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Abstract:

We experimentally test different rule-based contribution mechanisms in a repeated *4*-player public goods game with endowment heterogeneity and compare them to a *VCM*, distinguishing between a random- and an effort-based allocation of endowments. We find that endowment heterogeneities limit the efficiency gains from minimum contribution rules under random allocation. Under effort-based allocations, substantial efficiency gains relative to a *VCM* occur, though being largely driven by significant reductions of contributions in *VCM*. By apparently influencing the perception of fair burden sharing, the endowment allocation procedure crucially impacts voluntary contributions under *VCM*, while the rule-based mechanisms generate stable efficiency levels, even though endowment heterogeneity substantially limits the ability of rule-based mechanisms to achieve the potential efficiency gains.

Keywords: public good, institutions, minimum contribution rules, cooperation, endowment heterogeneity

JEL: C72, C92, H41

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1. INTRODUCTION

Many problems in public economics, in particular the voluntary provision of public goods, require appropriate institutional mechanisms to achieve a burden sharing that is perceived to be "fair" by the relevant stakeholders.[1] As such, cooperation on the provision of public goods is particularly challenging if individual preferences for burden sharing schemes differ among heterogeneous agents. Individual perceptions on what constitutes a fair distribution of cooperation gains from the provision of a public good may depend on agents' initial roles within a group of heterogeneous players, but also on issues regarding procedural fairness, i.e. under which circumstances and how these different positions accrue. That is, preferences for burden sharing schemes may depend on whether a person considers its current individual position within a society being determined mainly by its own decisions and achievements or rather as exogenously given. The accountability principle as a prominent concept within the theory of economic fairness, for instance, is inspired by ideas of proportionality and responsibility. It requires "that a person's entitlement or fair allocation (e.g., of income) varies in proportion to the relevant variables which he can influence (e.g., work effort), but not according to those which he cannot reasonably influence (e.g., a physical handicap)" (Konow 1996: p.14). Following this idea, a random allocation of different initial positions within a group of agents may foster claims for a fairness norm tending to equalize payoffs whereas an allocation based on individual efforts may rather provoke a distribution rule that assigns equal contributions to all types of players.

Against this background, we show in a related paper that the equal-payoff rule outperforms other distribution rules as well as the voluntary contribution mechanism in a public goods game when randomly allocated benefits from the public good differ between agents (Kesternich et al. 2014). Specifically, we investigate the performance of mechanisms which first require agents to agree upon a common group provision level of the public good (via implementing the minimum of proposals from group members, i.e. the smallest common denominator), before this is allocated across agents according to some predetermined burden sharing rule, without allowing for a direct redistribution of initial endowments. While the identified dominance of the payoff-equalizing rule is consistent with inequality-averse players (e.g., Fehr and Schmidt 1999), it is noteworthy that payoff-equalization can be achieved already for low levels of total public good provision since agents start with equal

[1] Ongoing discussions in international climate policy on historical responsibility of current generations in industrialized countries for past emissions and the right for economic development in emerging countries may serve as a prominent example.

endowments. This is different when agents are heterogeneous with respect to endowments, a clearly highly realistic setting.

This paper experimentally tests the performance of rule-based contribution mechanisms relative to a voluntary contribution scheme (*VCM*) under endowment heterogeneities. In a repeated *4*-player public goods game, we particularly focus on the impact of the procedure by which heterogeneous endowments are allocated to the respective players. The minimum contribution rules are inspired by two different fairness norms: equality in contributions and equality in payoffs. While the former norm may serve as a simple focal point which allows players to easily coordinate on contributions, the latter norm leads to a more differentiated burden regime but may be attractive if individuals were inequality-averse (e.g., Fehr and Schmidt 1999, Bolton and Ockenfels 2000, Charness and Rabin 2002). In order to account for procedural fairness we distinguish between a random- and an effort-based allocation of individual endowments to mimic various underlying procedures leading to initial heterogeneity within a group. One may expect the equal-payoff rule to lose some attractiveness if endowment heterogeneities were earned rather than randomly determined: the equal-payoff scheme requires larger contributions from rich players, while potentially existing inequality-aversion of players with high endowment may be reduced due to the effort-based allocation of endowments. The experiment in this paper may, thus, be interpreted as a "robustness check" for the efficiency increasing effects of burden sharing schemes, in particular of the equal-payoff rule.

Our experimental results indicate that the efficiency gains from rule-based contribution mechanisms relative to *VCM* are limited when different endowment levels are randomly allocated. Neither an equal-payoff nor an equal-contribution scheme lead to significantly larger provision levels of the public good, while they clearly affect the distribution of contributions. This finding stands in stark contrast to our previous findings. Together we can therefore conclude that different dimensions of heterogeneity, i.e. endowments vs. marginal benefits, substantially influence fairness perceptions and therewith the performance of specific distributional rule-based mechanism.

Interestingly, this picture changes under effort allocation of endowments: here, both rule-based contribution schemes generate larger average profits than *VCM*. The difference between effort-based and random allocation thereby is in part driven by the different behavior under the *VCM*: here, we observe a substantially smaller average contribution under effort-based allocation than under random allocation which originates from lower contributions by agents with high endowments. That is, voluntary contributions by highly-endowed players are reduced if those feel they deserved the higher income. Under effort, rule-based contribution schemes therefore successfully counteract coordination failures and typical downward trends in contributions in *VCM*.

However, the allocation procedure also affects the behavior in the different burden sharing mechanisms. When the equal-contribution rule is applied, agents with low endowment make lower minimum proposals under effort-based than under random allocation, thereby "accepting" disadvantageous inequality. Differently, agents with high endowment tend to increase their minimum proposal under the equal-payoff rule when comparing effort-based with random allocation. Overall, however, the equal-payoff rule under endowment heterogeneity lifts less than half of the possible efficiency gains across players. In a robustness check, we consider an increase in marginal benefits (for low-type agents) which – under the equal-payoff rule – would benefit both players: in it, we do not see enhanced coordination. As such, our results indicate that the performance of specific rule-based mechanisms is limited in the presence of endowment heterogeneities among players.

The paper is structured as follows: We summarize related literature in Section 2, before laying out the theoretical predictions for our treatments in Section 3. Section 4 explains the experimental design, before the experimental results are presented in Section 5. Section 6 concludes the paper.

2. Related Literature

This paper is related to several recent studies on contributions mechanisms that rely on a smallest common denominator rule have been found in the literature (e.g., Orzen 2008, Dannenberg et al. 2014) to be effective in enhancing cooperation gains in homogeneous settings or under heterogeneity with respect to benefits from the public good (Kesternich et al. 2014). However, these studies did not investigate endowment heterogeneities. The literature on the impact of endowment heterogeneities in a public goods context largely focuses on contribution behavior in traditional *VCM* schemes. It is found to be sensitive to the distribution of initial wealth but also to be affected by the endowment's origin and the reason for endowment heterogeneity among agents – thereby motivating our study on the performance of different distribution rules in rule-based mechanisms.

In a meta-analysis on the experimental literature on the voluntary public goods provision Zelmer (2003) finds endowment heterogeneity among agents to have a significantly negative impact on contribution behavior. Experimental results from a prisoner's dilemma experiment with heterogeneous initial endowments but homogeneous benefits suggest that subjects earning their endowments contribute more to the joint project when they are matched with subjects whose endowment is randomly allocated (Spraggon and Oxoby 2009). In contrast, studies by Chan et al. (1996, 1999) and Buckley and Croson (2006) provide evidence for a rather positive effect of endowment heterogeneity on the group provision level. Similarly, Georgantzis and Proestakis (2011) find heterogeneity in lab incomes to have a positive effect both on absolute and relative contribution levels but this does not hold when additional information on real wealth inequality of participants is available. Further recent experimental evidence on the effect of endowment heterogeneity and the relevance of information or communication is, among others, given by Anderson et al. (2008), Koukoumelis et al. (2010), and van Dijk et al. (2002).

The literature on the impact of the origin of endowment differences on individual behavior in public goods games appears ambiguous. On the one hand, Harrison and El Mouden (2011) report that the requirement for endowments to be earned through labor reduces cooperation in the public goods game among a subset of participants (those who were not familiar with game theory). On the other hand, Cherry et al. (2005) find no effect of the origin of endowments (windfall vs. earned) on contributions. Reinstein and Riener (2012) show in a charitable giving experiment that the probability of donating decreases if endowments are earned in contrast of being randomly allocated. In the same vain, Cherry (2001), Cherry et al. (2002), and Oxoby and Spraggon (2008) observe that selfish behavior in a dictator game significantly increases when the money has to be earned in a task previous to the genuine experiment.

Our study on the performance of different distribution-rules under endowment heterogeneity is further related to a stream of the experimental literature which aims at tying contribution behavior to social norms based on different fairness principles. Reuben and Riedl (2013) find contributions to be proportional to endowments if punishment is allowed and contribution possibilities are unrestricted. Kittel et al. (2012) focus on group decisions on redistribution in a *3*-player real-effort experiment. After endowments being allocated among participants according to their performance in a quiz task in the first stage, the group agrees upon redistribution of endowments by different voting rules, i.e. majority and unanimity, in the second stage. Their experimental results indicate tendencies of equalization of profits under a majority rule because of a coalition against the rich player. They conclude that "equity concerns become irrelevant against the pressure for equality" (p.26) if initial endowments are skewed and a majority rule is applied. In dictator games, experimental evidence suggest allocation decisions in many cases to correspond to certain fairness principles such as egalitarianism (i.e., equalizing all inequalities) or libertarianism (i.e., to allocate to each person what he or she produces) (e.g., Frohlich et al. 2004, Cappelen et al. 2007, Ubeda 2010). As mentioned above, in a previous experimental setting (Kesternich et al. 2014), we find that rule-based contribution schemes lead to substantial cooperation gains if agents differ in their benefits from the public good. In particular, we observe that a burden sharing rule aiming at equalizing payoffs by explicitly addressing redistribution among heterogeneous agents payoff-dominates all other burden sharing mechanisms. This paper considers the robustness of these results under endowment heterogeneity.

3. Treatment Description and Theoretical Predictions

The experimental design includes several treatments that vary along two important dimensions: (i) we study different institutions which may reduce free-riding incentives when agents are heterogeneous with respect to income, and (ii) we investigate how the performance of these institutions depends on the way income positions are allocated, i.e. randomly or based on effort.

