supposed to cooperate. Selten, Mitzkewitz & Uhlich (1997) identified in a strategy experiment on an asymmetric duopoly "decisions guided by ideal points". The ideal points, however, were defined in a number of different ways. Thus, it comes with no surprise that Mason, Phillips & Nowell (1992) and Keser (2000) observe more cooperative outcomes in symmetric than in asymmetric oligopolies.

Hofmeyer, Burns & Visser (2007) conducted linear VCM experiments, where they find that endowment heterogeneity does not have any significant impact on contributions to the public good. Furthermore, they observe that low and high endowment players contribute the same fraction of their endowment ("fair-share rule"). Similarly, Sadrieh & Verbon (2006) vary players' endowments in a dynamic public-good game, where each round's earnings are added to the available endowment in the following round, and find that the contribution level is neither affected by the degree nor the skew of endowment inequality.

In contrast to this, Cherry, Kroll & Shogren (2005) observe that endowment heterogeneity in a one-shot linear VCM game decreases the contribution level relative to homogeneous endowments. Their experiment is less controlled than the experiments in Hofmeyer, Burns & Visser (2007) and our study, in that they do not keep constant the sum of endowments across the homogeneous and heterogeneous treatments.

The provision of public goods and the appropriation of common pool resources are two related instances of collective action. The modeling of public-good situations as simple VCMs (without thresholds) provides dominant strategy solutions, which are stronger and more obvious than the Nash-equilibrium solutions in the Common-Pool Resource (CPR) experiments (as in the seminal paper by Ostrom, Gardner and Walker 1994). Also the social optima are easier to identify in VCM than in CPR games. It thus does not come by surprise that the effects of heterogeneity in the endowments of appropriators of a CPR appear to be mixed as well (e.g., Keohane & Ostrom 1995, who request a better understanding of these effects in order to deal with the problem of institutional design).

Cardenas & Carpenter (2008) report on CPR experiments in the field, 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 & Carpenter (2004) show that mixed groups of students from different countries perform noticeably worse than homogenous groups in a CPR game. We have to take into account that such field experiments are likely to capture (additional) aspects that are different from the pure endowment-allocation aspect investigated in the experimental-economics lab. In the lab we can more easily focus on specific aspects and (to some extent) filter out others, but we need to be very cautious if we want to apply results from lab experiments for the interpretation of specific real-life situations.

Buckley & Croson (2006) present a comparison of contribution behavior of “more and less wealthy” participants in a linear VCM experiment with heterogeneous endowments. They observe that the less wealthy in endowment give the same absolute amount and thus more as a percentage of their endowment as the more wealthy. They demonstrate that this result is contradicting the assumptions of inequity aversion (Fehr & Schmidt 1999, Bolton & 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, while altruism would predict higher absolute contributions by the wealthier participants. Their result also is in contrast to the “fair-share rule” observed by Hofmeyer, Burns & Visser (2007).

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 through a laboratory task. In bargaining and dictator games, earned endowments tend to lead to more inequitable outcomes than randomly allocated endowments (e.g., Hoffman & Spitzer 1985, Loomes & Burrows 1994, Cherry, Frykblom & Shogren 2002).

Van Dijk & Wilke (1994) observe in a one-shot public-good experiment with heterogeneous endowments that the more endowment participants possess, the more they contribute (“noblesse oblige”). However, the difference between the contributions of low-endowment and high-endowment players is larger in the case of random allocation of endowments than in the case that the difference in endowments was justified by (making the subjects believe in) the requirement to spend unequal time in the experiment. In contrast to this, Cherry, Kroll & Shogren (2005) observe that the origin of heterogeneous endowments (earned or randomly allocated) does not have a significant effect on voluntary contributions in a one-shot public-good game.

Van Dijk & Wilke point out that the provision of a public good is an indirect opportunity to reallocate wealth. Thus, experiments with heterogeneous endowments involve re-allocation aspects like in a dictator game, for which we have plenty of evidence that it matters whether the endowments are earned or randomly allocated. We still 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 have only achieved this control through a tournament element, which might impact behavior in the public-good game in an uncontrolled way.

2. The Game

In our public-good game n players form a group. Each player i (i = 1, …, 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:

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

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 his 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 ($t = 1, \ldots, T$) each player contributes his 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. Experimental Design

We conducted the computerized experiments in the *Göttingen Laboratory of Behavioral Economics* at the Georg-August-Universität Göttingen, Germany, between December 2009 and March 2010. The experiment software was based on z-Tree (Fischbacher 2007).

