RANK-ORDER COMPETITION IN THE VOLUNTARY PROVISION OF IMPURE PUBLIC GOODS

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Abstract: Publicly provided goods often create differential payoffs due to timely or spatial distances of group members. We design and test a provision mechanism which utilizes rank competition to mitigate free-riding in impure public goods. In our Rank-Order Voluntary Contribution Mechanism (Rank-Order-VCM) group members compete via observable contributions for a larger share of the public good; high contributors receive preferential access (a larger share), while low contributors receive restricted access (a lower share). In a laboratory experiment Rank-Order-VCM elicits median contributions equal to the full endowment throughout the finitely played games with constant groups. In the control treatment, with randomly assigned ranks, the contributions are significantly lower and decline over time. We thus provide evidence of rank competition, in situations where discriminatory access to public goods is possible, being efficiency enhancing.

Keywords: Competition, contest, cooperation, public goods, experiment, voluntary contribution mechanism.

JEL Classifications: C91, H41

I. INTRODUCTION

A (pure) public good is characterized by two features: non-rivalry and non-excludability (e.g., Varian, 1992). However, in reality many publicly provided goods are inherently rivalrous or congestible in terms of consumption, and are thus regarded as impure public goods (a mixture of private and public good). One's own consumption of such goods diminishes but does not fully eliminate the benefits for others.[1]

Most public goods today are still funded through tax revenues, but tax financing is impossible for private organizations and not always viable or efficient for governments, for both economic and political reasons. The former therefore often have to employ voluntary contribution mechanisms (VCMs) which persistently trigger contributions below the social optimum level. In the current paper we focus on situations where preferential access to a publicly provided good is feasible and acceptable. For such situations, we propose a new mechanism which enriches the standard voluntary mechanism by rank-order competition with higher ranked contributors receiving preferential access. Such rank-order competition for in the context of public goods is related to contests such as Tullock lotteries, rank-order tournaments, or all-pay auctions that provide participants of VCMs with an opportunity to win a private prize which is higher than their contribution to the public good, mitigating or possibly even eliminating free-riding behavior.[2] We contribute to the growing experimental literature that investigates how incentives or competition impacts cooperation in public goods games (e.g, Dickinson and Isaac, 1998; Falkinger et al., 2000; Gunnthorsdottir et al., 2010; Cabrera et al., 2013; Croson et al.,

[1] Publically funded sports facilities, like community swimming pools, are an example of a congestible public good. They often offer time slots, at a price, to swim schools, sports teams and other individuals or organizations. The remaining slots are open to recreational swimmers. However, if recreational swimmers are willing to stick to the one or two non-bookable swim lanes, they can use the swimming-pool at any time.

[2] Warr (1983) demonstrated that when a single public good is provided at positive levels by private individuals, small redistributions of income among contributors will leave the total provision of public goods unchanged; which is known as Warr's neutrality finding. However, in models with impure public goods, such as public good funded by contests, neutrality does not hold (Cornes and Sandler, 1994; Morgan, 2000).

2015; for details see the literature review in the following section). In contrast to the previous studies where incentives impact the game structure, the introduction of rank-order competition does not affect the uniqueness of the free-rider equilibrium in the repeated game. This kind of competition only eliminates the dominance of free riding in the one-shot game, such that the best-response function suggests a higher contribution than the others for a large range of contribution profiles.

National lotteries have, for centuries now, been used by governments as a method to fund impure public goods.[3] One issue with mechanisms which use contests to fund public goods is that the cost of the prize must be covered by contributions, making them expensive and not always feasible (see the literature review section for details). The prize awarded to the contest winner(s) can constitute a considerable fraction of the total endowment of all participants, leaving the contributions pool further away from the socially optimal provision. This is of particular concern when the number of possible contributors is not sufficiently large, as can be the case with local public goods.[4] An important advantage of our private provision mechanism is that it takes away the fixed-prize component that has been used in almost all contests as a mean to mitigate free-riding, thus eliminating the efficiency loss.

While our mechanism keeps the rivalry component by not excluding anyone from accessing the public good, preferential or discriminatory access is what limits its applicability. One important instance where we envision the mechanism to potentially be applied is organ donation; the transplant needs to happen as soon as it becomes available yet there are many

[3] For example, in the UK 28% of the funds collected through the national lottery goes to charity and public good projects, while 12% goes back to the state. Lotteries are considered a joint public-private good (impure public good) as purchasing lottery tickets leads to a chance win a private prize as well as contribute to a public good (Morgan, 2000).

[4] For a review of local public goods (identified by geographical space), and club goods (local public goods not identified by geographical space; mostly by size and crowding costs), see Scotchmer (2002).

potential recipients who can receive it. Currently, a recipient is usually randomly chosen among candidates with equal medical and other characteristics (the equivalence classes are quite large; see Gueth et al., 2001, for the allocation algorithm used by Eurotransplant). However, an alternative to randomly choosing a recipient would be if a preferred recipient was the person who is contributing "the most," meaning that individuals who have signed-up as potential donors could receive preferential access to available organs (See Kessler and Roth, 2012 and Herr and Normann 2016, for evidence of positive influence of giving organ priority to registered organ-donors). If one interprets time since registering as a potential donor as contribution to the organ pool, it would allow for assigning ranks to all candidates who are eligible for receiving an available organ transplant. This means that one could give preferential access to those who themselves have been potential donors for longer, rather than assigning them randomly.

In the example above, rank-order competition suggests important psychological motives as well: when becoming a potential donor one does not have to consider only the worst-case scenario where one's organs are donated, but also cases of urgently needing an organ, where low chances of receiving it would be enhanced by becoming a potential donor as soon as possible. Such obvious reciprocal incentives are excluded by nearly all organ allocation mechanisms although they would likely improve their social acceptability and boost the sign-up rate of potential donor clubs.

Our *Rank Order Voluntary Contribution Mechanism* (hereafter Rank-Order-VCM) utilizes competition to mitigate free-riding by setting up a contest in the form of rank-order tournament. Under voluntary contribution the collection of public good funds is straightforward, but the incentive to free-ride always persists. If exclusion of free-riders is undesired or too costly, the social planner can devise a contest which gives high contributors preferred access to the public good. Rank-Order-VCM allows the planner to implement a relative reward system in which, through the allocation decision, free-riding incentives are counteracted by making the enjoyment of an (impure) public good more restrictive for low contributors. While all individuals may have the right to access the public good, timely or spatial distances can make access easier for some and more restrictive for others.[5] We conjecture that competition created by this mechanism will result in increased contributions to the public good, because the impulse response dynamics (Neugebauer, Sadrieh, and Selten, 2014) for randomly chosen initial contributions lead to efficient median contributions.

In Rank-Order-VCM individuals compete with their observable contributions towards a public project for a larger share of the payoff that the project generates. The design of the mechanism ensures that people who contribute more (and thus earn a larger share of the payoff) are less likely to feel taken advantage of as it has often been reported by subjects in VCM experiments.[6] To test whether presence of competition in Rank-Order-VCM overcomes the free-rider problem we compare it to *Random Rank Voluntary Contribution Mechanism* (hereafter Control treatment) – an institution that allocates the shares from the public project randomly (but maintains all other features of the Rank-Order VCM environment) and thus provides a control treatment in which competition for preferred access is not feasible.

Next we present a literature review, the mechanism, experimental setup and our results, followed by a short discussion. Subject instructions are provided in the appendix.

[5] Another specific example is financing a cultural event (e.g., a theater play) through voluntary contributions with the person who contributed more receiving higher quality seats. In the same fashion, a person who exerts more effort, spends more time on the project or invests more money into it would earn a larger share of the profit in a team production scenario, or airlines with higher contributions towards the airport would get their preferred time slots or gates.

