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Fundraising through Competition: Evidence from the Lab

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Fundraising through Competition: Evidence from the Lab

by

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Abstract

This paper investigates mechanisms for the private provision of a public good which utilize competition to incentivize contributions. Theory predicts that "all-pay" competition is particularly effective for fundraising. Within this class of mechanisms different types of lotteries and all-pay auctions are analyzed and ranked. Four all-pay competition mechanisms are then examined in a laboratory experiment vis-à-vis a voluntary contribution mechanism (VCM). All four outperform the VCM and towards the end of the experiment *fully efficient* outcomes are attained in the "lowest common denominator" scheme, which is particularly accommodating for people who have a preference for cooperating conditionally on others doing their bit.

Keywords

Public Goods; Provision Mechanisms; Experiments; Contests

JEL Classification Numbers

C72, C92

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1 Introduction

Although many people voluntarily contribute to public goods notwithstanding the incentive to free ride, such contributions are typically far below socially optimal levels. Over the last decades economists have developed a range of mechanisms that are theoretically capable of overcoming this problem. However, most of these are in the domain of optimal tax systems and rely on the social planner's ability to penalize individuals. Effective mechanisms for the *private* provision of a public good where the fundraiser does not have the power to sanction remain, by comparison, relatively unexplored.[1]

The focus of this paper is on private provision mechanisms which utilize *competition* as a means of mitigating free riding. Consider a situation in which funds for a public good are to be collected on the basis of individual voluntary contributions. Simply collecting money in a hat is uncomplicated but likely to perform poorly because of the associated free riding problem. By posting a prize for which individuals compete via their contributions, the fundraiser can create an additional private incentive for giving. However, because the contributions must cover the cost of the prize, it is a priori uncertain whether there will be a positive net effect. Morgan (2000) has shown that a simple raffle, where bidders contribute to a public good by purchasing lottery tickets, can indeed increase the equilibrium provision level vis-à-vis a pure voluntary contribution mechanism (VCM). Morgan and Sefton (2000) find experimental support for the superiority of the raffle relative to a VCM.

Lotteries are quite commonly employed for charitable fundraising. A related mechanism used in the field is best described as an all-pay auction. For example, some charities award prizes to their top fundraisers. These prizes can be substantial: in the "2005 Glendale Love Ride 22" fundraising event the most successful fundraiser received a two-person holiday trip to Switzerland including airfares, hotel accommodation and motorcycle rental—presumably, this generated a substantial incentive for participating volunteers. Similarly, the most generous donors are often rewarded with special prizes, e.g. through free advertising, general publicity or the renaming of a building. Goeree, Maasland, Onderstal and Turner (2005) analyze the theoretical properties of various auction types in the context of raising money for a public good. They find that while conventional winner-pay auctions are predicted to be ineffective, all-pay auctions increase revenues substantially in equilibrium.

[1] Much of the existing literature on methods for private provision focuses on provision point mechanisms (Bagnoli and Lipman, 1989; Bagnoli and McKee, 1991; Alston and Nowell, 1996; and Rondeau, Poe and Schulze, 2005).

The revenue-maximizing type of auction is a *last-price* all-pay auction where all players pay the lowest bid. This mechanism is not commonly seen in practice, yet its theoretical properties make it an interesting candidate for further examination.

Clearly, which format a fundraiser should adopt is a behavioral question. The theoretical rankings are quite fragile in the sense that some of the schemes can be vulnerable to behavior that violates conventional model assumptions (e.g. unbounded rationality). Conversely, mechanisms like the VCM often perform significantly better than standard theory predicts. In this paper laboratory methods are used to study the effectiveness of five mechanisms in a common setting characterized by a simple stylized public good problem. The experiment examines a VCM as a baseline treatment, a lottery, a first-price all-pay auction, a last-price all-pay auction and a "lowest common denominator" (LCD) scheme, which is in essence a last-price all-pay auction without an explicit reward. In each treatment subjects encounter one of these mechanisms twenty-five times under a random-matching protocol.

The experimental results show considerable differences between first-round behavior and behavior towards the end of the experiment. In the first round contributions are, in contrast to the theoretical predictions, quite similar across treatments. The only mechanism to elicit significantly higher contribution than the VCM is the first-price all-pay auction. However, the first-price all-pay auction does not (systematically) outperform the VCM in terms of the level of public good provision, i.e. after taking into account the cost of providing the prize. The picture changes once subjects have had the chance to gain experience with the mechanisms: contributions in the VCM collapse and all alternative schemes now outperform the baseline, in terms of contributions as well as provision levels. Remarkably, in the last period of the sessions employing the last-price all-pay auction and the lowest common denominator mechanism subjects contribute their *full endowments* to the public good.

The paper is structured as follows. The setup and the mechanisms are described in Section 2. Section 3 discusses these against the backdrop of a more general theoretical analysis and gives details of the experimental design. The results from the experiment are reported in Section 4. Section 5 concludes by discussing the findings and related experimental work.