Along the first dimension, we test in particular two rule-based contribution schemes that are inspired by different notions of distributional fairness, i.e. *eq*uality in *cont*ributions (*eqcont*) and *eq*uality in *pay*offs (*eqpay*) and compare them to the standard voluntary contribution mechanism (*VCM*).

The payoff to player i, π_i, is determined by a linear public goods game and given by

$$\pi_i = e_i - q_i + b_i Q$$

where e_i marks the initial individual endowment, q_i the individual contribution to the public good, b_i the marginal benefit from the joint project and $Q = \sum_{j=1}^{n} q_j$ the aggregated provision level of the public good.

Players in our experimental setting differ by their initial endowment: each group of four players ($n = 4$) consists of two low-type players with an endowment of $e_L = 10$ and two high-type players with $e_H = 30$. Therefore, there is a total group endowment $E =$

$\sum_{j=1}^{n} e_j = 80$ and we have $q_L \in [0,10]$ and $q_H \in [0,30]$, respectively. We focus on treatments which assume identical marginal benefits ($b_i = 0.4 < 1$) across all group members (in treatments *VCM*, *eqcont* and *eqpay*). We also include a robustness check for the equal-payoff mechanism where low-type players benefit disproportionally large from contributions to the public good ($b_H = 0.4$, $b_L = 0.8$), in *MPCR-eqpay*).

The rule-based contribution schemes (*eqcont* and *eqpay*) consist of two stages: In the first stage, the minimum stage, all players simultaneously suggest a minimum group provision level $Q_i^{min} \in [0,80]$.[2] The smallest suggested proposal then determines the lower level for the sum of individual contributions in the second stage: $Q^{min} = min_{j \epsilon S}\, Q_j^{min}$ where S is the set of players in a group. In the second stage, the contribution stage, the minimum individual contribution level, q_i^{min}, is derived from the binding minimum group provision level according to the specific predetermined burden sharing rule, i.e. $q_i^{min}(Q^{min})$.[3] Subjects have to contribute at least the minimum contribution level q_i^{min}, i.e. $q_i \geq q_i^{min}$ but can go voluntarily beyond this level.

The schemes differ in the underlying burden sharing principle: equal contributions (*eqcont*) vs. equal payoffs (*eqpay*). Depending on the suggested level Q^{min}, these principles cannot be fully realized as we do not allow for redistribution of initial endowments. In *eqcont*, the individual minimum contribution is given by $q_i^{min} = Q^{min}/4$ if $Q^{min} \leq 40$, and $q_L^{min} = 10$ and $q_H^{min} = 10 + (Q^{min} - 40)/2$ if $Q^{min} > 40$. That is, equal contributions can only be enforced as minimum requirement if the level assigned to the low-type agents does not exceed their endowment. Any additional level above $Q^{min} > 40$ has to be equally allocated across the two high-type players.

Full equalization of income would require

$$q_i^{min} = \left(e_i + b_i Q^{min}\right) - \frac{E + Q^{min}(\sum_{j=1}^{n} b_j - 1)}{n}. \quad (1)$$

In *eqpay*, given $e_L = 10$ and $e_H = 30$, $b_i = 0.4$, this is only possible if $Q^{min} \geq 40$ where $q_i^{min} = e_i - (E - Q^{min})/n$. For $Q^{min} < 40$, payoffs are maximally equalized when demanding all contributions to come from high-type agents, i.e. $q_L^{min} = 0$ and $q_H^{min} = Q^{min}/2$.

[2] Multiples of four are required.

[3] For deriving minimum individual contribution levels, integer numbers are required.

In *MPCR-eqpay*, given $e_L = 10$ and $e_H = 30$, $b_H = 0.4$ and $b_L = 0.8$, full payoff equalization according to (1) is only possible for $0 \leq -10 + 0.45Q^{min} \leq 10$ or $22.2 \leq Q^{min} \leq 44.4$. Noting that Q^{min} is constrained to multiples of 4, we obtain $q_L^{min} = 0$ and $q_H^{min} = Q^{min}/2$ for $Q^{min} \leq 20$, $q_L^{min} = 10$ and $q_H^{min} = (Q^{min} - 20)/2$ for $Q^{min} \geq 44$, while $q_L^{min} = -10 + 0.45Q^{min}$ and $q_H^{min} = 10 + 0.05Q^{min}$ for $20 < Q^{min} < 44$.

With these definitions of the treatments, we turn to the theoretical predictions. We concentrate on payoff-maximizing preferences. The predictions are graphically summarized in Figure 1. In the *VCM*, theory clearly predicts full free-riding and zero contributions in the Nash equilibrium with individual earnings $\pi_L = e_L$ and $\pi_H = e_H$.

In all burden sharing schemes, the same free-riding argument leads agents to contribute exactly the minimum level, $q_i = q_i^{min}$. Anticipating this, agents consider their potential impact on payoffs from suggesting Q_i^{min}. Their suggestion only has effect if it is binding, i.e. $Q_i^{min} = Q^{min}$.

It follows that, e.g. in *eqcont*, low-type players' payoff is increasing in Q^{min} such that they have a weakly dominant strategy to suggest $Q_i^{min} = E = 80$. High-type players would only benefit from increasing Q^{min} as long as $Q^{min} \leq 40$. As such, high-type agents have a weakly dominant strategy to choose $Q_i^{min} = 40$. Therefore, a subgame perfect equilibrium in weakly dominant strategies is characterized by $Q^{min} = 40$, $q_L = q_H = 10$ which results in $\pi_L = 16$ and $\pi_H = 36$.[4]

Applying the same logic to *eqpay*, implies that, again, low-type players have a weakly dominant strategy to suggest full contribution, i.e. $Q_i^{min} = 80$. High-type players' payoffs are first decreasing, then increasing in Q^{min}. As such, they do not have a weakly dominant strategy. Instead, they should suggest full contribution levels if they expect low-type agents to propose a minimum of $Q_i^{min} \geq 68$. For any proposal from low-type agents $Q_i^{min} < 68$, high-type players prefer $Q_i^{min} = 0$. The payoff dominant equilibrium is given by $Q^{min} = 80$ with equal payoffs at $\pi_L = \pi_H = 32$ with $q_L = 10$ and $q_H = 30$.[5] However, as high-type players do not have a weakly dominant strategy, one may expect reaching this equilibrium to be more

[4] If agents prefer to equalize payoffs they can make use of this mechanism in order to equalize their earnings by adjusting their minimum proposals. To reach the highest possible equal payoffs under this burden sharing scheme, agents have to choose the contributions $q_L = 10$, $q_H = 30$ which result in $\pi_L = \pi_H = 32$. This would be possible, for instance, if all agents agree upon $Q^{min} = 40$ and high-types voluntarily contribute more than their minimum contribution level.

[5] The highest possible payoffs with equal contributions ($q_L = q_H = 10$) under the equal-payoff rule are $\pi_L = 16$ and $\pi_H = 36$. To achieve this allocation, subjects could, for instance, agree on $Q^{min} = 20$ and low-types voluntarily contribute more.

complicated than in *eqcont* (as well as compared to the treatments in Kesternich et al. 2014, where players had homogenous endowments).

Finally, in *MPCR-eqpay*, low-type players again have weakly dominant strategy to suggest $Q_i^{min} = E$, while high-type agents would be predicted to suggest $Q_i^{min} = 44$ if low-types would suggest at least $Q_i^{min} \geq 40$ (again see Figure 1). For any proposal from low-type players $Q_i^{min} < 40$, high-type players prefer $Q_i^{min} = 0$. Therefore, the payoff dominant equilibrium in *MPCR-eqpay* is characterized by $Q^{min} = 44$, $q_L = 10$, $q_H = 12$ which results in $\pi_L = 35.2$ and $\pi_H = 35.6$.[6]

Note that we also vary the procedure of allocating the subject's endowments: it is allocated either randomly or according to the performance in an effort-related task. For payoff maximizing agents, the theoretical predictions are not to be sensitive to the endowments' origin. But given the experimental literature on earned versus windfall endowments (see Section 2) there are reasonable doubts on the hypothesis that the performance of rule-based contribution schemes may not be sensitive to the way how the endowment emerges. Our design, thus, aims at investigating whether the efficiency gains through those schemes are also observed when subjects have to show effort for earning endowment.

4. Experimental Design

We conducted the experiment at the MaXLab laboratory of the University of Magdeburg in Germany with 336 students from various academic disciplines in October 2012 and July 2013. We ran 14 sessions with 24 subjects each. We used ORSEE (Greiner 2004) for recruiting and z-tree software (Fischbacher 2007) for programming. Subjects of each session were divided randomly into six groups with four players with two high-type and two low-type agents. The group composition remained fixed throughout the experiment (partner matching).

At the beginning of each session, participants went through a set of neutrally-worded experimental instructions (see appendix) with verbal descriptions of the game and numerical examples. These instructions also contained some control questions to ensure that every participant understood the game. After that, the experiment was run on the computer. Information on player's type (high-type or low-type player), contributions (in tokens) and payoffs (in Labdollars LD) was provided via screen. The four subjects of one group received

[6] The highest possible payoffs with equal contributions ($q_L = q_H = 10$) under the equal-payoff rule with heterogeneous marginal benefits are $\pi_L = 32$ and $\pi_H = 36$. To achieve this allocation, subjects could, for instance, agree on $Q^{min} = 20$ and low-types voluntarily contribute more.

full information on minimum proposals, individual and average contributions and payoffs within their group. Furthermore, each subject knew which group member was a high-type and which was a low-type player. The experimental design is summarized in Table 1.

We consider seven different treatments. Each treatment was conducted in two sessions, we have 12 independent observations per treatment. In three of the seven treatments (*R-VCM*, *R-eqcont*, *R-eqpay*) subjects were *r*andomly chosen to be a low- or a high-type player at the beginning of the experiment. In four treatments (*E-VCM, E-eqcont, E-eqpay, E-MPCR-eqpay*), the performance of the players within one group in a real *e*ffort task determined whether a player became a high-type or a low-type.

The real effort was introduced by a slider task (Gill and Prowse 2011, 2012). We provide a screenshot in the appendix (Figure 4). The task is given by a single screen containing 48 sliders which players have to position exactly at 50 within a time frame of 180 seconds. For each slider, correctly positioned at the end of the time period, one point is allocated to the subject's point score. There was information on the own current point score and the amount of time remaining on the screen. Separated instructions for the slider task were transmitted via screen to the participants. Furthermore, we implemented a trial phase of 30 seconds at the beginning of the real effort task to make participants familiar with the slider task and avoid technical problems. After the real effort task was finished, the two subjects with the highest point score within one group became high-type players in the public goods game; the remaining two players became low-type players. Subjects were only informed about their own point score after the real effort task. If there was a tie, if necessary lots were drawn automatically by the computer to take the final decision. This happened in three out of 48 groups.