[6] The idea of focusing on preferences for cooperation in a VCM setting has been suggested by Andreoni (1995). For studies and details on conditional cooperation in the VCM see Keser and van Winden (2000), Fischbacher et al. (2001), Levati and Neugebauer (2004), Burlando and Guala (2005), Kurzban and Houser (2005), Chaudhuri and Paichayontvijit (2006), Chaudhuri (2007), Gunnthorsdottir et al. (2007), Neugebauer et al. (2009), or Fischbacher and Gachter (2010).

II. LITERATURE REVIEW

Substantial literature, both theoretical and experimental, has identified the free-rider problem in organizational and societal settings (see Ledyard, 1995 for a review). A small but growing research stream recognizes institutions that mitigate or completely eliminate this problem (Kosfeld and Riedl, 2004 review the literature). Other papers test these institutions experimentally. It is this literature to which we wish to contribute.

One type of mechanism that has been proposed to alleviate free-riding involves sanctions and rewards. These sanctions and rewards, usually based on some form of rank-ordering of contributions, are either experimenter-imposed (e.g., Groves and Ledyard, 1977; Walker, 1981; Dickinson and Isaac, 1998; Falkinger et al., 2000; Dickinson, 2001; Orrison et al., 2004; Harbring and Irlenbusch, 2005; Croson et al., 2006), or participant-imposed (e.g., Fehr and Gächter, 2000; Masclet et al., 2003; Noussair and Tucker, 2005). However, even though some of these studies do lead to competition occurring, competition is not their main focus and therefore they cannot provide a direct answer whether competition is capable of increasing voluntary contributions on its own. For example, Dickinson (2001) investigates a mechanism in which all but the most cooperative member of the group have to incur a fixed fine and the most cooperative member receives a bonus payment. Orrison et al. (2004) and Harbring and Irlenbusch (2005) use a tournament incentive structure involving rewards for winners and sanctions for losers, and find that the additional incentives provide a large initial boost to cooperation, which diminishes over time. In Croson et al. (2015), the minimum contribution within a group is sanctioned implying a game structure with multiple equilibria among which the Pareto efficient is selected by subjects in the experiment. In this paper we go further by showing that neither the exclusion of non-contributors nor the change in the equilibrium structure is required to trigger high contributions; even a change in the best-response functions can change observed behavior dramatically. Another closely related study to ours is Falkinger et al. (2000) in which subjects pay a tax if they contribute below the mean contribution and receive a subsidy if they contribute above the mean. The authors find not only a significant initial effect on contributions but also increasing cooperation over time. In contrast to continuous changes in the marginal per capita return (MPCR) due to the tax/subsidy, our study focuses on discrete changes due to rank-order tournament rather than by comparing one's contribution to the average of the group. The other notable difference between the two studies is that in Falkinger et al. experiment the efficient level of public good provision is achieved as a Nash equilibrium, whereas in our implemented parameterization of Rank-Order-VCM free riding is still the unique Nash equilibrium (as will be discussed in the next section) as high contributions are driven by competing for a higher rank.

While experimentally imposed sanctions and rewards have been successfully used to solve the free-rider issue, mostly in the form of tax systems, they all assume that the social planner can penalize non-contributors. This, however, is often not a feasible solution, either because the social planner might not have the power to impose punishment or because it could be too costly to enforce.

More recently, incentive mechanisms in the form of contests (see Konrad, 2009; Dechenaux et al., 2014 for a review on contests) have been found to successfully mitigate free-riding without requiring the institution conducting the contest to impose sanctions. While revenue comparisons of all-pay and first-prize (winner-pay) auctions as mechanisms to increase contributions to a public good (e.g., Goeree et al., 2005; Carpenter et al., 2008; Orzen, 2008; Schram and Onderstal, 2009) still need further experimental testing, most of the research has zeroed in on all-pay lotteries and all-pay auctions. Next we elaborate on the most relevant contests used to enhance the standard VCM.

Morgan (2000) and Morgan and Sefton (2000) theoretically and experimentally show that Tullock fixed-prize lotteries (Tullock, 1980) can be successfully used to increase public good provisions and substantially decrease free-riding. Participants purchase tickets for a lottery with a single fixed prize. A ticket is randomly drawn and the holder wins the prize. The model suggests public good provision via the sum of all purchased lottery tickets net the prize offered to the winner. Without budget constraints, the model suggests that the higher the prize of the contest, the closer the contributions are to the social optimum level. Goeree et al. (2005) show that winner-pay auctions are not very efficient fund-raising mechanisms, and that all-pay auctions dominate lotteries and popular winner-pay auctions. They also find that the optimal fund-raising mechanism is an all-pay auction augmented with an entry fee and reserve price that, however, might be difficult to execute in the field. Corrazini et al. (2010), Faravelli and Stanca (2012), and Bos (2011) extend these results to all-pay contests with heterogeneous endowments. Lange et al. (2007) compare the efficiency of contests when participants have both homogeneous and heterogeneous marginal per capita returns (MPCRs), while Faravelli and Stanca (2014) look at the relation between competitive economic incentives and social preferences. The results in all these papers confirm that prize-based mechanisms lead to higher levels of contributions and to lower levels of free riding than the standard VCM.

Corazzini et al. (2010) compare lottery and an all-pay auction to the VCM with heterogeneous incomes. In the lottery treatment participants purchase lottery tickets for each point they contribute. At the end of the round a ticket is drawn and a fixed prize is awarded. In the all-pay auctions treatment, the person who contributes the most gets awarded the fixed prize.

They find that both contests perform better over time than the VCM, and that the lottery does slightly better than the all-pay auction. In all treatments contributions rise with income, but the difference is larger with the prize-based mechanisms.

Similarly, Faravelli and Stanca (2014) design an experiment to disentangle the level of competition through the economic incentive (lottery vs. all-pay auction) and the presence of social returns (rent seeking vs. public good). Their findings suggest that both competition and the presence of social returns increase bids, but that there is not an additional significant increase in contribution growth when combining the two. Even though all-pay auctions usually outperform lotteries in rent-seeking, this is not the case when one compares the two as mechanisms for fundraising; in such environment they perform equally well. This finding is in line with Orzen (2008) who shows that single-prize all-pay auctions and lotteries perform similarly. Orzen further finds that last-price all-pay auctions outperform standard contests in the presence of social returns, but like the $k+1$th price all-pay auction of Goeree et al. (2005), this contest, while not hard to implement, is not intuitive and could require auction-specific training of participants.

Faravelli and Stanca (2012) compare the performance of single- and multiple-prize all-pay auctions as fundraising mechanisms to finance public goods in a setting where participants have heterogeneous endowments. They find that a single large prize generates higher total contributions than a multiple-prize auction but that multiple prizes lead to higher participation. Further, they find that a single-prize is a more effective incentive for high endowed participants, confirming the theoretical prediction. Contrary to the theory, however, multiple-prize auctions do not lead to more contributions for low earners.

One issue with all current studies which look at contests as a mechanism to solve free-riding is that the contest prize is expensive and must be covered by the contributions. The reason for using a fixed prize in lotteries, rather than a prize that is a percentage of total contributions, is that the equilibrium provision in such a fractional-prize contest is equal to that obtained by the standard VCM (Morgan, 2000). Thus, the majority of the above-mentioned papers provide a fixed reward to the contest winners, which still constitutes a considerable fraction of the total endowment of all participants. Once the prize is subtracted from the contributions, what is left in the pool is guaranteed to be below the social optimum, leading to an efficiency loss compared to the standard VCM. To the best of our knowledge the experimental studies on contests and public goods that have an identical number of group members (four), as well as identical average multiplier (0.5) as we do, provide a fixed-prize ranging from 25% (e.g. Orzen, 2008) to 33% (e.g. Corazzini et al., 2010; Faravelli and Stanca, 2012) of the sum of the endowments. To the best of our knowledge, in various single-prize auction, multiple-prize auction, and Tullock lottery treatments, average contributions to the public good tend to range from around 30% to 50%.