2 General setup and the fundraising mechanisms

All five mechanisms investigated in the experiment can be understood as specifications within a simple general framework. The key idea is that rewarding players based on their relative contributions creates a situation of a competitive nature (more precisely: a contest), which can be exploited to improve social efficiency. The most important and defining properties of any such scheme are (a) how the winner of the competition is determined and (b) who pays how much. Suppose each player starts with an endowment of *A* and is then asked to submit a "bid", x_i. Generally, we can think of these bids as voluntary but binding commitment to make a contribution. The payoff of a player *i* is

$$\pi_i(x_i) = \alpha\left[A - g(x_i, \mathbf{x_{-i}})\right] + \beta\left[\sum_{j=1}^{n} g(x_j, \mathbf{x_{-j}}) - R\right] + \alpha R \cdot f(x_i, \mathbf{x_{-i}}) \qquad [1]$$

where $\mathbf{x_{-i}}$ is the set $\{x_1, \ldots, x_{i-1}, x_{i+1}, \ldots x_n\}$ and *R* represents the reward or prize, which is allocated to the winner.[2] The most interesting parameter constellation, on which we will focus here, is $n\beta > \alpha > \beta > 0$ because it implies a tension between social efficiency and individual incentives under voluntary contributions when there is no prize.

Thus, players benefit from private consumption, $A - g(x_i, \mathbf{x_{-i}})$, but also benefit, via a positive externality, from the sum of contributions to the public good. The functions $g(.)$ and $f(.)$ describe the rules of the competition: given all bids, including player *i*'s own, $g(.)$ defines how much player *i* actually contributes and $f(.)$ represents the probability that she wins the prize. Note that the opportunity cost of providing an extra incentive to contribute has to be considered: the cost of making a prize $R > 0$ available uses up funds that could otherwise be spent on the public good itself.

Equation [1] can be viewed as a general representation of a wide range of incentive mechanisms. A fundraiser's task is to find specifications of the prize *R*, the prize allocation rule *f* and the contribution rule *g* that maximize (net) revenues. However, since a private fundraiser does not have the authority to enforce contributions, there must be an $x_i = \tilde{x}$ such that $g(\tilde{x}, \mathbf{x_{-i}}) = 0 \;\forall\, \mathbf{x_{-i}}$, that is every player must have the right to refuse making contributions irrespective of other players' bids.

The following five mechanisms were investigated experimentally for this paper.

1. VCM: The baseline treatment of the experiment is a conventional voluntary contribution mechanism that emerges when $g(x_i, \mathbf{x_{-i}}) = x_i$ and $R = 0$. Joint payoffs are highest when all players contribute *A*, but individual rationality dictates to contribute nothing.

[2] In the following I will restrict attention to single-prize contests. For a theoretical analysis of a multiple-prize setting in the context of fundraising, see Faravelli (2008). For experimental evidence relating to Faravelli's model see Corazzini, Faravelli and Stanca (2007).

2. LOT: In the lottery treatment players receive lottery tickets in exchange for their contributions. The holder of the winning ticket, randomly selected from all issued tickets, receives the prize. Thus, $R > 0$ and $f(x_i, \mathbf{x_{-i}}) = x_i \Big/ \sum x_j$ (see Morgan and Sefton, 2000).

3. FPA: The first-price all-pay auction is identical to LOT except that the prize allocation is deterministic: whoever contributes most, wins the prize, subject to a tie-breaking rule. Thus,

$$f(x_i, \mathbf{x_{-i}}) = \begin{cases} 1 & \text{if } x_i > \max(\mathbf{x_{-i}}) \\ 1/m & \text{if } i \text{ is tied for the highest bid with } m-1 \text{ other players} \\ 0 & \text{if } x_i < \max(\mathbf{x_{-i}}) \;. \end{cases}$$

4. LPA: In the last-price all-pay auction the highest bidder still wins the prize (as in FPA), but this mechanism departs from the simple pay-as-you-bid contribution rule. Now, the *lowest bid* determines a *minimum contribution level*, which is fixed and identical for all participants: $g(x_i, \mathbf{x_{-i}}) \geq \min(x_1, \ldots, x_n)$.

5. LCD: This scheme completes the circle. It is, in principle, identical to LPA but like in VCM there is no prize. All players submit a bid and are required to contribute at least the lowest common denominator.

Table 1 summarizes the key properties of all five mechanisms.