A session consisted of 12 rounds, including two practice rounds at the beginning. Individual earnings were chosen randomly out of one none-practice round at the end of the experiment and paid out confidentially. The exchange rate between Euro and LD was 1:2. Sessions, on average, lasted about 60 minutes with windfall allocations and about 70 minutes if the real effort task was part of the treatment. Subjects on average earned about 13 Euros. We did not pay any additional show-up fee.

5. Experimental Results

Table 2 reports average contributions and average profits for each treatment across all periods, and across the first and second half of the sessions. We further provide results of non-parametric Mann-Whitney U tests (MW-U) in Table 4. Moreover, Figure 2 and Figure 3 plot contribution behavior and profits over time. Further statistical evidence is given by a series of random effects regression models (see Table 6 and Table 8) which control for treatment differences, time effects and some socio-demographic variables (gender, lab experience, economics student y/n). Throughout the paper our discussion is primarily based on the non-parametric tests in order to avoid repetitions. We refer to the regression results only in cases where differences between the two statistical methods appear.

Initial insights into the respective treatments are best obtained by considering contribution behavior. Averaged over all periods (excluding trial periods) and agents, contributions are lowest in *VCM* under effort (4.3 tokens) and highest in an equal-payoff scheme under effort (9.6) (see Table 2). If we focus on the second part of the sessions (periods 6-10) the picture is even more pronounced: In the last 5 periods, average contributions decline to 2.9 in *E-VCM* and stabilize at 9.5 in *E-eqpay*. In general, as can be derived from Figure 2, average contributions in our rule-based contribution schemes rather quickly stabilize after the first periods and tend to be successful in counteracting typical downward trends in contribution patterns in *VCM* over time. Further evidence for this observation is provided by our regression results (Table 6, columns 1-3) and non-parametric tests on time trends (Table 7): While contributions clearly decline in *VCM* over time ($p<0.01$), there is only weak statistical evidence for decreasing contributions in *eqcont* (both variants) and for *R-eqpay* ($p<0.1$). In an equal-payoff scheme with effort-based allocation our results do suggest contributions to be stable over time.

For the further discussion on the performance of rule-based mechanisms, we focus on the last 5 periods. The tables also report the results for the first 5 periods as wells as for averages across all 10 periods.

It is instructive to first consider the performance of rule-based mechanisms vs. *VCM* under random allocation as this can directly be linked to the results under heterogeneity with respect to marginal benefits as reported in Kesternich et al. (2014). While Kesternich et al. (2014) find both equal-contribution and equal-payoff rule to lead to significantly larger contributions (and payoffs) than the VCM, we do not find such result when heterogeneous endowments are randomly allocated. Instead, the contribution averages in *R-eqcont* (7.6) and *R-eqpay* (6.5) are not significantly larger than in *VCM* (5.8) (MW-U, Table 4, see also regressions Table 6, column 4). The different mechanisms have, however, distributional consequences: contributions by low-type players are larger under *R-eqcont* than under *R-eqpay* ($p<0.05$, MW-U) and *VCM* (p<0.01, MW-U). This directly leads high-type players to have larger payoffs in *R-eqcont* than in the other two mechanisms (MW-U, p<0.01; mixed evidence in regressions Table 8), while for low-types and averaged across types no significant payoff changes are observed.[7] We summarize these observations as follows:

Result 1. *Under random allocation of heterogeneous endowments, both minimum contribution schemes based on equal contributions and equal payoffs do not generate larger contributions and payoffs than a VCM.*

Result 1 stands in stark contrast to the results in Kesternich et al (2014). Together we can therefore conclude that the type of heterogeneity (endowment vs. benefits) has a strong influence on the performance of specific distributional rule-based mechanisms.

Interestingly, the situation changes when considering an effort-based allocation. Here, average contributions in the last 5 periods in both burden sharing schemes (*eqcont* 6.6, *eqpay* 9.5) are significantly larger (at least p<0.1, MW-U, Table 4, regressions Table 6, p<0.05) than in *VCM* (2.9). The difference is driven by increased contributions from both players in *eqcont* (high: 7.5, low: 5.7) relative to *VCM* (high: 3.6, low: 2.3) (at least p<0.1), while particularly high-types significantly (p<0.01) increase contributions under *eqpay* (high: 14.1, low: 5.0). Consequently, both rule-based mechanisms significantly increase average payoffs and payoffs of low-types (at least p<0.1, MW-U; only obtained for *eqpay* in Table 6, column 6: p<0.01). High-types only have significantly larger payoffs under *eqcont* (p<0.01), these also being significantly larger than in *eqpay* (p<0.01). It is noteworthy that the benefits particularly accrue over time: non-parametric tests show a declining trend for payoffs in *E-VCM* for all player types (p<0.01, Table 8), while payoffs are more stable in the rule-based mechanisms, in particular *E-eqpay*.

We thus can formulate our second result:

Result 2. *Under effort-based allocation of heterogeneous endowments, both minimum contribution schemes lead to increases in average contributions and payoffs in contrast to a VCM. Low-endowed players benefit from both burden sharing rules. Players with high endowments benefit relative to VCM only under the equal-contribution rule which leads to strictly larger payoffs than the equal-payoff rule.*

[7] As can be seen from Figure 3, average profits rather tend to decline over time, most notably in the last 5 periods. The results of a non-parametric trend test (Table 8) also confirm this downward trend for all treatments under random allocation.

For effort-based allocations, Result 2 thus reestablishes the benefits from minimum contribution mechanisms that have been identified in the literature for homogeneous agents (Orzen 2008, Dannenberg et al. 2010) and under heterogeneities with respect to benefits from the public good (Kesternich et al. 2014). Although we found differing results on the performance of rule-based mechanisms relative to *VCM* under random vs. effort-based allocations, neither average nor type-specific contribution level significantly differ when directly comparing *R-eqcont* vs. *E-eqcont* and *R-eqpay* vs. *E-eqpay*. For payoffs, the difference is only (marginally) significant for high-types who generate larger payoffs in *E-eqpay* than *R-eqpay* (p<0.1).

Instead, the differences between Result 1 and 2 appear to be partly driven by the significantly reduced contributions by high-type players in *VCM* when turning from a random to an effort-based allocation of endowments (3.6 vs. 8.3, p<0.05).[8] This already indicates that the allocation procedure may change potential fairness norms which trigger voluntary contributions: while high-type players are willing to contribute substantially more than low-type players in *R-VCM* (p<0.01, Wilcoxon-matched pairs test; further evidence in Table 6, columns 5,6), the difference is insignificant under effort-based allocation of endowments in *E-VCM*.[9]

The rule-based mechanisms implement specific burden shares: for both random and effort-based allocations, the resulting contribution levels under *eqcont* do not differ across types, while high-types contribute significantly more than low-types in *eqpay* (p<0.01, postestimation in Table 6, column 6). As such, it is instructive to have a closer look at how the allocation procedure changes the acceptance of the two implemented burden-sharing rules: considering the endogenous burden sharing under *VCM*, one may expect an equal minimum contribution requirement (*eqcont*) to be better suited under effort-based allocation, while the stronger contribution requirements for high-types in *eqpay* might be more acceptable under random allocation. To investigate this, we consider two different indicators for the acceptance of the implemented burden-sharing rules: (i) the proposed minimum levels Q_i^{min} and (ii) voluntary contributions, defined by $q_{delta} = q_i - q_i^{min}$, i.e. contributions which go beyond the thereby determined individual minimum contribution levels.

The summary statistics for minimum proposals and voluntary contribution levels for the rule-based mechanisms are reported in Table 3. Non-parametric Mann-Whitney U tests on

[8] Across all periods, the difference is also significant when comparing average contributions (p<0.1).
[9] Note that high-type players earn more than low-type players in all treatments (p<0.01, MW-U).

treatment effects are summarized in Table 5. We again concentrate the discussion on the last 5 periods.

As derived in Section 2 and illustrated in Table 1, in equal-contribution schemes payoff-maximizing high-type players are expected to make a group minimum contribution proposal of $Q = 40$, while low-types may suggest anything between 40 and 80, in fact leading to $q_L^{min} = q_H^{min} = 10$. Binding minimum group contribution levels in *eqcont* are lower under effort (20.9) than under random allocation (26.0) in our experimental data (Table 3). In line with the theoretical predictions, average proposals from high-type players (random: 44.8, effort: 39.1) are lower than those of low-type players (random: 59.8, effort: 44.6). Due to differing proposals from the group members, it is further instructive to compare the minimum of the type-specific minimum proposals, i.e. $\min_{j\epsilon \text{high}} Q_j^{min}$ vs. $\min_{j\epsilon \text{low}} Q_j^{min}$. This is larger for low-types than high-types under random allocation (49.2 vs. 31.9, p<0.05, Wilcoxon matched pairs test) in *eqcont*, while being almost identical under effort-based allocation (30.4 vs. 31.1). As such, the binding minimum group contribution levels in *eqcont* predominantly stem from high-type players under random allocation (71%), while low-types more often determine the binding minimum level under effort-based allocation (52%). Allocating endowments based on effort rather than randomly therefore appears to particularly decrease the proposals from low-types (p<0.05, Table 5). Considering the distribution of proposals allows gaining insights into possible motivation for this decline: under random allocation, 51% of low-type players' suggestions correspond to their (potentially) payoff maximizing group contribution level ($Q = 80$), while less than 4% suggest a level which maximizes high-type players' payoffs ($Q = 40$). Under effort-based endowment allocation, the rate of low-type players suggestions at $Q = 80$ drops to 26%, while 13% of suggestions are at $Q = 40$. This may indicate that low-type players tend to better accept larger payoffs to high-types at the expense of their own payoffs under effort-based allocation than under random allocation of endowments. In this sense, equal-contribution schemes appear to be accepted under effort-based allocations, even though this does not result increased total (minimum) contributions.

In the equal-payoff scheme, we expect both players to suggest $Q = 80$ in the payoff-dominant equilibrium. Both under random and effort allocation suggestions from low-types (random: 58.1, effort: 61.7) exceed those of their rich counterparts (random: 34.8, effort: 52.1) (both p<0.01, Wilcoxon matched pairs). The same relationship holds when just considering the lowest proposal per type (for low-types random: 48.7, effort: 50.1; for high-types random: 25.3, effort: 41.3). Differently from the equal-contribution schemes, the endowment allocation procedure under the equal-payoff rule primarily affects suggestions by high-type players, even though the difference is not significant.