In addition, while past experiments have shown that fixed-prize contests can increase contribution levels in comparison to a voluntary contribution mechanism even after subtracting the prize, they have also shown that the size of the prize does matter. This means that it is not always a priori certain whether the contest will have a positive net effect. If the number of participants is sufficiently large a high prize might behaviorally entice participants to contribute more, even though this decreases the probability of winning. However, when the number of possible contributors is limited, either by distance or crowding, as is often the case in the provision of local public goods, the size of the fixed prize may be of particular concern.

In comparison to previous studies, our Rank-Order-VCM mechanism takes away the fixed-prize component and instead differentiates access to the public good. With our mechanism free-riding is still a unique Nash-equilibrium, just as in the standard VCM, however it is no longer a dominant strategy equilibrium in the stage game. Our mechanism thus decreases the cost of the contest compared to the previously studied mechanisms that involve a fixed prize and, as supported by our results, appears to be more efficient in eliminating free-riding.

According to Buchanan (1968), who defines an impure public good as "any departure from the availability of equal quantities of homogeneous-quality consumption units to all customers", as long as the supply of the good is collectively and cooperatively organized, the public goods model holds even if impurities are present. However, the introduction of competition allows us to alter the incentives to free-ride. Cornes and Sandler (1994) show that compared to a pure public good, an impure public good decreases incentives to free-ride and increases provision.

Our Rank-Order-VCM not only rewards high contributors as in typical contest mechanisms but also directly decreases the free-riding incentives. Importantly, it does so by still providing access to the public good for everyone, regardless of contributions. The access is preferential to those who contribute the most while free-riders are sanctioned by limited access. The mechanism requires no taxation or fine, both of which might come at an administrative cost, of any kind.

In a related study to ours in terms of competition effects, Gunnthorsdottir and Rapoport (2006) show that combining voluntary contribution mechanism with intergroup competition for an exogenous and commonly known prize reduces free-riding. Gunnthorsdottir and Rapoport implement two different profit sharing rules (egalitarian and proportional) under which the prize is distributed to members of the winning group and find that the proportional sharing rule does better than the egalitarian one. However, from their design it is not obvious to what degree the proportional sharing rule contributes to the reduction of free-riding as it is coupled with intergroup competition. Finally, Cabrera et al. (2013) hierarchically divide participants in two groups who simultaneous play the voluntary contribution game; one group is called the major and the other the minor league. After each period there is a regrouping; the most cooperative subject of the minor league promotes to the major league and the worst free rider of the major league demotes to the minor league. Cabrera et al. find that this kind of competition leads to increased contribution levels in both leagues relative to the standard voluntary contribution mechanism.

In contrast to papers that study the impact of group formation based on the ranks of observable contributions, in our experiment we avoid using different groups and focus solely on the situation where a larger share of the public good goes to a higher contributor. Our Rank-Order-VCM (to be described in detail below) creates competition among contributors who are randomly assigned to a group and who repeatedly interact within the same group without having to change its composition.

III. EXPERIMENTAL DESIGN AND PROCEDURES

3.1 Rank Order Voluntary Contribution Mechanism

In Rank-Order-VCM, each individual from a group of four faces the following decision problem: How much of the initial endowment (e = 50 New Zealand cents) to contribute to a public good (c_i), respectively how much of it to keep ($e - c_i$). Each cent kept generates a payoff only for the given individual; each cent contributed towards the public good generates payoffs for all group members. The final payoff to individual i is determined by his own and the others' contributions via:

$$\pi_i(c_i, c_{-i}) = e - c_i + m_i \sum_{j=1}^{n} c_j$$

The individual multiplier (m_i) is determined by the contribution rank of individual i (i's contribution relative to the amount contributed by the other members of the group); the higher the contribution the higher the multiplier. In the experiment, we have implemented the following parameterization; based on an average MPCR from the project of 0.5:[7]

- If i's contribution is the highest one, the multiplier (marginal return); $m_i = 0.65$.
- If i's contribution is the second highest; $m_i = 0.55$.
- If i's contribution is the third highest; $m_i = 0.45$.
- If i's contribution is the lowest; $m_i = 0.35$.[8]

In case of a tie, i.e., if two or more group members allocate the same amount to the project, the corresponding multipliers are averaged. For instance, if the highest allocation is equal to the second highest, the multiplier for the two group members is 0.6 [= (0.65 + 0.55)/2]. If all four group members contribute the full endowment (e = 50), the multiplier for each one of them is 0.5. Hence, group members contributing the same amount earn the same.

[7] Although we did not run the standard VCM with the marginal per capita return = 0.5, this choice of design makes our results comparable to previous studies implementing such setup (e.g., Herrmann et al. 2008).

[8] Note that our general setup includes as special cases the standard symmetric VCM ($m_i = m$ for all i) and the proportional rule ($m_i = \frac{2c_i}{\sum_{j=1}^{n} c_j}$ for all i if $\sum_{j=1}^{n} c_j > 0$, and 0 otherwise) studied in Gunnthorsdottir and Rapoport (2006).

In Rank-Order-VCM, individuals are rewarded based on their contribution rank towards a group project. Given our parameterization, the unique Nash equilibrium is the situation where everyone free-rides, but it is not a dominant strategy equilibrium of the stage game as in the standard VCM.[9]

However, if we were to observe a different behavior in Rank-Order-VCM than in VCM it would not be obvious whether it is due to competition or not. In particular, Rank-Order-VCM and the standard VCM differ mainly in two additional aspects: the heterogeneity of marginal returns and the endogeneity of individual marginal per capita returns, related to the fact that subjects learn about their marginal returns only *after* their decision has been made as opposed to knowing what the MPCR *before* the decision is made as is the case in VCM. Thus Rank-Order-VCM does not only capture the voluntary cooperation possibilities of standard VCM but also the competition for a higher rank. To identify the competition effect of Rank-Order-VCM, we run an appropriate control treatment with identical payoff parameters but randomly assigned ranks.

3.2 Control Treatment

Our Rank-Order-VCM differs from the standard VCM in two ways, one is the element of competition, and the second is the marginal return parameter m_i which group members learn only after the contribution decisions are made. In order to isolate the effect of competition in the Rank-Order-VCM, our control treatment implements identical payoff parameters as Rank-Order-VCM by randomly assigning ranks to all members of the group. The software draws a rank for each individual from the set {1, 2, 3, 4} with replacement. Just as before, the individual marginal returns from a project are 0.65, 0.55, 0.45, or 0.35, based on this random rank. In case of a tie,

[9] If, for instance, the three other members of the group contribute 49 and the individual *i* rides free, he misses out on gaining more by contributing 50 instead.

the marginal returns get averaged. Group members learn their marginal returns after the simultaneous decisions are made. In the Control treatment free-riding equilibrium of the stage game is unique and in dominant strategies.

3.3 Testable Hypothesis

Based on the Nash equilibrium predictions, we would expect no differences in behavior between Rank-Order-VCM and Control. Mutual free riding defines the best-responses. In particular, the unique Nash equilibrium implies free-riding in each stage of the repeated game for both treatments. This null hypothesis assumes (unbounded) rationality and self-regarding preferences.

Our alternative hypothesis is that the competition in Rank-Order-VCM induces an upward shift towards the efficient allocation as in some (non-equilibrium) instances more cooperative individuals may earn more than the less cooperative ones. Thus, we expect a significantly higher contribution level in Rank-Order-VCM than Control. Our hypothesis can be based on the learning direction theory of Selten (2004) and impulse response dynamics as proposed in Neugebauer, Sadrieh, and Selten (2014). Learning direction theory suggests that subjects adjust their strategies in the direction of the ex post best-response. Neugebauer et al. (2014) suggest simple individual learning trajectories according to which individuals make *one-step* adjustments $r_i(t)$ of their strategy in the direction of the ex-post best-response, $c^*_{it-1}(c_{-it-1})$, given the observed actions played by the others.[10] The impulse response trajectories are described as follows.