In total, 108 students from various disciplines participated in the experiments. 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 experiments.

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 (a German version is included in the Appendix A) 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 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. 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 α = 2 and β = 1. This implies that the marginal per-capita return (MPCR)[1] of the investment in the public account is constant and amounts to 0.5.

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 him 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 in addition to a show-up fee of 3 € in cash after the experiment. The conversion factor is the same for each player.

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.

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.

[1] 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.

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, Burns & Visser (2007), whose experiment is very similar to ours.

Hypothesis 3: *Players use the reciprocity principle.*

Keser & 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 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.*

As mentioned in the introduction above, Van Dijk & 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, whatever 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 significant 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, requiring significance at the 10-percent level ($p = 0.7694$). 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 contribution in the AsymStrong treatment is significantly lower than in the two other treatments.

The standard deviations of group contribution (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: 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—a 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.[2] 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.[3]

In none of the three treatments do we observe a significant change in the standard deviation of the group contribution 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.[4]

Result 4.1: *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, Burns & Visser (2007). However, in the AsymStrong treatment we do observe a significantly lower contribution level than in the two other treatments.*

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

[3] 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.

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

This latter result could potentially be considered as confirmation of the result by Cherry, Kroll & Shogren (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.[5]

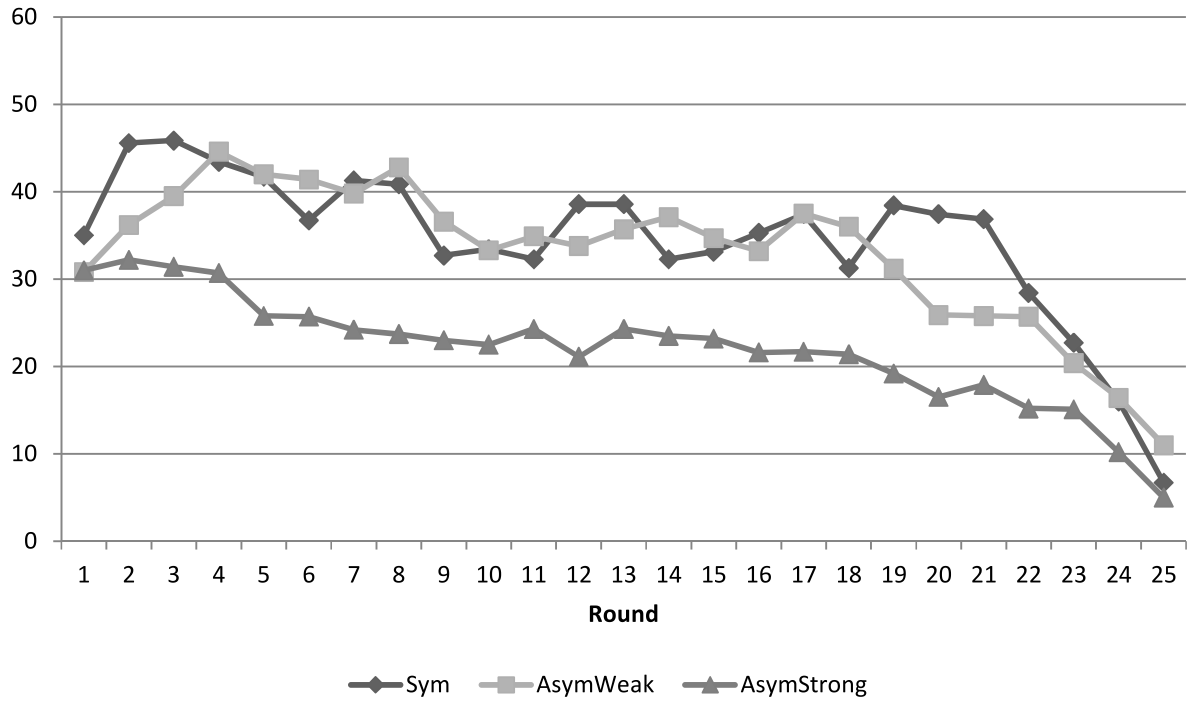

Figure 1: Group contribution to the public investment over the 25 rounds

4.2 Contribution 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.

[5] 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.

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 4.2a: *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, Burns and Visser (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 4.2b*: 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 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 players do 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. Otherwise, contributions stay within a four-percent range around 20 percent zero contribution and 30 percent full contribution.