Comparing both allocation procedures, we see surprisingly similar suggestions for the minimum contribution levels under random allocation (for low-types 49.2 vs. 48.7; for high-types 31.9 vs. 25.3 in *R-eqcont* and *R-eqpay*, respectively) even though both mechanisms substantially differ in the distribution of burdens. Under effort-based allocation, however, proposals from low-types in *eqcont* are reduced relative to random allocation ($p<0.05$), while high-types tend to make larger proposals in *eqpay* under effort-based than under random allocation (though not significant). Consequently, under effort-based allocation, both player types tend to make larger proposals in *E-eqpay* than in *E-eqcont* (for low-types, $p<0.1$).

It is noteworthy that players voluntarily go beyond the minimum contribution requirement. Under the equal-contribution rule, this applies particularly to high-type players (*R-eqcont*: 1.4, *E-eqcont:* 1.9), and less to low-types (*R-eqcont*: 0.7, *E-eqcont:* 0.8). Under equal-payoff rules, this is reversed such that voluntary contributions largely stem from low-types (*R-eqpay*: 0.7, *E-eqpay:* 1.1 for low-types vs. *R-eqpay*: 0.1, *E-eqpay:* 0.1 for high-types). As such, the equal-contribution rule appears to be seen as requiring disproportionately large contributions from low-types, while the equal-payoff rule may require too much from high-types.

We summarize our findings as follows:

Result 3. *(i) No differences in the performance of the rules exist under random allocation, and only marginal differences exist under effort-based allocation, both with respect to minimum proposals as well as voluntary contributions. (ii) The allocation procedure does not significantly affect the efficiency reached under both rule-based mechanisms, while the efficiency of the VCM is inferior under effort-based relative to random allocation.*

Our experiment therefore shows that while rule-based mechanisms, in particular the equal-payoff scheme, can increase contributions to a public good relative to a *VCM* under effort-based allocation of endowments, these gains are largely due to the mediocre performance of the *VCM* under effort-based allocation. As such, in particular the equal-payoff scheme can counter the failure of individuals to voluntary cooperate when their (endogenously determined) endowments differ. However, the equal-payoff rule lifts less than half of the possible efficiency gains across players (average contributions 9.5 vs. possible 20). While higher efficiency levels were reached in homogeneous settings (Orzen 2008, Dannenberg et al. 2014), the efficiency levels we identified under the equal-payoff scheme are similar to those found in Kesternich et al. (2014) under heterogeneities with respect to the marginal benefits from the public good (MPCR 0.3 and 0.7, for 2 low- and 2 high-types, respectively; endowment 20 tokens for all).

As a robustness check to this positive interpretation of our results for the equal-payoff rule under effort-based allocation, we finally discuss the results from the final treatment which introduces an additional dimension of heterogeneity: agents are both unequally endowed agents and differ with respect to their benefits from the public good. In contrast to the previous treatments, low-type players have a MPCR of 0.8 while benefits for high-type players remain at 0.4. Given our experimental setting, players are expected to coordinate towards the payoff-dominating equilibrium $Q = 44$ which would require $q_L = 10$ and $q_H = 12$ and $\pi_L = 35.2$ and $\pi_H = 35.6$. In this setting, equalizing payoffs at the same time would require nearly identical contributions from both types of players which may facilitate coordination in contrast to the homogeneous MPCR setting where redistribution of efficiency gains is addressed by requiring higher contributions from well-endowed agents. As depicted in Figure 1, the payoff to high-type agents is relatively flat for changes in the minimum requirement, while low-type agents substantially benefit from increases in the binding group minimum level. For any given binding minimum, Q^{min}, both types can generate larger payoffs in *E-eqpay-MPCR* than in *E-eqpay*. However, we observe players on average to agree upon $Q^{min} = 27.3$ which is even below the proposals with homogeneous MPCRs in *E-eqpay* (35.7). In particular, high-type players make smaller suggestions, even though these differences and also those in contribution behavior are not significant. Comparing *E-eqpay* and *E-eqpay-MPCR* therefore shows that an increase in marginal benefits does not necessarily enhance coordination, even though the distribution scheme is designed such that both players benefit. This final treatment thereby further indicates that heterogeneities among players may obscure the performance of specific rule-based mechanisms, potentially because players have different views on what constitutes a fair distribution.

6. CONCLUSIONS

The (voluntary) provision of public goods relies on effective ways to limit free-riding behavior. When the relevant agents are heterogeneous, for example with respect to endowment or benefits from the public good, questions arise on how to share the burden of the provision of the public good. The perception of fair distributions interacts with issues regarding procedural fairness, i.e. under which circumstances and how these different positions are determined.

In this paper, we experimentally test different rule-based contribution mechanisms in a repeated *4*-player public goods game and compare them to a *VCM*. In our experimental setting, the players differ in their individual endowments. With this, we provide a robustness check and extend the existing literature that concentrates on homogeneous players or on heterogeneous benefits from the public good.

We find that endowment heterogeneities limit the efficiency gains from minimum contribution rules, in particular under random allocation. Here, they just appear to redistribute voluntary contributions that even would occur under a VCM. Under effort-based allocations, however, the schemes generate substantial efficiency gains relative to a VCM. These efficiency gains can in particular be obtained with a scheme that aims at harmonizing payoffs, consistent with findings in Kesternich et al. (2014). However, the improvements relative to VCM appear to be largely driven by an even worse performance of the VCM than under random allocation as players with high endowment reduce their contributions. Our results therefore show that the procedure how allocations are distributed indeed has an impact on the potential benefits from using minimum mechanisms, but not necessarily through affecting the efficiency of the different rule-based mechanisms themselves. However, endowment heterogeneity appears to substantially limit lifting the potential efficiency gains under rule-based mechanisms. This also holds when low-endowed agents disproportionally benefit from contributions to the public good.

Our results indicate that heterogeneities (randomly or effort-based induced) may induce differing views on what agents perceive as a fair distribution, thereby limiting the coordination under a given allocation procedure. In this paper, we concentrated on the equal-payoff and the equal-contribution schemes only. Clearly, other distribution schemes may improve upon the performance of the rule-based mechanism, for example a rule which distributes burdens proportional to endowment. Furthermore it is worthwhile to explore if an endogenous choice of the specific burden sharing rule may lead to further efficiency gains. We leave these questions to further research.

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APPENDIX

Table 1: Experimental design

Treatment	Stages	No. of subjects (ind. obs.)
R-VCM	contribution stage	48 (12)
E-VCM	real effort task, contribution stage	48 (12)
R-eqcont	minimum and contribution stage	48 (12)
E-eqcont	real effort task, minimum and contribution stage	48 (12)
R-eqpay	minimum and contribution stage	48 (12)
E-eqpay	real effort task, minimum and contribution stage	48 (12)
E-MPCR-eqpay	real effort task, minimum and contribution stage	48 (12)

Table 2: Summary statistics for contributions and profits

Treatment	q_{all}	q_L	q_H	π_L	π_H	π_{all}
			All periods			
R-VCM	7.6	4.1	11.1	18.1	31.1	24.6
E-VCM	4.3	3.2	5.5	13.8	31.4	22.6
R-eqcont	8.2	6.6	9.8	16.5	33.3	24.9
E- eqcont	6.9	5.9	7.8	15.1	33.2	24.1
R-eqpay	7.0	2.9	11.0	18.2	30.1	24.2
E-eqpay	9.6	5.1	14.1	20.3	31.2	25.7
E-MPCR-eqpay	7.1	5.3	8.8	27.3	32.5	29.9
			Periods 1-5			
R-VCM	9.5	5.0	13.9	20.1	31.3	25.7
E-VCM	5.7	4.0	7.4	15.1	31.8	23.4
R-eqcont	8.8	6.7	10.9	17.4	33.2	25.3
E-eqcont	7.2	6.1	8.2	15.3	33.3	24.3
R-eqpay	7.4	2.7	12.1	19.1	29.8	24.4
E-eqpay	9.6	5.1	14.1	20.3	31.2	25.7
E-MPCR-eqpay	7.0	5.5	8.6	27.1	32.6	29.9
			Periods 6-10			
R-VCM	5.8	3.2	8.3	16.0	30.9	23.4
E-VCM	2.9	2.3	3.6	12.4	31.1	21.8
R-eqcont	7.6	6.4	8.7	15.7	33.4	24.5
E- eqcont	6.6	5.7	7.5	14.8	33.1	23.9
R-eqpay	6.5	3.1	10.0	17.4	30.5	23.9
E-eqpay	9.5	5.0	14.1	20.3	31.2	25.7
E-MPCR-eqpay	7.1	5.2	9.0	27.5	32.3	29.9

Note: q = average contributions: per group (q_{all}), for low-types (q_L) and for high-types (q_H), π = average profits: per group (π_{all}), for low-types (π_L) and for high-types (π_H)

Table 3: Summary statistics for minimum proposals and voluntary contributions

Treatment	$Q_{min_p,L}$	$Q_{min_p,H}$	min (Q_{min_p})	min ($Q_{min_p,L}$)	min ($Q_{min_p,H}$)	$q_{min,L}$	$q_{min.H}$	$q_{delta,a}$	$q_{delta,L}$	$q_{delta,H}$
					All periods					
R-eqcont	58.5	45.7	26.1	47.6	31.8	5.6	7.5	1.6	1.0	2.3
E-eqcont	43.9	37.6	19.6	30.4	28.3	4.7	5.2	2.0	1.3	2.7
R-eqpay	56.2	37.9	24.1	46.7	26.2	1.9	10.1	0.9	1.0	0.9
E-eqpay	63.9	52.0	33.4	52.8	40.4	3.4	13.4	1.2	1.7	0.7
E-MPCR-eqpay	59.5	44.0	24.7	51.0	28.0	4.2	8.2	0.9	1.1	0.7
					Periods 1-5					
R-eqcont	57.1	46.6	26.3	46.1	31.7	5.5	7.7	2.2	1.2	3.3
E-eqcont	43.1	36.1	18.3	30.3	25.5	4.4	4.7	2.6	1.8	3.5
R-eqpay	54.4	41.0	23.8	44.7	27.1	1.5	10.5	1.4	1.3	1.6
E-eqpay	66.0	51.9	31.1	55.5	39.5	2.8	12.8	1.8	2.3	1.3
E-MPCR-eqpay	55.7	43.4	22.1	45.1	27.3	3.7	7.4	1.5	1.8	1.2
					Periods 6-10					
R-eqcont	59.8	44.8	26.0	49.2	31.9	5.7	7.3	1.1	0.7	1.4
E-eqcont	44.6	39.1	20.9	30.4	31.1	4.9	5.6	1.3	0.8	1.9
R-eqpay	58.1	34.8	24.4	48.7	25.3	2.4	9.8	0.4	0.7	0.2
E-eqpay	61.7	52.1	35.7	50.1	41.3	3.9	13.9	0.6	1.1	0.1
E-MPCR-eqpay	63.2	44.6	27.3	56.9	28.7	4.8	8.9	0.2	0.4	0.1