[10] Impulse response dynamics move in the same direction as Cournot dynamics. In contrast to Cournot dynamics, which adjust exactly to the ex post response, the impulse response dynamics move by one step on the scale only.

$$\tilde{c}_{it} = \tilde{c}_{it-1} + r_i(t-1) \text{ where}$$

(1) $$r_i(t) = \begin{cases} 1, if\ \tilde{c}_{it} < e \wedge \tilde{c}_{it} < \tilde{c}^*_{it}(\tilde{c}_{-it}) \\ 0, if\ \tilde{c}_{it} = \tilde{c}^*_{it} \vee (\tilde{c}_{it} = e \wedge \tilde{c}_{it} \leq \tilde{c}^*_{it}) \vee (\tilde{c}_{it} = e \wedge \tilde{c}_{it} \leq \tilde{c}^*_{it}) \\ -1, if\ \tilde{c}_{it} > 0 \wedge \tilde{c}_{it} > \tilde{c}^*_{it}(\tilde{c}_{-it}) \\ -2, if\ \tilde{c}_{it} > 1 \wedge \tilde{\pi}_{it} < e \end{cases}$$

The impulse is positive (upward) if the ex-post best-response to the observed actions of the others is higher than the actual contribution was. The impulse response trajectory of *i*, $\tilde{c}_{it}$, moves up by one step, i.e., the contribution of *i* increases by one unit if the subject's best-response to the others' actions in the latest repetition would have been a higher contribution. The impulse is negative (downward) if the best-response would have been a lower contribution than the actual one. If a loss is experienced (where the reference point is the maximin of the subject) the move in the direction of the impulse is doubled. Finally the impulse is zero if the choice coincides with the best-response, or if the choice is on one boundary of the strategy space and no impulse exists in the direction of the other boundary.

In Rank-Order-VCM there exist two impulses, namely:

- An upward impulse: a foregone payoff results from a relatively low contribution rank. By contributing more, the subject could have reached a higher contribution rank and multiplier.
- A downward impulse: a foregone payoff occurs in many asymmetric contribution profiles where high contributors contributed more than necessary to obtain the assigned contribution rank and multiplier.

Upon receiving a downward or upward impulse subjects are predicted to adjust their behavior in the respective direction. Since the impulse response dynamics are slow, the two profiles (50, 50, 50, 1) and (49, 49, 49, 0) could be a dynamic cycle to which the dynamics of the Rank-Order-VCM converge.[11] On the other hand, the impulse response dynamics in the Control treatment lead to full free-riding after some repetitions. To show this we conducted simulations in which we apply the described impulse response process to independently and uniformly distributed initial contributions. We conducted 1000 simulations with 100 steps each, in which we successively applied the described dynamics. We used identical initial contributions for both environments. For the trajectories of the Control treatment, we chose the multiplier randomly in each step. Unlike Rank-Order-VCM, free-riding is a dominant strategy in Control, i.e., it is the unique best-response for any contribution profile of the others. In each step, we decreased the positive individual contributions by one unit, and after a loss by two units. We present the average and the median contribution trajectories in Figure 1 for both treatments. The starting point of the trajectories is 25 which is the average and median of the initially drawn contributions. The contributions in Rank-Order-VCM are increasing, the median is converging towards full contribution and the average is converging to 41.8. In Control, the contribution trajectories converge to 0, with the median trajectory converging faster than the average. In Control (and also in the standard VCM) only downward impulses due to foregone payoffs are

[11] It is easy to see that if the contribution profile is (49, 49, 49, 0), every contributor's response function suggests an upward impulse, because a contribution of 50 is an ex-post best response for each contributor assuming the others' contribution remain unchanged. In accordance with (1), all contributions would increase by one unit. In the (50, 50, 50, 1) profile, the high contributors' ex-post best response would be a contribution of 2, assuming no changes in the contributions of the others, and the low contributor's ex-post best response would be a contribution of 0, Each contributor thus experiences a downward impulse, and in accordance with (1), makes a downward adjustment of one unit. Generally, in sharp contrast to the VCM, if the other three participants make strictly positive contributions, with the sum of contributions being within the range of 3-149, then the best-response is a non-zero contribution.

present; upward impulses are absent. Since downward impulses are also present in Rank-Order-VCM, it is the upward impulses that imply the qualitative change in the best-response function.

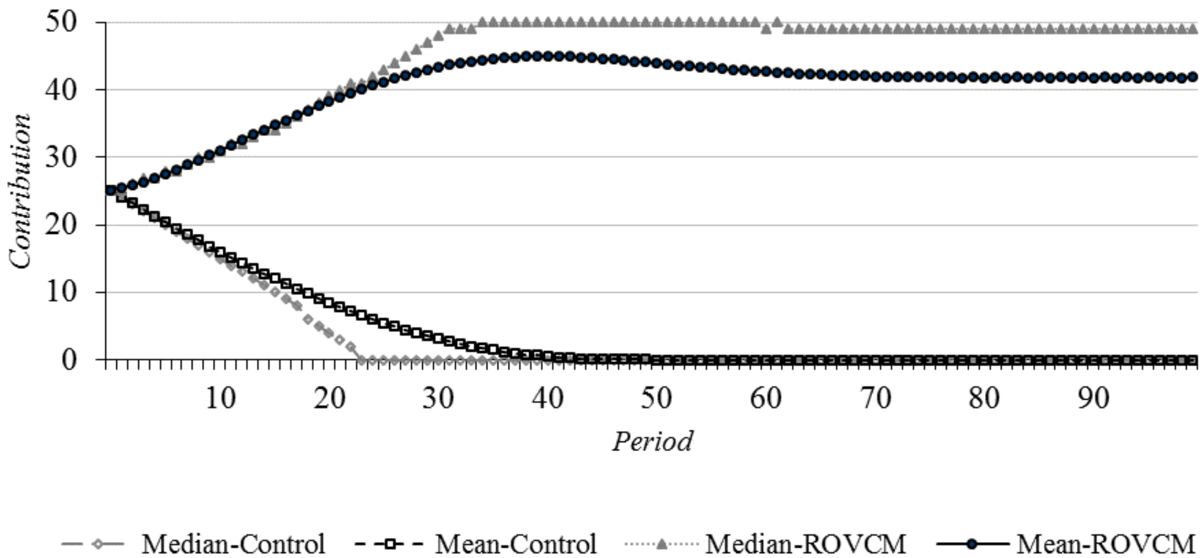


Figure 1. Simulated median and average contribution trajectories in Rank-Order-VCM and Control

In line with our alternative hypothesis is the literature on social competition which finds that providing information on the relative performance affects behavior of individuals and entire markets, even when direct tournament incentives are not present (e.g. Fischbacher and Gächter, 2010; Schoenberg and Haruvy, 2012; Fatas et al., 2015). While in our setup the participants do not receive a direct payoff feedback of the other three members, they do receive (anonymous) information about the individual contributions, ordered from highest to lowest, which allows them to calculate their relative performance. In our view, these additional non-monetary incentives, which Rank-Order-VCM crowds in, might explain why it may convincingly outperform the standard VCM. Like Nobel laureates or Olympic medalists, who are not only richly awarded but also acknowledged as outstanding individuals in their discipline, the group members of Rank-Order-VCM receive rank-acknowledgement and are rank-dependently awarded. The discreetness of these effects may, however, question the existence of pure strategy equilibria when incorporating other-regarding concerns in the form of continuous trade-offs (e.g., Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999; and the review of Cooper and Kagel, 2013). While this is an interesting phenomenon in its own right, in the current paper we focus on the overall performance of rank order tournaments in a VCM setting and leave the separation of monetary from non-monetary incentives for future research.