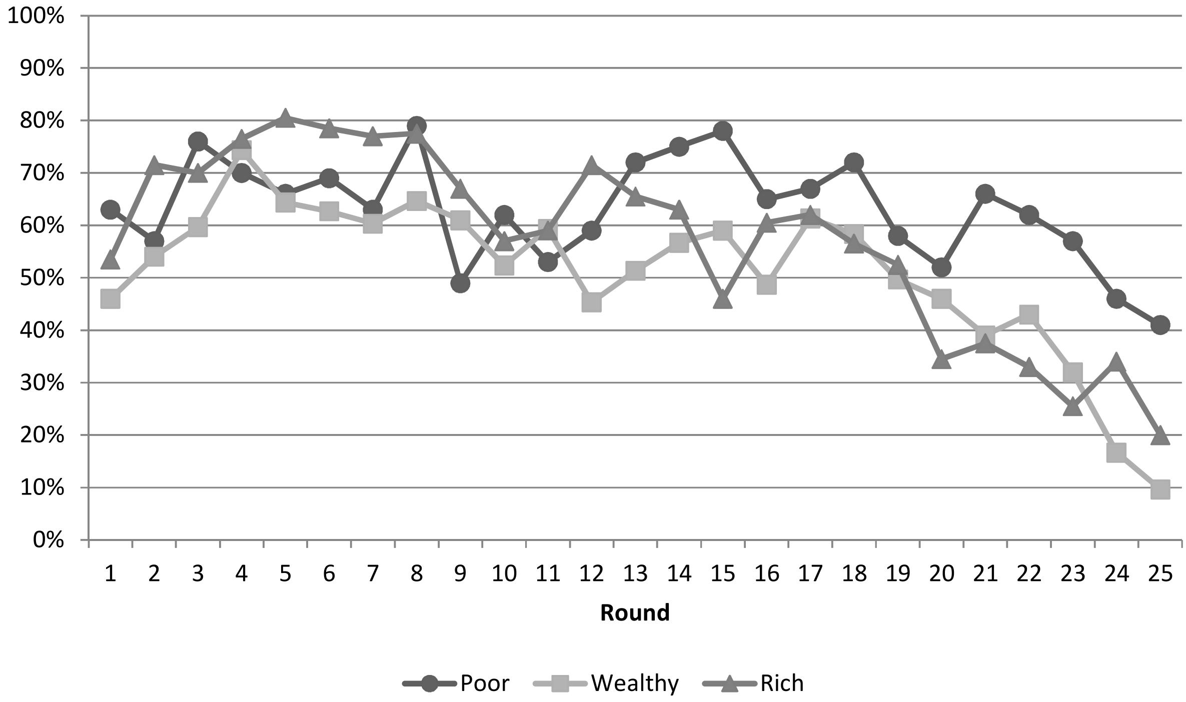

Figure 2: Proportion of endowment contributed in AsymWeak

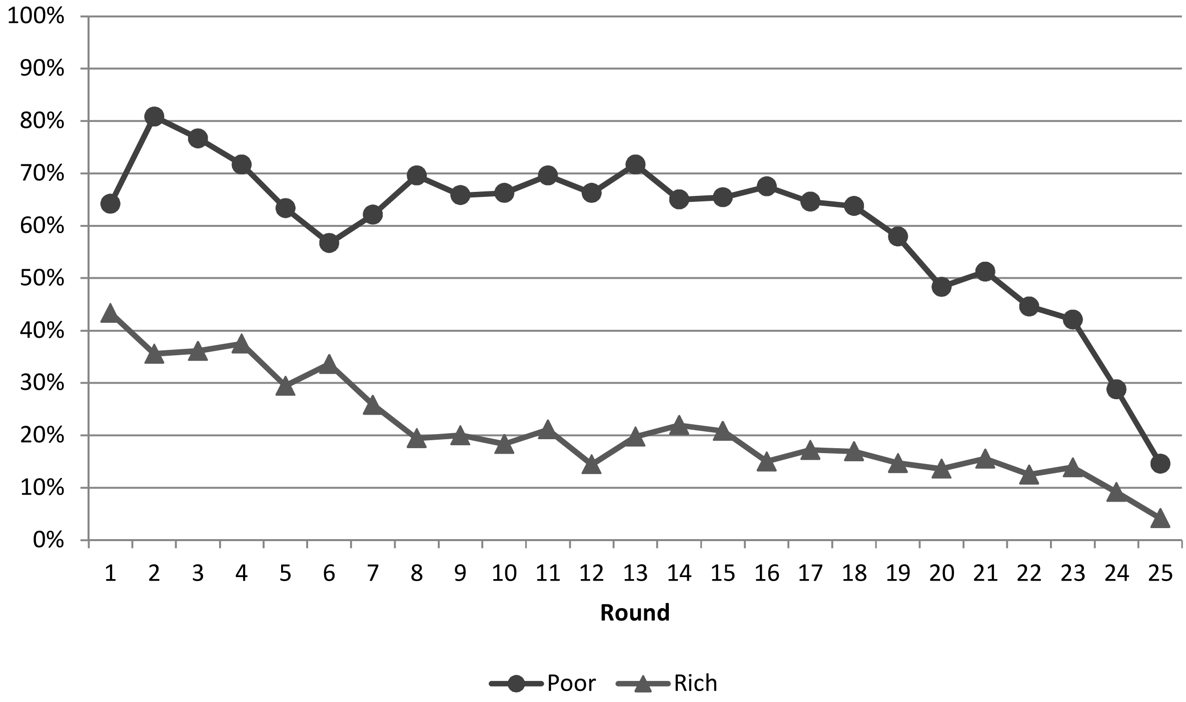

Figure 3: Proportion of endowment contributed in AsymStrong

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 independent (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. Only for the AsymStrong-rich player do we find significant evidence of reciprocity with respect to absolute values only.

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 4.3: *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 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.[6]

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 2007/08. It provides Gini coefficients of 0.283 for Germany, 0.327 for France or 0.586 for Colombia.

[6] 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)
Average inequality reduction[7]	---	51.35%	10.13%

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

We observe that the inequality decreases by 51 percent in the AsymWeak and by 31 percent in the AsymStrong treatment. These reduction in inequality are statistically significant (signed-rank test,

[7] The average inequality reduction measures the difference in realized per-period profits of rich and poor players relative to the equilibrium profits.

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 4.4: *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.*

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, Burns & Visser (2007), which gives hope for its robustness. However, our experiment also shows that a strong inequality in endowments may lead to significantly lower contributions. Our AsymStrong treatment differs from the typical VCM experiments, though, in that a super-rich player exists that is not interested in achieving the group optimum.

Similarly, our experimental results of the AsymWeak treatment confirm the observation by Hofmeyer, Burns & Visser (2007) that cooperation is largely based on the principle that players tend to contribute the same proportion of their respective endowment to the public investment (fair-share rule). This is not the case, though, in the strongly asymmetric treatment. The rich player tends to contribute an amount that is not significantly different from the average contribution of the poor players.