Note: Q_{min_p} = average minimum contribution proposals from low-type $\left(Q_{min_p,L}\right)$ and from high-type $(Q_{min_p,H})$, min(Q_{min_p}) = minimum of the minimum contribution proposals from low-type $\left(\min(Q_{min_p,L})\right)$ and from high-type $\left(\min(Q_{min_p,H})\right)$, q_{min} = average binding minimum contribution level: for low-type $\left(q_{\min,L}\right)$ and for high-type $(q_{\min,H})$, $q_{\text{delta}} = q_i - q_{min}$: for low-type $\left(q_{\text{delta},L}\right)$ and for high-type $(q_{\text{delta},H})$ and averaged over all players $(q_{delta,a})$

Table 4: Tests between treatments (MW U test)

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
q_i all	Period 1-10						Period 6-10					
E-VCM	<*						<					
R-eqcont	>	>**					>	>***				
E-eqcont	>	>*	<				>	>**	<			
R-eqpay	<	>	<	<			<	>	<	<		
E-eqpay	>	>	>	>	>		>	>*	>	>	>	
MPCR-E-eqpay	>	>	<	>	<	<	>	>	<	>	>=	<

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
q_L	Period 1-10						Period 6-10					
E-VCM	<						<					
R-eqcont	>**	>***					>***	>***				
E-eqcont	>*	>***	<				>*	>***	<			
R-eqpay	<	<	<***	<***			<	>	<**	<*		
E-eqpay	>	>	<	<	>		>	>	<	<	>	
MPCR-E-eqpay	>	>*	<	<	>**	>	>	>*	<	<	>	<

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
q_H	Period 1-10						Period 6-10					
E-VCM	<**						<**					
R-eqcont	<	>*					>	>**				
E-eqcont	<	>	<				>	>*	<			
R-eqpay	<	>	>	>			<	>*	<	>		
E-eqpay	>	>*	>	>	>		>	>**	>	>	>	
MPCR-E-eqpay	<	>	<	>	<	<	>	>*	>	>	<	<

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
π_i all	Period 1-10						Period 6-10					
E-VCM	<*						<					
R-eqcont	>	>**					>	>***				
E-eqcont	>	>*	<				>	>**	<			
R-eqpay	<	>	<	<			<	>	<	<		
E-eqpay	>	>	>	>	>		>	>*	>	>	>	
MPCR-E-eqpay	>	>**	>	>*	>**	>*	>	>**	>	>	>*	>

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
π_L	Period 1-10						Period 6-10					
E-VCM	<***						<**					
R-eqcont	<	>**					>	>**				
E-eqcont	<**	>	<				<	>*	<			
R-eqpay	<	>**	>	>			<	>*	>	>		
E-eqpay	>	>**	>	>*	>		>	>**	>	>	>	
MPCR-E-eqpay	>**	>***	>**	>***	>**	>**	>	>***	>*	>*	>*	>

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*
π_H	Period 1-10						Period 6-10					
E-VCM	>						<					
R-eqcont	>***	>***					>***	>***				
E-eqcont	>***	>***	>=				>***	>***	<			
R-eqpay	<***	<***	<***	<***			<	>	<***	<***		
E-eqpay	>=	>	<***	<***	>***		>	>	<***	<***	>*	
MPCR-E-eqpay	>***	>***	<**	<	>***	>***	>*	>	<	>	>**	>*

Note: According to a MW-U test, the null hypothesis states that the median of two independent groups is equal. In our case, average contributions respectively profits per group over all periods or in the last 5 periods serve as one observation. We compare rows with columns. *p<0.1, **p<0.05 and ***p<0.01. Example: average contributions q_i of all players over all periods in *eqpay* are higher than in *VCM*, this difference is significant at the 1%-level

Table 5: Tests between treatments (MW U test): Minimum of minimum contribution proposals

Treatment	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*
Min(Qmin)all	Period 1-10				Period 6-10			
R-eqcont	>	>	<	<	>	>	<	<
E-eqcont		>	<	<		>	<	<
R-eqpay			<	>			<	=
E-eqpay				>				>
Treatment	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*
Min(Qmin)low	Period 1-10				Period 6-10			
R-eqcont	>**	<	<	<	>**	<	<	<
E-eqcont		<	<**	<**		<	<*	<**
R-eqpay			<	<			<	<
E-eqpay				>				<
Treatment	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*
Min(Qmin)high	Period 1-10				Period 6-10			
R-eqcont	>	>	<	>	>	>	<	>
E-eqcont		>	<	<		>	<	<
R-eqpay			<	>			<	<
E-eqpay				>				>

Note: According to a MW-U test, the null hypothesis states that the median of two independent groups is equal. In our case, the average of the minimum of the minimum contribution proposal per group over all periods or in the last 5 periods serve as one observation. We compare rows with columns. *p<0.1, **p<0.05. Example: average min(Qmin) of low-type players over all periods in *R-eqcont* are higher than in *E-eqcont*, this difference is significant at the 5%-level.

Definition of variables

q_i	Individual contribution of subject i to the public good
profit	Subject i's profit
eqcont	= 1 if subject i played treatment *R-eqcont*/*E-eqcont*, 0 else
eqpay	= 1 if subject i played treatment *R-eqpay*/*E-eqpay*, 0 else
MPCReqpay	= 1 if subject i played treatment *E-MPCR-eqpay*, 0 else
per6_10	= 1 for the last 5 periods, 0 else
per6_10Xeqcont	= 1 for the last 5 periods <u>and</u> played *R-eqcont*/*E-eqcont,* 0 else
per6_10Xeqcont	= 1 for the last 5 periods <u>and</u> played *R-eqpay*/*E-eqpay,* 0 else
per6_10XMPCReqpay	= 1 for the last 5 periods <u>and</u> played *E-MPCR-eqpay,* 0 else
eff	= 1 if endowment was allocated based on real effort task, 0 else
effX*burden sharing rule*	= 1 under effort allocation and played *burden sharing rule*, 0 else
high	= 1 if subject i is a high-type player, 0 else
highX*burden sharing rule*	= 1 if subject i is a high-type player <u>and</u> played *burden sharing rule*, 0 else
highXeff	= 1 if subject i is a high-type player <u>and</u> effort allocation of endowments
highXeff*burden sharing rule*	= 1 if subject i is a high-type player <u>and</u> effort allocation of endowments <u>and</u> subject i played *burden sharing rule*, 0 else
male	= 1 if subject i is male, 0 if female
exp	number of experiments subject i has taken part in MaXLab
eco	= 1 if subject i is economics student, 0 else

Estimation strategy:

We report results from using a random-effects Feasible Generalized Least Square estimator (RE FGLS) for determining differences in individual contributions and payoffs. 2 individuals had to be removed from the econometric analysis due to missing sociodemographic information. Moreover, the discussion of the regression results throughout the paper is based on standard errors computed at individual levels. This approach explicitly considers individual heterogeneity across participants. For robustness check, we further applied pooled FGLS regressions without explicitly modeling of the individual heterogeneity but allowing the error terms of observations from one single individual to be correlated over time. We specified the model in a way that error correlation declines as the time differences between observations increase. That is, the decision behavior of the current period may be influenced by some effects from past periods (that do not enter the regression as explanatory variables) but this effect lowers if time lags increase. In the FGLS random effect model, error correlation can only be captured by clustering observations on the individual level without accounting for declining error correlation over time. We apply a AR(2) approach which adequately fits to the error correlation observed after running a standard OLS regression.

For estimating contribution decisions, we further run a panel Tobit model. This estimator controls for the fact that the dependent variable (individual contributions to the public good) may be left-censored with a known lower limit of 0 (28.71% of all contribution decisions). We do not specify an upper limit since endowments vary across individuals. Specification tests suggest the Tobit model not to be sensitive to the number of quadrature points used in the estimation process. Similar to the regression on payoffs, results for contribution behavior in the pooled model are similar to the random effects model. We therefore do not include these results in the paper but provide the tables upon request.

Table 6: FGLS Random-effects regression of individual contributions

VARIABLES	(1) q_i Period 1-10	(2) q_i Period 1-10	(3) q_i Period 1-10	(4) q_i Period 6-10	(5) q_i Period 6-10	(6) q_i Period 6-10
eqcont	-0.529	0.622	1.425	1.815	2.535*	3.310***
	(1.917)	(1.431)	(0.916)	(1.875)	(1.447)	(0.984)
eqpay	-2.094	-4.209**	-2.849**	0.757	-1.700	-0.252
	(2.301)	(1.806)	(1.125)	(2.463)	(1.949)	(1.301)
MPCReqpay	1.295	1.930	0.885	4.102**	3.875***	3.046**
	(1.586)	(1.179)	(0.999)	(1.846)	(1.421)	(1.274)
per6_10	-3.164***	-3.164***	-3.164***			
	(0.355)	(0.355)	(0.355)			
per6_10Xeqcont	2.241***	2.241***	2.241***			
	(0.727)	(0.727)	(0.727)			
per6_10Xeqpay	2.720**	2.720**	2.720**			
	(1.103)	(1.104)	(1.104)			
per6_10XMPCReqpay	3.122***	3.122***	3.122***			
	(1.044)	(1.045)	(1.045)			
eff	-3.333*	-3.259*	-1.078	-2.817	-2.761	-1.025
	(1.769)	(1.736)	(0.862)	(1.761)	(1.728)	(0.954)
effXeqcont	1.800	1.431	-0.182	1.729	1.403	-0.152
	(2.279)	(2.243)	(1.145)	(2.341)	(2.308)	(1.343)
effXminQeqpay	5.939*	5.849*	3.177**	5.790*	5.723*	2.866
	(3.164)	(3.151)	(1.534)	(3.478)	(3.477)	(1.800)
high		4.788***	6.956***		3.391***	5.118***
		(1.198)	(1.775)		(1.128)	(1.628)
highXeqcont		-2.216	-3.821*		-1.367	-2.914
		(1.533)	(2.319)		(1.474)	(2.221)
highXeqpay		4.165**	1.506		4.846**	2.000
		(1.879)	(2.584)		(1.900)	(2.561)
highXMPCReqpay		-0.896	1.321		0.795	2.559
		(1.623)	(1.726)		(1.494)	(1.679)
highXeff			-4.398**			-3.500*
			(2.226)			(2.111)
highXeffXeqcont			3.304			3.165
			(2.876)			(2.786)
highXeffXeqpay			5.352			5.715
			(3.771)			(3.833)
male	-0.487	-0.957	-0.914	-0.473	-0.879	-0.862
	(0.812)	(0.707)	(0.712)	(0.877)	(0.776)	(0.778)
exp	-0.0381	-0.0935	-0.0901	-0.00345	-0.0551	-0.0523
	(0.0620)	(0.0572)	(0.0564)	(0.0621)	(0.0575)	(0.0569)
eco	-0.257	0.0233	0.205	-0.177	0.0732	0.217
	(1.031)	(0.882)	(0.898)	(1.107)	(0.965)	(0.971)
Constant	9.815***	7.966***	6.775***	6.118***	4.917***	3.977***
	(1.793)	(1.351)	(1.005)	(1.808)	(1.414)	(1.135)
Observations	3,340	3,340	3,340	1,670	1,670	1,670
R-sq	0.04	0.17	0.17	0.05	0.15	0.15