Rank-Order-VCM also implies another subtle change in the public goods game vis-à-vis conditional cooperation (e.g., Fischbacher et al. 2001). Cooperators are not being exploited to the same degree as in the standard VCM because higher cooperation is rewarded by a larger share of the contribution pool for which the group members compete. In our design only two group members need to cooperate, by contributing similar amounts, for their payoff to be higher than if both contributed zero (assuming that the other two are free-riding). In comparison, in the standard VCM with our mean multiplier, m_i = 0.5, two group members would have to contribute an identical amount just to break even compared to not contributing at all, again assuming that the other two also ride free.

In this situation, where only two cooperators contribute similar amounts while the other two ride free, the possibility of exploitation at a low cost would drive contributions up. The two high contributors would either want to contribute one cent higher than the other high contributor, so as to obtain a larger share of the contributions through a higher multiplier, or alternatively they would want to contribute one cent higher than the two free-riders, so that he can free-ride more efficiently. At the same time, however, the two free-riders would also be better off if they increased their contributions by one cent compared to the other free-rider so as to free-ride more efficiently of the contributions of the two high contributors, which ultimately is likely to push all contributions up.

3.4 Procedures

The experiment consisted of two treatments, Rank-Order-VCM and Control, implemented in an across subjects design. All sessions were conducted in the New Zealand Experimental Economics Laboratory (NZEEL) at the University of Canterbury. A total of 64 undergraduate subjects were recruited for the experiment. Most of the subjects had not previously participated in economics experiments (and none had participated in a social dilemma experiment). Each subject only participated in a single session of the study. We ran four sessions with exactly 16 subjects in each session. On average, a session lasted 75 minutes including initial instructional period and payment of subjects. Subjects earned on average 23.51 NZD.[12] We did not pay a show up fee. All earnings were calculated in New Zealand cents. All sessions were computerized and run under single blind social distance protocol. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

The assignment of subjects into groups was done according to the following process. Upon entering the laboratory subjects drew a number from an envelope. The number indicated their computer terminal for the experiment. The terminals were randomly matched into anonymous groups of four by the server. The composition of each group remained the same throughout the experiment. All this was known to the subjects and so was the fact that all members of the group faced the same decision problem.

[12] The adult minimum wage in New Zealand at the time of the experiment was 10.25 NZD per hour.

Each participant was provided a hard copy of neutrally framed instructions that were identical across subjects. The experimenter read the instructions aloud with subjects following the text in their own hard copy. After finishing reading the instructions and answering the questions we administered a computerized test to check for understanding of the decision making environment. The subjects were asked to individually select four numbers (with two numbers being equal) that would represent four contributions. After choosing the four numbers the test software asked them to calculate the multipliers and profits for all group members. It did not allow them to proceed until they answered all questions correctly.

The decision making part of the experiment followed. Each session consisted of 2x15 rounds to check for a restart effect. After restart the subjects remained in the same group as before (partners design). In every round of the play the subjects were endowed with 50 NZ cents and had to decide how much of this endowment to allocate to a project and how much to keep for themselves.

The individual round payoffs were computed as the money the subjects kept plus the sum allocated to the project by all four members of the group where the latter was multiplied by their own personal multiplier. In the Rank-Order-VCM treatment the personal multiplier was determined depending on the amount the subject contributed towards the project and on the rank order of this amount relative to the contributions of the other members of the group. In the Control treatment the multiplier was randomly determined by the computer. The software would draw a number 1, 2, 3, or 4 (with replacement to allow for ties) for each participant. The subject's individual multiplier was determined according to the rank of his random number. In particular, if the subject's number was the highest in the group, the multiplier was 0.65; 0.55 if it was the second highest; 0.45 if it was the third; and finally, 0.35 if the number was the lowest.

After each round the subjects received feedback information on the amount they and their group allocated to the project. They received information on the individual allocation ordered from highest to lowest, but were not be able to trace the amount to the person who allocated it. They also received information about their personal multiplier, the resulting payoff from the project, the amount of money kept and their round payoff. This information was recorded in a table on the subjects' screen and was available for all past rounds. At restart, the information for the first 15 rounds was cleared.

At the end of the experiment subjects were asked to fill out a questionnaire on demographics and strategies used when making the decisions. Finally, they were privately paid their earnings for the session.

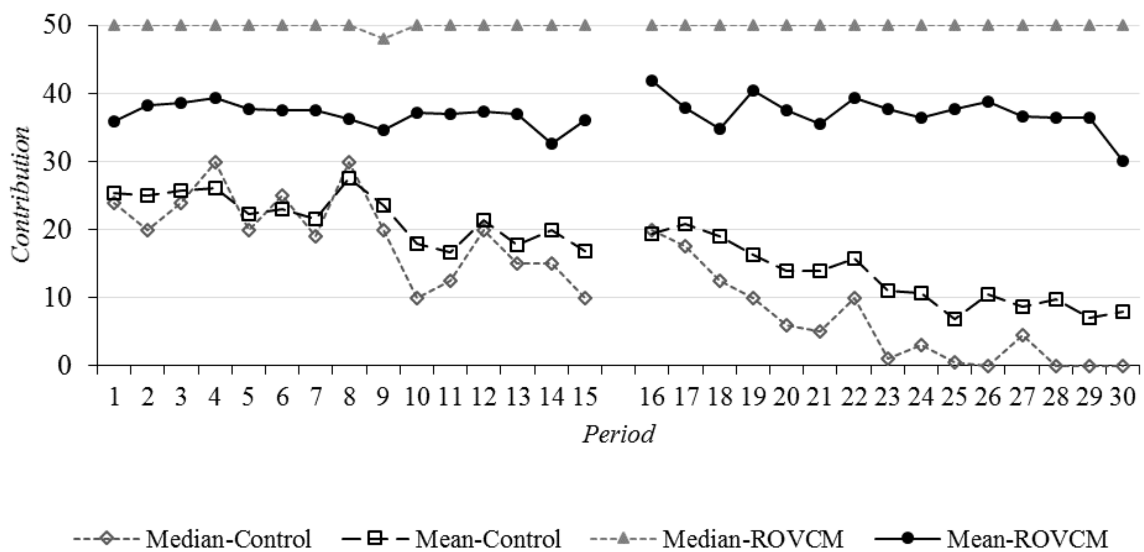
IV. RESULTS

Figure 1 presents the comparison of average contributions in the 2x15 periods of the Rank-Order-VCM and Control treatments. While the average contribution in Rank-Order-VCM starts at 35.9 and oscillates between 30.1 and 41.8, the average contribution in Control starts at 25.4 and steadily declines throughout the whole experiment to reach its minimum of 6.8 in period 25. In the last period, the average contribution is equal to 7.9. The median contribution shows even a sharper contrast: In Rank-Order-VCM, the median contribution is equal to the endowment in all periods but 9, while in Control the median contribution starts at 24 and drops down to 0 by the end of the experiment (see Figure 2).

4.1 Treatment effect

The exact two-tailed Wilcoxon test for independent samples reveals that the group contributions in Rank-Order-VCM and Control are significantly different at 5% level for both the first 15 periods (p-value = 0.038) and for the second 15 periods (p-value = 0.005). Each treatment involved eight independent groups. The average contribution per group member was 38.5 (13.8) in Rank-Order-VCM and 16.4 (11.5) in Control (standard deviation in parentheses). This difference is also statistically significant (p-value = 0.005). The sample of individual first contributions which involves 32 observations per treatment suggests that the differences in contributions are significant right from period 1; the p-value of the two-tailed Wilcoxon test is 0.037. Hence, we can conclude that Rank-Order-VCM leads to significantly higher contributions than Control.

Figure 2. Median and average contributions in Rank-Order-VCM and Control



4.2 Repetition effect

Our results from Control are in line with the stylized facts on the symmetric voluntary contribution mechanism reported by Ledyard (1995): The initial contributions are almost exactly half of the endowment and their decline is significant as shown by the random effects regression of the average group contribution on the time trend. The details are presented in Table 1, column (1). The regression involves a dummy variable for the restart of the game interacted on the time trend. The decline is significant in both the original and in the restart game. The difference in contributions between the original and the restart game is evident: Each group contributes less in the restart game than in the original game. The probability that such an extreme outcome occurs due to chance is 0.008.