The different behavioral patterns in the strongly asymmetric from the weakly asymmetric treatment can be interpreted as follows. In the weakly asymmetric treatment, full contribution defines the ultimate cooperative goal for each of the 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. However, in our strongly asymmetric treatment, the rich player has no interest in achieving the full contribution social optimum, where the sum of profits is maximized. It would imply equal profit to all players, which for the rich player is below his Nash equilibrium profit. While public-good provision under asymmetric endowments generally involves an equalizing redistribution aspect, this aspect becomes, at some level of public-good provision below the social optimum, unfavorable to the super-rich player in the strongly asymmetric treatment. We can define, though, a social optimum under the constraint that everybody contributes the same amount. This implies that everybody contributes an amount equal to the poorest player's endowment and imposes an upper limit for the absolute contribution of the rich player. This constrained optimum is favorable to all players.

Thus, the rich man in our strongly asymmetric experiments is not quite as greedy as the rich man in the parable but he leaves not more than breadcrumbs to the poor Lazarus.

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Appendix A: Instructions (AsymWeak, in German)

Experiment-Anleitung

Sie nehmen an einem wirtschaftswissenschaftlichen Entscheidungsexperiment teil. In diesem Experiment können Sie bares Geld verdienen. Wie viel Sie verdienen, hängt von Ihren Entscheidungen und den Entscheidungen anderer Teilnehmer ab. Jeder Teilnehmer trifft seine Entscheidungen isoliert von den anderen an seinem Computer. Wir bitten Sie, von nun an nicht mehr mit anderen Teilnehmern zu sprechen.