Note: We consider individual level random effects, i.e. one observation for one individual corresponds to the panel variable and the period sets the time variable: 334 individual observations x 10 periods (columns 4-6: 5 periods) = 3,340 (1,670) total observations. Robust standard errors in parentheses, adjusted for group clusters, *** p<0.01, ** p<0.05, * p<0.1

Table 7: Time trends in contributions over time

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*
All players	▼***	▼***	▼*	▼*	▼*		
low-type	▼***	▼***					
high-type	▼***	▼***	▼**				

Note: Average contributions per (sub-)group in each of the ten periods of the game serve as one observation. Jonckheere-Terpstra for ordered differences of a response variable among classes, the null hypothesis states that the distribution of the frequency of a given contribution level does not differ among rounds. ▼:= decreasing profits over time, ▲:= increasing profits over time,* p<0.1, ** p<0.05, *** p<0.01

Table 8: FGLS Random-effects regression of individual profits

VARIABLES	(1) profit Period 1-10	(2) profit Period 1-10	(3) profit Period 1-10	(4) profit Period 6-10	(5) profit Period 6-10	(6) profit Period 6-10
eqcont	-0.560	-1.588	-2.372	0.891	0.260	-0.488
	(1.219)	(1.772)	(2.233)	(1.206)	(1.697)	(2.146)
eqpay	-1.309	0.698	-0.671	0.441	2.852	1.463
	(1.407)	(2.106)	(2.628)	(1.491)	(2.214)	(2.727)
MPCReqpay	5.851***	11.16***	12.21***	7.688***	13.82***	14.59***
	(1.890)	(3.479)	(3.515)	(2.275)	(4.014)	(4.054)
per6_10	-2.013***	-2.013***	-2.013***			
	(0.220)	(0.220)	(0.220)			
per6_10Xeqcont	1.459***	1.459***	1.459***			
	(0.439)	(0.440)	(0.440)			
per6_10Xeqpay	1.747***	1.747***	1.747***			
	(0.664)	(0.665)	(0.665)			
per6_10XMPCReqpay	1.933	1.933	1.933			
	(1.388)	(1.389)	(1.390)			
eff	-2.218*	-2.000*	-4.175**	-2.026*	-1.790	-3.409*
	(1.196)	(1.107)	(2.097)	(1.213)	(1.104)	(2.048)
effXeqcont	2.104	1.430	3.005	2.166	1.453	2.953
	(1.557)	(1.445)	(2.745)	(1.628)	(1.486)	(2.717)
effXminQeqpay	3.923**	3.614*	6.304*	3.969*	3.638*	6.379
	(1.976)	(1.926)	(3.731)	(2.148)	(2.102)	(3.946)
high		15.21***	13.05***		16.57***	14.96***
		(1.133)	(1.709)		(1.043)	(1.597)
highXeqcont		2.239	3.805*		1.455	2.948
		(1.480)	(2.235)		(1.392)	(2.136)
highXeqpay		-3.924**	-1.246		-4.727**	-1.996
		(1.933)	(2.588)		(1.940)	(2.569)
highXMPCReqpay		-9.934***	-12.15***		-11.55***	-13.19***
		(3.482)	(3.516)		(3.696)	(3.743)
highXeff			4.387**			3.264
			(2.101)			(2.001)
highXeffXeqcont			-3.226			-3.052
			(2.806)			(2.713)
highXeffXeqpay			-5.389			-5.486
			(3.711)			(3.765)
male	1.931**	1.012*	0.969*	2.115**	1.135**	1.121**
	(0.962)	(0.523)	(0.516)	(1.028)	(0.575)	(0.567)
exp	0.0881	0.0111	0.00769	0.0982	0.0182	0.0156
	(0.0759)	(0.0431)	(0.0427)	(0.0770)	(0.0416)	(0.0410)
eco	-0.389	0.465	0.281	-0.217	0.664	0.532
	(1.086)	(0.664)	(0.665)	(1.138)	(0.710)	(0.711)
Constant	24.08***	17.21***	18.40***	21.75***	14.24***	15.12***
	(1.273)	(1.457)	(1.831)	(1.282)	(1.408)	(1.770)
Observations	3,340	3,340	3,340	1,670	1,670	1,670
R-sq	0.06	0.53	0.54	0.07	0.56	0.56

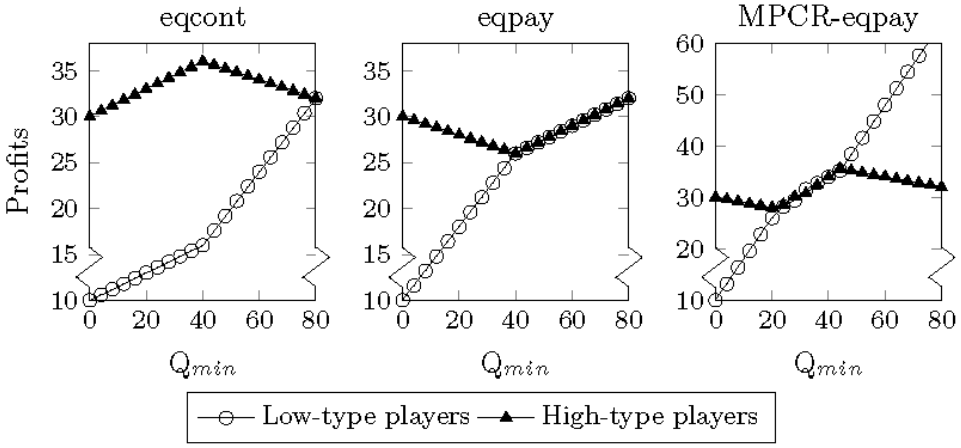
Note: We consider individual level random effects, i.e. one observation for one individual corresponds to the panel variable and the period sets the time variable: 334 individual observations x 10 periods (last two columns: 5 periods) = 3,340 (1,670) total observations, robust standard errors in parentheses, adjusted for group clusters, *** p<0.01, ** p<0.05, * p<0.1

Table 9: Time trends in profits over time

Treatment	*R-VCM*	*E-VCM*	*R-eqcont*	*E-eqcont*	*R-eqpay*	*E-eqpay*	*MPCR-E-eqpay*
All players	▼***	▼***	▼*	▼*	▼*		
low-type	▼***	▼***	▼**				
high-type	▼*	▼***					

Note: Average profits per (sub-)group in each of the ten periods of the game serve as one observation. Statistical results for time trends are based on a non-parametric Jonckheere-Terpstra for ordered differences of a response variable among classes, the null hypothesis states that the distribution of the frequency of a given profit level does not differ among rounds. ▼:= decreasing profits over time, ▲:= increasing profits over time,* p<0.1, ** p<0.05, *** p<0.01

Figure 1: Theoretical predictions for burden sharing schemes



	eqcont	*eqpay*	*MPCR-eqpay*
Proposal Q_L^{min}	40	80	80
Proposal Q_H^{min}	80	(i) 80 if $Q_L^{min} \geq 68$ (ii) 0 else	(i) 44 if $Q_L^{min} \geq 40$ (ii) 0 else
q_L	10	(i) 10/(ii) 0	(i) 10/(ii) 0
q_H	10	(i) 30/(ii) 0	(i) 12/(ii) 0
π_L	16	(i) 32/(ii) 10	(i) 35.2/(ii) 10
π_H	36	(i) 32/(ii) 30	(i) 35.6/(ii) 30