Table 1. Random-effects dummy regression: average contribution/group on time trend

(column ID)	(1) Control	(2) Rank-Order-VCM	(3) Both treatments
Number of observations	240	240	480
Number of independent observations	8	8	16
Independent variables			
Intercept	27.847* (4.415) [.000]	39.999* (5.195) [.000]	37.708* (4.619) [.000]
DummyRestart	1.467 (2.372) [.536]	4.759 (2.468) [.054]	
Period	-.708* (.217) [.001]	-.334 (.221) [.131]	.049 (.069) [.478]
DummyRestart $\times$ *(period – 15)*	-.310 (.275) [.259]	.279 (.286) [.330]	
DummyControl			-8.929 (6.532) [.172]
DummyControl-VCM $\times$ *(period)*			-.847* (.098) [.000]

Note: estimated coefficient (standard errors in parenthesis); [p-values in brackets]; *significant at 5%.

Table 2. Random-effects dummy regression: contribution on lagged others' average contribution

(column ID)	(4) Control	(5) Rank-Order-VCM	(6) Both treatments
Number of observations	928	928	1856
Number of individual observations	32	32	64
Independent variables			
Intercept	17.882* (2.441) [.000]	16.759* (4.450) [.000]	9.753* (2.031) [.000]
Lagged others' average contribution	.176* (.063) [.005]	.470* (.061) [.000]	.417* (.046) [.000]
DummyRestart	-8.980* (1.568) [.000]	-2.861 (2.354) [.224]	
DummyRestart × lagged others' average contribution	.115 (.068) [.093]	-.078 (.059) [.185]	
DummyRank-Order-VCM			11.447* (3.389) [.001]
DummyRank-Order-VCM × lagged others' average contribution			.009 (.070) [.895]

Note: estimated coefficient (standard errors in parenthesis); [p-values in brackets]; *significant at 5%.

For Rank-Order-VCM, the average contribution increases from 37.3 to 39.6 between the original and the restart game. However, this difference is not significant as three groups increase and three groups decrease their contributions while two groups always contribute their full endowment. No significant time trend can be detected by the random effects dummy regression in the original or in the restart game for Rank-Order-VCM. The regression results are recorded in Table 1, column (2). Finally, based on the group data we observe that average contributions decline significantly more in Control than in Rank-Order-VCM (column (3)).

In summary, we observe no repetition effect and no contribution decline in Rank-Order-VCM. In contrast, there is a significant contribution decline in Control.

4.3 Absence of restart effect

Andreoni and Croson (2008) provide evidence that following a surprise restart in the symmetric VCM contributions jump back almost to their initial level after having declined in the original game. In our experiment, the restart was announced at the beginning of the experiment and so the subjects anticipated the restart game. In the absence of surprise, we do not find a significant restart effect. From period 15 to period 16 of Control (Rank-Order-VCM), three (four) groups increased, three (one) groups decreased and two (four) groups maintained their contributions on the same level. The two-tailed Wilcoxon matched-sample test reveals that these changes are not statistically significantly different from those that occur between period 14 and 15 (the p-values are 0.208 and 0.600 for Control and Rank-Order-VCM, respectively).

4.4 Conditional cooperative behavior

In the symmetric VCM subjects' contributions are positively correlated to the lagged average contribution of others (e.g., Gunnthorsdottir et al., 2010; Neugebauer et al., 2009). We observe the same effect for Control and find that it is even more pronounced in Rank-Order-VCM. Table 2 records the corresponding dummy regression results in columns (4) and (5), which are based on the individual data. The data show that contributions are positively correlated to the lagged average contributions of the other group members in both treatments. The differences between treatments with respect to this evidence of conditional cooperation are not significant as indicated by the binary variable for Rank-Order-VCM interacted on lagged contributions of others (see Table 2 column (6)). However, the sign is in the expected direction.

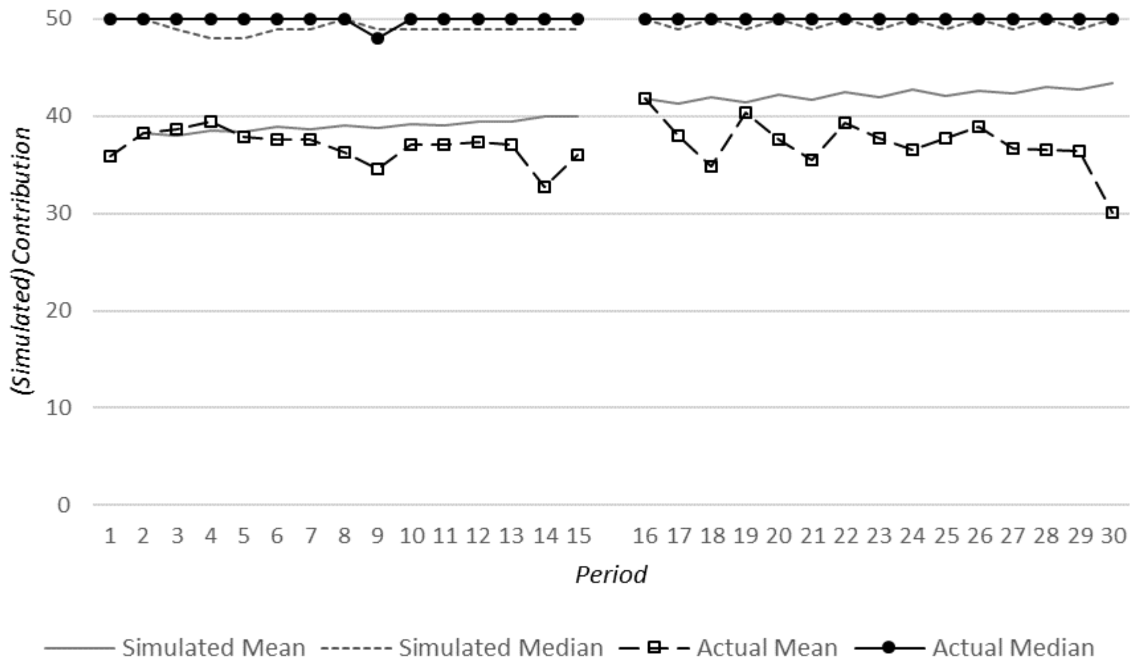
4.5 Impulse Response Dynamics

Given that individual learning trajectories are based on *one-step* adjustments $r_i(t)$ of their strategy in the direction of the ex-post best-response to the observed actions of others, starting from period 2 we simulate the individual dynamics based on the actual starting contributions of the participants. As can be seen in Figure 3, which compares the simulated mean and median contributions to the actual mean and median in Rank-Order-VCM, there is a very close resemblance between the actual and simulated behavior.

To check the significance of the impulse response dynamics (1) vis-à-vis the observed data, we propose Cournot dynamics as the alternative adjustment model. In contrast to the one-step adjustment of the impulse response model described in (1), Cournot dynamics require a full adjustment towards the ex-post best response contribution. For the simulation, we maintain the discrete strategy space of contributions when we simulate the Cournot dynamics starting from the initial contribution profile. Cournot dynamics ends after a finite number of repetitions in the free rider equilibrium. To test for significance, we compute the average and median contribution per cohort and compute the absolute difference of simulated from observed contributions. According to the two-tailed Wilcoxon signed ranks test, the average and the median of the impulse response dynamics are significantly closer than Cournot dynamics to the observed average and median.[13]

[13] The p-values of the Wilcoxon test are .0251 (periods 1..15) and .0357 (periods 16..30) when comparing the averages, and .0888 (periods 1..15) and .0348 (periods 16..30) when comparing the medians.