Das Experiment läuft über **25** Runden. Zu Beginn des Experiments werden Sie zufällig mit **drei** weiteren Personen einer **4er**-Gruppe zugeordnet, in welcher Sie während des gesamten Experiments verbleiben. Die Identität Ihrer Gruppenmitglieder wird Ihnen dabei zu keinem Zeitpunkt bekannt.

Jedes Gruppenmitglied verfügt **in jeder Runde** über eine bestimmte **Ausstattung an Spielmarken**. Spieler 1 verfügt in jeder Runde über **10** Spielmarken, Spieler 2 und 3 verfügen jeweils über **15** Spielmarken und Spieler 4 verfügt über **20** Spielmarken. Die Spielernummern (und damit die Ausstattungen) werden zufällig den einzelnen Gruppenmitgliedern zugeordnet und zu Beginn des Experiments bekannt gegeben.

Gruppenmitglied	Ausstattung (Spielmarken)
Spieler 1	10
Spieler 2	15
Spieler 3	15
Spieler 4	20

Die Entscheidungen

Jedes Gruppenmitglied muss sich in jeder der 25 Runden entscheiden, wie es seine Spielmarken auf zwei Alternativen aufteilt. Die beiden Alternativen heißen X und Y. Die Spielmarken bringen Ihnen in beiden Alternativen jeweils unterschiedliche Erlöse, die in Geldeinheiten (GE) berechnet werden. Die Erlöse berechnen sich wie folgt:

Jede Spielmarke, die Sie X beisteuern, bringt Ihnen einen Erlös von **2 GE**. Wenn Sie nichts zu X beisteuern, ist Ihr Erlös aus X gleich Null.

Jede Spielmarke, die Sie Y beisteuern, bringt sowohl Ihnen, als auch jedem anderen Mitglied Ihrer Gruppe jeweils einen Erlös von **1 GE**.

Sie können Ihre Spielmarken entweder nur X oder nur Y beisteuern oder auf beide Alternativen aufteilen. Es können jedoch nur ganze Spielmarken den Alternativen beigesteuert werden. Im Eingabefeld müssen Sie für jede Alternative die Anzahl der Spielmarken eingeben, die Sie der entsprechenden Alternative beisteuern wollen. Wenn Sie der Alternative X oder Y nichts beisteuern wollen, tippen Sie eine Null ein. Die Spielmarken für X und für Y müssen zusammen immer Ihrer Ausstattung entsprechen, d.h. diese muss vollständig verwendet werden. Mit der <Tabulator>-Taste können Sie die Eingabefelder für Ihre Entscheidung wechseln. Die Eingaben werden mit einem Klick auf die <OK>-Taste abgeschlossen.

Ihr individueller Rundenerlös ergibt sich aus der Summe der Erlöse aus X und Y. Er errechnet sich wie folgt:

Rundenerlös = Ihr verdoppelter X-Beitrag + die Summe der Y-Beiträge in Ihrer Gruppe.

Auszahlung

Die Rundenerlöse eines Spielers werden für alle **25** Runden aufaddiert. Dieser Gesamterlös in GE wird in € umgerechnet, wobei jede GE **1** Cent wert ist. Ausbezahlt wird am Ende des Experiments. Die Auszahlung erfolgt individuell und anonym.

Verfügbare Informationen

In jeder Runde verfügen Sie auf Ihrem Bildschirm über eine Übersichtstabelle mit den Ergebnissen aller bisherigen Runden. Die Ergebnisse umfassen jeweils folgende Information:

Ihre Ausstattung, Ihr X-Beitrag, Ihr Y-Beitrag, die Y-Beiträge der einzelnen anderen Gruppenmitglieder, Ihr Erlös aus X, Ihr Erlös aus Y, Ihr Rundenerlös und Ihr Gesamterlös.

Falls Sie sich das Ergebnis lange zurück liegender Runden betrachten wollen, können Sie die Scroll-Funktion auf der rechten Seite der Übersichtstabelle benutzen.

Wir bitten Sie nun, sich zu dem Computer mit Ihrer Teilnehmernummer zu begeben. Dort müssen Sie auf die <Weiter>-Taste klicken. Es werden Ihnen auf dem Bildschirm einige Fragen zum Verständnis dieser Anleitungen gestellt. Erst wenn alle Teilnehmer alle Fragen korrekt beantwortet haben, kann das Experiment beginnen.

Appendix B: Additional Data Tables

Table B.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 B.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 B.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 B.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