Note: in *eqpay* and *MPRCR-eqpay*, (i) is the payoff-dominant equilibrium

Figure 2: Mean contributions over periods

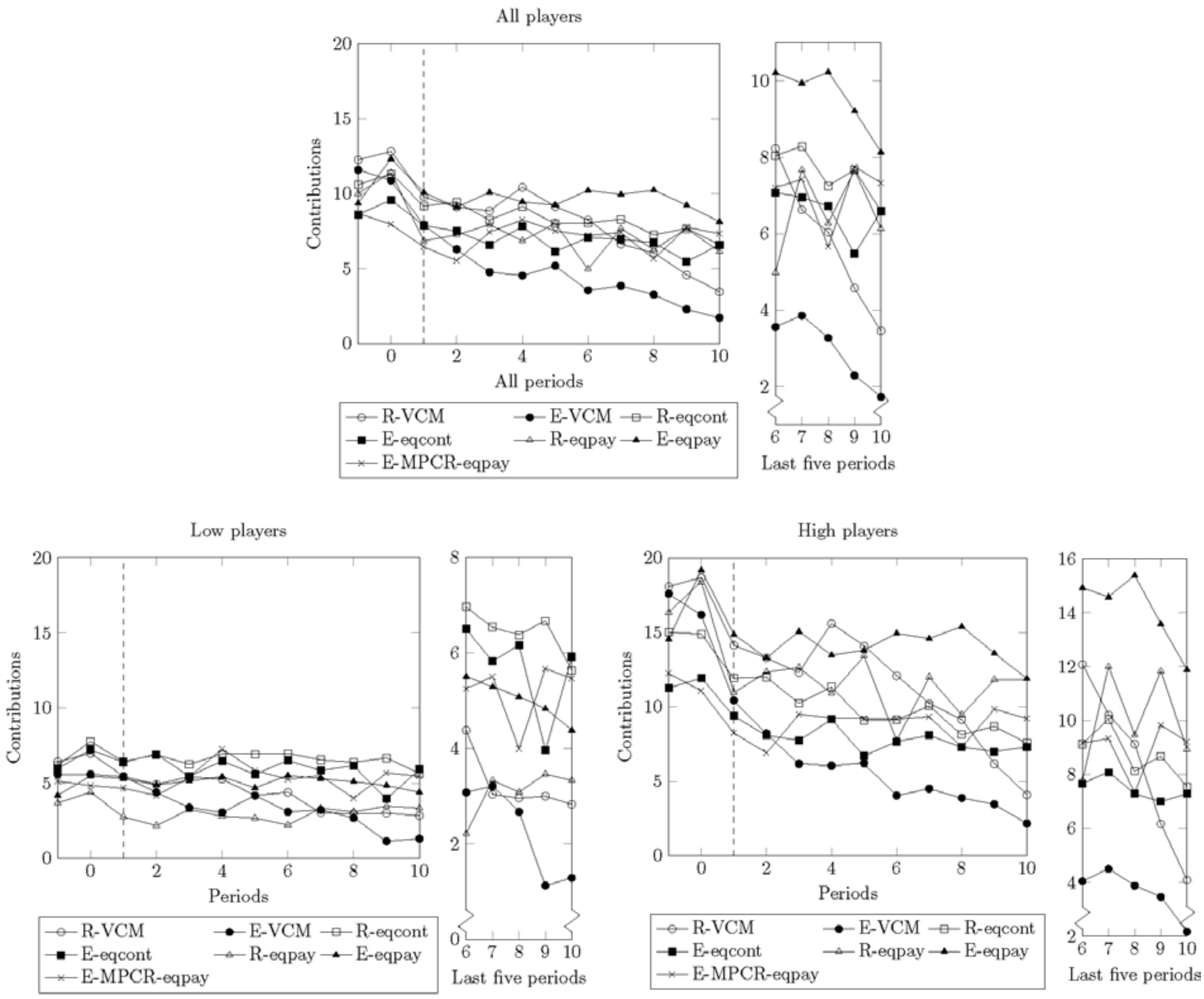


Figure 3: Mean profits over periods

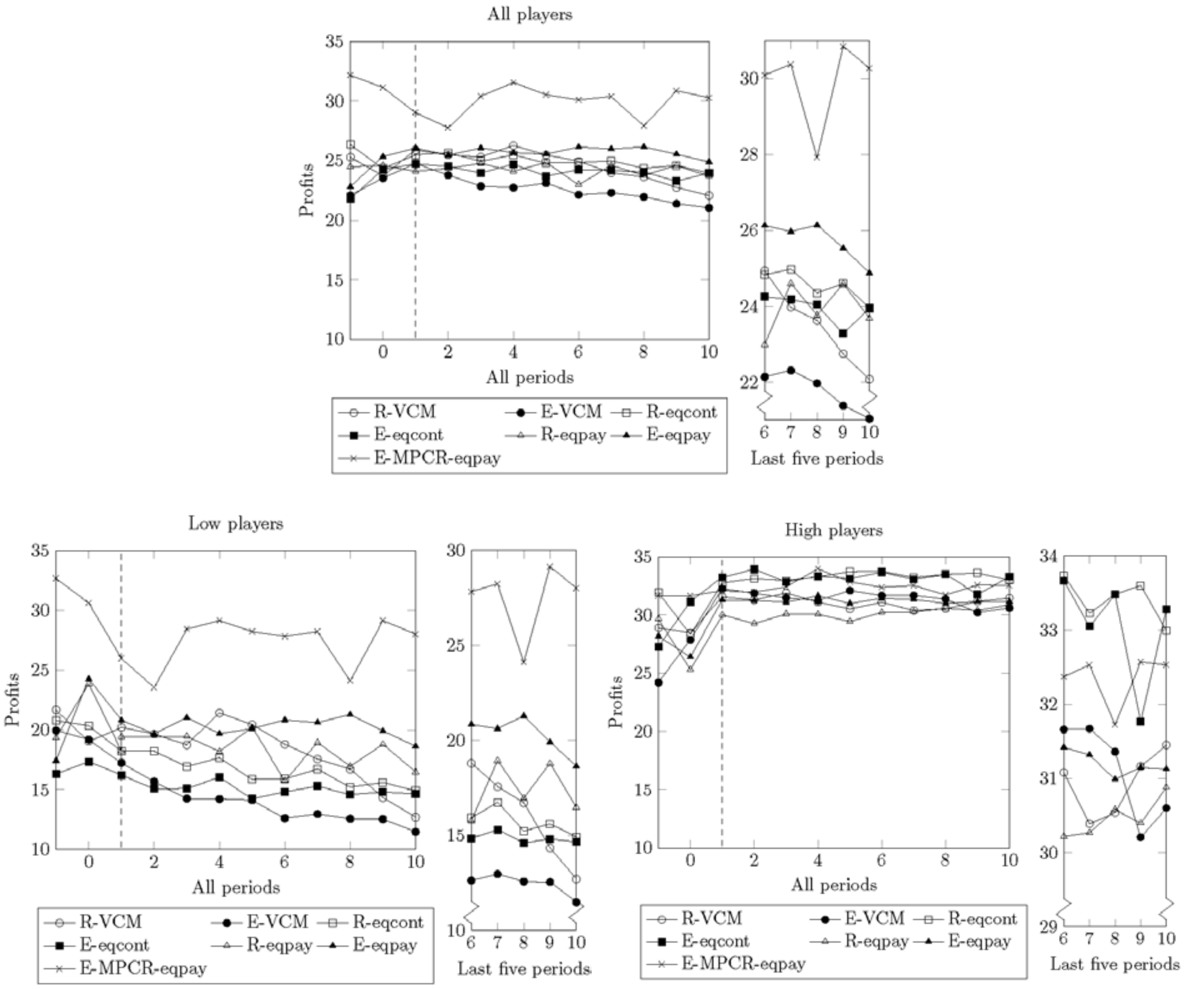


Figure 4: Slider task

Instructions

Welcome to the Magdeburg Experimental Laboratory MaXLab!

Please read these instructions carefully and should you have any questions please signal us by opening the door or a show of hands. Please do not talk to other participants. Please do not use any electronic devises like smartphones.

In the laboratory experiment you are taking part in, you can win money depending on your decisions and the decisions of your fellow players. Your payoff from the experiment will be calculated in LabDollars (LD). The conversion rate between € and LD is **1:2**, i.e. 1 LD are 0.50 €. All your decisions made in the experiment will remain **anonymous**. Only the experimenter will know your identity, but your data will be treated confidentially.

[Additional paragraph for effort based allocation of endowments:

The experiment consists of an **earning stage** (stage 1) and a **game** (stage 2). In order to become familiar with the game, please read the following instructions. Thereafter you will get additional information on the earning stage via screen.]

Rules of the game

Now you will learn more about the rules of the game you will be participating in. Altogether **4 players** take part in the game, so besides you there are 3 more players. The group of 4 players has an initial endowment of 80 points. Two players have an initial endowment of 10 points each ("low-type") and two players have an initial endowment of 30 points each ("high-type").

[Additional paragraph for random allocation of endowments:

There will be a **random draw** whether you are a low- or a high-type.]

[Additional paragraph for effort-based allocation of endowments:

Whether you are a low- or a high-type agent will be depend on your effort in the earning stage before the game that is described in the following starts]

Your task in the game, and also your fellow players' task, is to decide how many points you would like to contribute to a **joint project**. Your **contribution, q,** can be set between 0 and 10 points (only integer numbers) if you are a low-type agent or between 0 and 30 points (only integer numbers) if you are a high-type agent.

Your individual and also your fellow players' **payoff** will be calculated as follows:

Your payoff = (E – your contribution to the project) + 0.4·(sum of all contributions of all players to the project)

Assuming you to be a low-type: Your payoff (in LD) will be calculated as follows:

Payoff = (**10** – your contribution to the project) + 0.4·(sum of all contributions of all players to the project)

That is, if for example all other players have contributed altogether 70 points to the project and your contribution is 10, then your payment will be:

Payoff = (10 – 10) + 0.4·(70 + 10) = 32

If, however, all other players have contributed a total amount of 70 points and you do not contribute anything, your payoff will be:

Payoff = (10 – 0) + 0.4·(70 + 0) = 38

If you are a high-type, then your payoff (in LD) will be calculated as follows:

Payoff = (**30** – your contribution to the project) + 0.4·(sum of all contributions of all players to the project)

MPCR-eqpay

Your individual and also your fellow players' **payoff** will be calculated as follows:

Your payoff = (E – your contribution to the project) + b·(sum of all contributions of all players to the project)

The factor *b* is *b* = 0.8 for low-types and *b* = 0.4 for high-types.

Assuming you to be a low-type: Your payoff (in LD) will be calculated as follows:

Payoff = (**10** – your contribution to the project) + **0.8**·(sum of all contributions of all players to the project)

That is, if for example all other players have contributed altogether 70 points to the project and your contribution is 10, then your payment will be:

Payoff = (10 – 10) + 0.8·(70 + 10) = 64

If, however, all other players have contributed a total amount of 70 points and you do not contribute anything, your payoff will be:

Payoff = (10 – 0) + 0.8·(70 + 0) = 66

If you are a high-type, then your payoff (in LD) will be calculated as follows:

Payoff = (**30** – your contribution to the project) + **0.4**·(sum of all contributions of all players to the project)

The information, whether you are a low-or a high-type will be displayed on your screen.
[Additional paragraph in

eqcont:

There are **two stages** in this game. In **stage 1** you choose a **minimum contribution,** $Q_{min} \geq 0$, that should be contributed to the joint by the group as a whole. Simultaneously, all other players make their suggestions on a minimum contribution level, Q_{min}. The minimum of the suggested levels, min(Q_{min}), is then decisive for contributions in the second stage. In **stage 2** you decide on your contribution, q, to the joint project, thereby keeping in mind that for each player an individual minimum contribution level, q_{min}, will be calculated from min(Q_{min}) such that each player has to contribute at least a quarter of the minimum contribution level of the group, i.e. $q \geq 0.25 \cdot \min(Q_{min})$. Please keep in mind that low-types cannot contribute more than 10 LD such that high-types may contribute more to achieve the minimum group contribution level.

eqpay:

There are **two stages** in this game. In **stage 1** you decide on the **minimum contribution,** Q_{min}, that should be contributed to the joint project by the group as a whole. Simultaneously, all other players make their suggestions on a group minimum contribution level, Q_{min}. The minimum of the suggested levels, $\min(Q_{min})$, is then decisive for contributions in the second stage. In **stage 2** you decide on your contribution, q, to the joint project, thereby keeping in mind that for each player an individual minimum contribution level, q_{min}, will be calculated from $\min(Q_{min})$. The implementation of these individual minimum contributions, q_{min}, yields to **equal** payoffs or at least to a harmonization of payoffs. Please note that the harmonization of payoffs is subject to the constraint that Q_{min} will be achieved.