Figure 3. Simulated median and average contribution trajectories in ROVCM based on real initial contributions



V. DISCUSSION

Our paper introduces and theoretically and experimentally analyzes a rank order mechanism that counters the incentives to free-ride through competition in the VCM framework. Rank-Order-VCM assumes that one can give preferred access to the local public good to certain group members and thus generate heterogeneous payoffs. That is, a person who receives better access to the (publicly funded) good derives a higher utility from it than a person who receives restricted access. To model such situation we propose Rank-Order-VCM in which an individual who contributes more to a public good gains more from it than an individual who contributes less. This is accomplished by ranking the observed contributions and assigning a higher personal marginal return from the public good to a higher contributor. Rank-Order-VCM thus adds a contest aspect into the picture but keeps contributions voluntary. Furthermore, it does not require the social planner to award a fixed prize, which could change the equilibrium predictions.

In the experiment we test the hypothesis that rank-order competition, created by such assignment of shares, overcomes the incentives to free-ride. This hypothesis is motivated by the analysis of impulse-response trajectories (Neugebauer et al. 2014) which lead to high contribution profiles in the repeated play of Rank-Order-VCM. Our results suggest that repeated play of subjects moves in the direction of the (ex-post) best-response.[14] Although Rank-Order-VCM maintains a unique Nash equilibrium of zero contributions, it does not only elicit higher contribution levels than our Control treatment with random ranks but also sustains a median contribution of 100% of the endowment throughout the entire experiment, including the last period. Our results thus emphasize the power of competition also in collective action scenarios involving a tension between the self-interest and the interest of the group. Where applicable, this solution leads to contributions closer to the social optimum.

If increasing competition is desirable, a noteworthy extension of our design would be a situation where history of contributions resolves ties. On the other hand, competition can be a double-edged sword as high-power incentives in certain tournaments schemes are known to decrease contributions and can even lead to dysfunctional behavioral responses such as collusion of workers (e.g. Malcomson, 1984) or sabotage (e.g., Lazear, 1989, 2000; Falk and Fehr, 2001; Falk et al., 2008; Harbring and Irlenbusch, 2008).

While previous studies have also shown that contests can lead to decreased free-riding, in majority of them high-contributors get rewarded with fixed prizes. In our view that approach has two downsides: First, it is a costly solution, as any prize must be subtracted from the collected contributions. Second, as the size of the prize has been found to influence behavior, it is not always a priori guaranteed whether the contest will have a positive net effect. This is of

[14] Such behavior is described by learning direction theory which reportedly explains the behavior of laboratory subjects in many different contexts (Selten 2004).

particular concern for local public goods, which are limited by geographical space, as well as congestible goods such as a publically funded swimming pool.

The mechanism we propose is related to the literature which supports adding private supplements to high-earners in redistributive income tax regimes. For example, Epple and Romano (1996) study three regimes: private provision of private goods, public provision of private goods, and public provision of private goods but with private supplements. They find that, by means of a vote, the majority prefers the latter option, since both the rich and the poor are better off. The rich are incentivized to donate to the publicly provided good, helping the poor to get some government provision. While in our design all participants have identical income, previously mentioned literature on contests and public goods has found that contributions rise with income, meaning that Rank-Order-VCM could possibly have a distributive effect and be favorable for all income levels. Testing this experimentally would be another natural extension of our work.

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APPENDIX

A.1. Rank-Order-VCM Treatment Instructions

The purpose of the experiment is to study how people make decisions. From now until the end of the experiment, unauthorized communication of any kind between participants is prohibited. If you want to ask any question, please raise your hand first. Please turn off your cell-phone and do not use the computer for any other purpose than your participation in the experiment requires. If you break these rules, we will have to exclude you from the experiment and from all payments.

In the experiment you will earn money according to your decisions and the decisions taken by the other participants. At the end of the experiment you will be privately paid the sum of your payoffs during the experiment.

With whom do you interact?

1. At the beginning of the experiment, all participants are randomly assigned to groups of four. The composition of each group remains the same throughout the experiment, but the identity of the participants in the group will not be revealed to you at any time.
1. The experiment consists of thirty rounds. After the first fifteen rounds, there will be a restart of another fifteen rounds.

What do you have to do?

2. In every round you are endowed with 50 Cents. You have to decide how to use this endowment; what amount you allocate to a Project and how much you keep for yourself. The other three participants in your group face the same decision problem.
3. The money you allocate to the Project generates payoff to you and to every other participant in your group. The money you keep generates payoff only to you.

What will you earn?

4. In every round, your payoff will be computed as follows.

Your round payoff

=

the money you keep for yourself

+

the sum allocated to the Project by the four participants in your group

×

your multiplier

5. Your multiplier is determined by the amount you allocate to the Project and the amount

allocated by the other participants in your group. Given the allocation of the others in your group, the higher your allocation to the Project, the higher are your chances for a larger multiplier in that round. In particular:

- If your allocation is the highest in the group, your multiplier is 0.65.
- If your allocation is the second highest, your multiplier is 0.55.
- If your allocation is the third highest, your multiplier is 0.45.
- If your allocation is the lowest, your multiplier is 0.35.

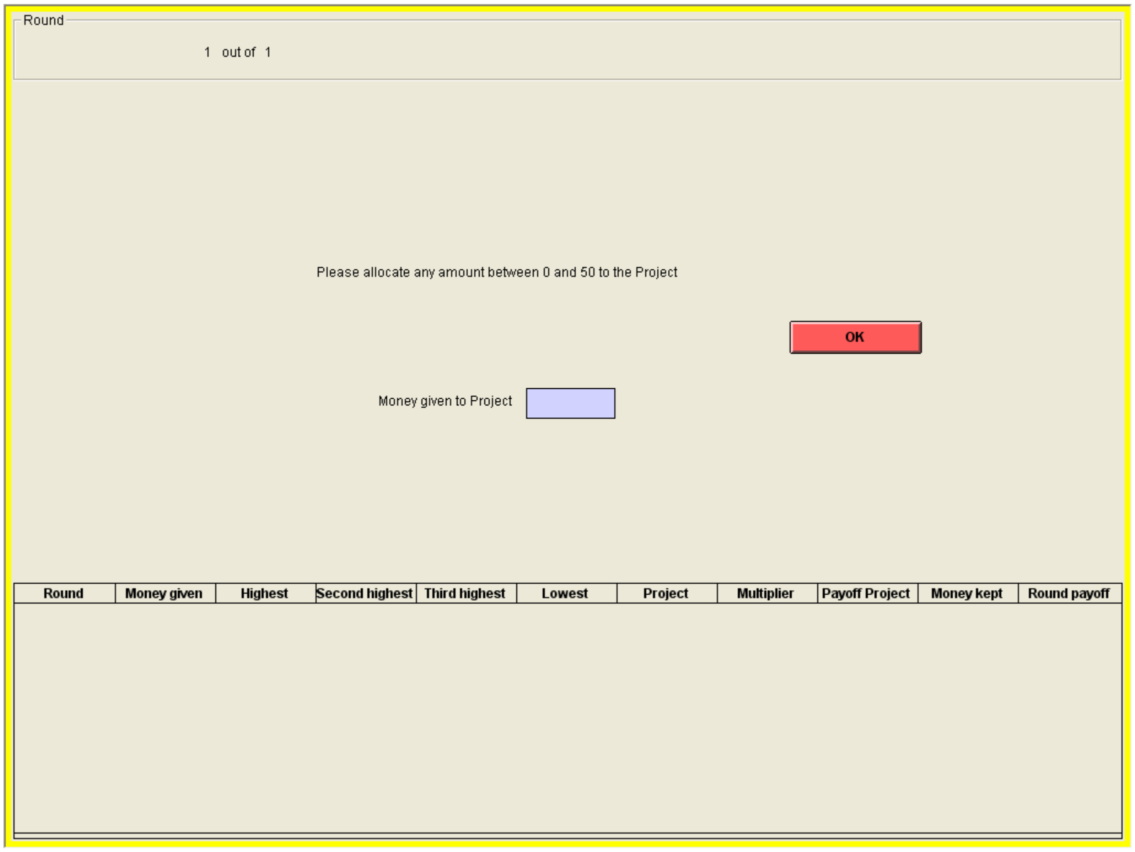
6. In case of a tie, i.e., if two or more participants allocate the same amount to the Project, the corresponding multipliers are averaged. For instance, if the second highest allocation is equal to the third highest, the multiplier for the two participants is 0.5 [= (0.55 + 0.45)/2]. Hence, participants who allocate the same amount to the Project get the same payoff.