An example: If the minimum group contribution level is $Q_{min} = 64$ low-type players are bound to an individual minimum contribution of $q_{min} = 6$ and high-type agents face $q_{min} = 26$. Assuming these contribution levels, the payoff for each player would be 29.6 LD. If, however, $Q_{min} = 20$, minimum contribution for high-types is $q_{min} = 10$ and for low-types $q_{min} = 0$. The payoff for a high-type subject would be 28 LD and for a low-type subject would amount 18 LD.

MPCR-eqpay:

There are **two stages** in this game. In **stage 1** you decide on the **minimum contribution,** Q_{min}, that should be contributed to the joint project by the group as a whole. Simultaneously, all other players make their suggestions on a group minimum contribution level, Q_{min}. The minimum of the suggested levels, $\min(Q_{min})$, is then decisive for contributions in the second stage. In **stage 2** you decide on your contribution, q, to the joint project, thereby keeping in mind that for each player an individual minimum contribution level, q_{min}, will be calculated from $\min(Q_{min})$. The implementation of these individual minimum contributions, q_{min}, yields to **equal** payoffs or at least to a harmonization of payoffs. Please note that the harmonization of payoffs is subject to the constraint that Q_{min} will be achieved.

An example: If the minimum group contribution level is $Q_{min} = 24$ low-type players are bound to an individual minimum contribution of $q_{min} = 1$ and high-type agents face $q_{min} = 11$. Assuming these contribution levels, the payoff for a high-type subject would be 26.2 LD and for a low-type subject would amount 25.8 LD. If, however, $Q_{min} = 64$, minimum contribution for high-types is $q_{min} = 22$ and for low-types $q_{min} = 10$. The payoff for a high-type subject would be 27.2 LD and for a low-type subject would amount 44.8 LD.

]

The game consists of **10 separate rounds** in each of which you will play the same two-stage game remaining the same type. The three other players you will interact with will be the same in every round. In every round you decide how many points, q you would like to contribute to the joint project. In each round you will receive information on individual contributions (q_1 to q_4), payoffs ($Payoff_1$ to $Payoff_4$) and [in **eqcont** and **eqpay**: minimum contribution proposals (Q_{min1} to Q_{min4})] for all your group members and average levels (D).

If the experiment is complete you will receive the **payoff of one of the rounds** in € (according to the conversion rate stated above). The round to be paid out will be determined

randomly. This means you should behave in **each** round as if it were the round relevant for payoff. In the beginning, **two trial rounds** will be played which are **not relevant for payoff**.

Control questions

If you have read the instructions and do not have any questions, please answer the following control questions:

[Additional question in

eqcont

Please assume that the four players suggested 4, 16, 52 and 72 as **minimum contribution levels** for the group as a whole to the joint project. Please indicate the range of your possible contribution levels to the joint project.

More than _____ and less than or equal _____

Is it possible that the minimum contribution rule forces players to contribute more than their own minimum contribution suggestions?

O yes O no

eqpay

Please assume that calculating individual minimum contribution levels, q_{min}, leads to 2 for each of the two low-type players and to 22 for the two high-type players respectively. Please indicate the range of your possible contribution levels to the joint project if you are a low-type.

More than _____ and less than or equal _____

MPCR-eqpay

Please assume that calculating individual minimum contribution levels, q_{min}, leads to 1 for each of the two low-type players and to 11 for the two high-type players respectively. Please indicate the range of your possible contribution levels to the joint project if you are a low-type.

More than _____ and less than or equal _____

]

Please assume that your contribution as a high-type to the joint project is 20 points. The contributions of the three other group members are 0, 10 and 30. What is your payoff?

My payoff is _______

Please assume that your contribution as a low-type to the joint project is 0 points. The contributions of the three other group members are 0, 10 and 30. What is your payoff?

My payoff is _______

Please assume that all three players have contributed their entire endowment to the project. Which of the following contribution levels results in **your** highest payoff if you are a high-type (please check the according box)?

O 0 points   O 5 points   O 10 points   O 30 points

Please assume that all three players have contributed entire endowment to the project. Which of the following contribution levels results in the highest payoff **for the group** if you are a high-type (please check the according box)?

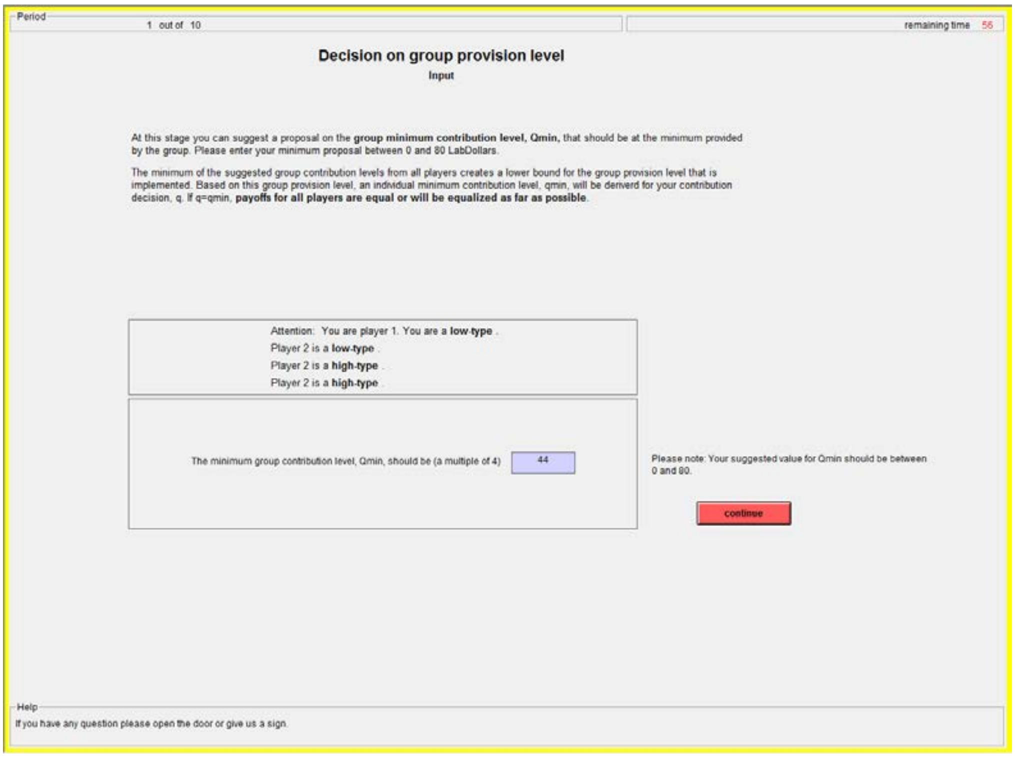
O 0 points O 5 points O 10 points O 30 points

If you have answered all questions, please signal us. We will then check your answers. The game begins when all participants in the experiment have successfully completed the test.

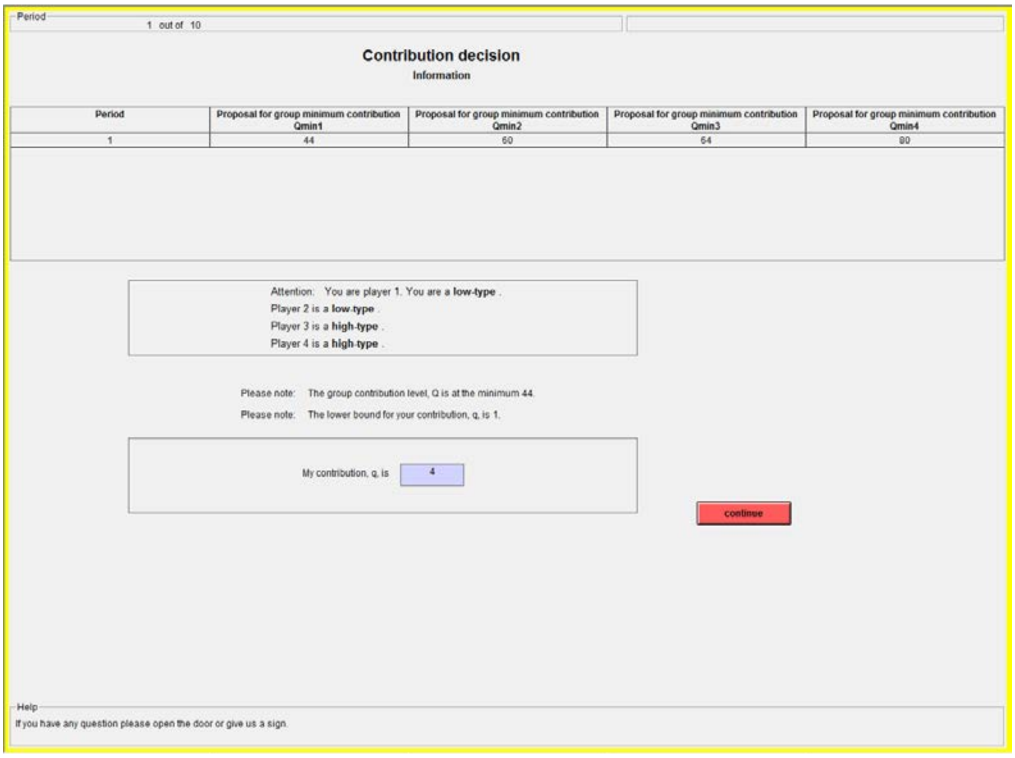
Good luck in the experiment! The MaXLab-Team

Screenshots for *eqpay* treatments

Decision on group provision level



Decision on individual contributions



Payoffs