<u>How do you make your decisions?</u>

7. In each round, you make your decision on the computer by entering an amount into the input field on the screen (you can select the input field with the mouse). Next you press the OK button (with the mouse) to confirm your decision. Note: After you have confirmed your decision you can not revise it anymore.

<u>What information will you receive?</u>

8. After each round you receive feedback information on the amount you and your group allocated to the Project. You receive information on the individual allocation ordered from highest to lowest, but you will not be able to trace the amount to the person who allocated it. You also receive information about your multiplier, the resulting payoff from the Project, the Money kept, and your round payoff.
9. This information is recorded in a table on your screen and will be available to you for all past rounds. At restart, the information for the first 15 rounds is cleared.


Round
1 out of 1
Please allocate any amount between 0 and 50 to the Project
OK
Money given to Project
Round
Money given
Highest
Second highest
Third highest
Lowest
Project
Multiplier
Payoff Project
Money kept
Round payoff

A.2. Control Treatment Instructions

The purpose of the experiment is to study how people make decisions. From now until the end of the experiment, unauthorized communication of any kind between participants is prohibited. If you want to ask any question, please raise your hand first. Please turn off your cell-phone and do not use the computer for any other purpose than your participation in the experiment requires. If you break these rules, we will have to exclude you from the experiment and from all payments.

In the experiment you will earn money according to your decisions and the decisions taken by the other participants. At the end of the experiment you will be privately paid the sum of your payoffs during the experiment.

<u>With whom do you interact?</u>

1. At the beginning of the experiment, all participants are randomly assigned to groups of four. The composition of each group remains the same throughout the experiment, but the identity of the participants in the group will not be revealed to you at any time.
2. The experiment consists of thirty rounds. After the first fifteen rounds, there will be a restart of another fifteen rounds.

<u>What do you have to do?</u>

3. In every round you are endowed with 50 Cents. You have to decide how to use this endowment; what amount you allocate to a Project and how much you keep for yourself. The other three participants in your group face the same decision problem.
4. The money you allocate to the Project generates payoff to you and to every other participant in your group. The money you keep generates payoff only to you.

<u>What will you earn?</u>

5. In every round, your payoff will be computed as follows.

Your round payoff

=

the money you keep for yourself

+

the sum allocated to the Project <u>by the four participants in your group</u>

×

your multiplier

6. In each round your multiplier is randomly determined by the computer; the computer draws a number 1, 2, 3, or 4 for each participant. The number is drawn with replacement; therefore it is possible for the computer to draw the same number for more than one

person in your group. Your multiplier is determined according to the rank of your random number. In particular:

- If your random number is the highest in the group, your multiplier is 0.65.
- If your random number is the second highest, your multiplier is 0.55.
- If your random number is the third highest, your multiplier is 0.45.
- If your random number is the lowest, your multiplier is 0.35.

7. In case of a draw, i.e., if two or more participants' random number is the same, the corresponding multipliers are averaged. For instance, if the second highest random number is equal to the third highest, the multiplier for the two participants is 0.5 [(= 0.55 + 0.45)/2]. You are informed about your multiplier only at the end of the period. Hence, you make your decision about your allocation without knowing the exact value of your multiplier.

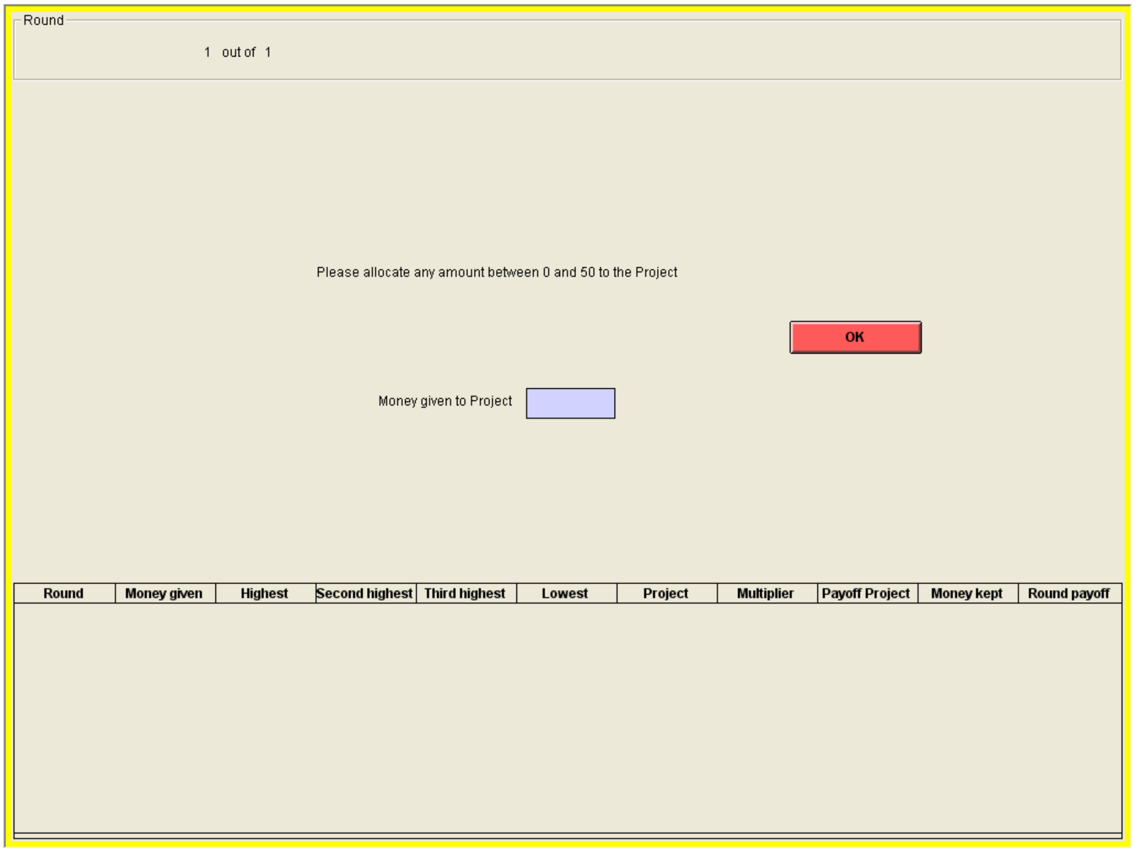
8. In case of a tie, i.e., if two or more participants allocate the same amount to the Project, the corresponding multipliers are averaged. For instance, if the second highest allocation is equal to the third highest, the multiplier for the two participants is 0.5 [= (0.55 + 0.45)/2]. Hence, participants who allocate the same amount to the Project get the same payoff.

How do you make your decisions?

9. In each round, you make your decision on the computer by entering an amount into the input field on the screen (you can select the input field with the mouse). Next you press the OK button (with the mouse) to confirm your decision. Note: After you have confirmed your decision you can not revise it anymore.

What information will you receive?

10. After each round you receive feedback information on the amount you and your group allocated to the Project. You receive information on the individual allocation ordered from highest to lowest, but you will not be able to trace the amount to the person who allocated it. You also receive information about your multiplier, the resulting payoff from the Project, the Money kept, and your round payoff.
11. This information is recorded in a table on your screen and will be available to you for all past rounds. At restart, the information for the first 15 rounds is cleared.


Round
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Please allocate any amount between 0 and 50 to the Project
OK
Money given to Project
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Money given
Highest
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Multiplier
Payoff Project
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