Table 1: The five fundraising mechanisms

	Contribution rule	
Prize allocation rule	*Pay as you bid*	*Pay lowest bid*
Highest bidder wins	FPA	LPA
Lottery	LOT	—
No Prize	VCM	LCD

3 Theoretical background

3.1 The advantages of "all-pay" schemes

A common feature of the mechanisms above is the "all-pay" property. This makes them fundamentally different from "winner-pay" formats such as conventional auctions. A drawback of an all-pay design is that contributors will anticipate that they run the risk of giving without receiving anything in return (except via the supply of the public good), which reduces the incentive to bid highly. However, two other effects work in the opposite direction, and both of these can be understood by thinking about the consequences of winning the prize. First, think about winner-pay versus all-pay in terms of a marginal analysis. In a winner-pay mechanism losers do not pay, but this implies that the *cost increase* for an individual is relatively high *if* she wins. In an all-pay contest it is, by comparison, relatively cheap to marginally increase any given level of contribution in an attempt to outbid other players. Second, and more importantly, winning does not annihilate the contributions of other participants, which the winner cares about via the given externality (see Goeree et al., 2005, for a more extensive discussion).

In a winner-pay system bids have to exceed the value of the prize to achieve a positive net effect, yet bidders have no reason to bid more than the prize is worth; thus in the framework used here any *k*th-price winner-pay auction is revenue-equivalent to a VCM.[3] Charitable winner-pay auctions observed in the field should hence not be seen as incentivized fundraising mechanisms but rather as a simple way of converting donated items into cash (perhaps with the side benefit of creating publicity). All-pay competition, on the other hand, can potentially achieve more, as we shall see in the following.

3.2 Probabilistic and deterministic first-price all-pay contests (LOT and FPA)

Consider first the most basic all-pay format where players simply pay what they bid, i.e. $g(x_i, \mathbf{x}_{-\mathbf{i}}) = x_i$. With this specification, how should the prize allocation rule be chosen to maximize public good provision? Morgan (2000) examines a simple raffle where a bidder's chance of winning is determined as the proportion of the number of tickets the bidder holds relative to all tickets sold. As Morgan shows, equilibrium contributions are higher than in a VCM. However, intuitively one might think that bidding may become even more aggressive if large contributions were favored *more* than proportionally. The following proves this intuition correct, but the link between revenues and the degree by which the reward mechanism discriminates between different contribution levels is not strictly monotonic.

To show this, it is useful to employ Tullock's (1980) well-known logit contest success function where player *i* wins the contest with probability

$$f(x_i, \mathbf{x}_{-\mathbf{i}}) = \frac{x_i^{\rho}}{\sum_{j=1}^{n} x_j^{\rho}} . \qquad [2]$$

This function has become a standard tool in the literature on rent-seeking competition, and Skaperdas (1996) shows that it satisfies a set of normatively appealing axioms. The

[3] Positive net revenues might be achieved in a winner-pay auction when the prize valuations are heterogeneous. However, Goeree et al. show that these are quite small, even when the marginal per capita return is close to one.

parameter ρ determines the degree to which the mechanism discriminates between different bids. When $\rho = 0$, a player's chance of winning is 1/*n*, regardless of the submitted bids. As ρ grows, it becomes increasingly likely that the highest bidder wins, and in equilibrium players make positive contributions when ρ is positive.

Proposition 1: *If (and only if)* $\rho \leq n/(n-1)$*, the Tullock-type first-price all-pay contest has a symmetric pure-strategy equilibrium where players bid*

$$x^* = \frac{n-1}{n^2}\frac{\alpha}{\alpha-\beta}\rho R \,. \tag{3}$$

Proof. *See Appendix A.*

Thus, equilibrium contributions increase linearly in ρ and in R (as long as the budget constraint is not binding). The case $\rho = 1$ describes Morgan's lottery mechanism (equivalent to the LOT treatment here). From Equation [3] we immediately get

$$\Theta_{\text{LOT}} = \frac{n\beta-\alpha}{n(\alpha-\beta)}R \tag{4}$$

as the total provision level in this case. Thus, there is an efficiency improvement vis-à-vis the VCM if $n\beta > \alpha$. That is, interestingly, the lottery generates positive net revenues only if it is socially desirable that players contribute to the public good (see Morgan).

When $\rho < 1$, social optimality is not a sufficient condition to generate contributions high enough to offset the cost of the prize. Since revenues increase with the exponent, the more interesting case is $\rho > 1$, which can be interpreted as an exponential quantity discount for purchasing lottery tickets (e.g., one receives 1 ticket for \$1, 4 tickets for \$2, 9 tickets for \$3, and so on). This discount stimulates ticket sales and produces positive net revenues even when this is not socially desirable (though from the fundraiser's viewpoint this may not be an issue). At $\rho = \tilde{\rho} \equiv n/(n-1)$ the mechanism guarantees positive net revenues as long as β is positive, and the provision level is

$$\Theta_{\rho=\tilde{\rho}} = \frac{\beta}{\alpha-\beta}R \tag{5}$$

and thus $\Theta_{\rho=\tilde{\rho}} > \Theta_{\text{LOT}}$ for any $n \geq 2$.

When $\rho > \tilde{\rho}$, the properties of the equilibrium change and require players to randomize between different bids. In the limit, when $\rho \to \infty$, the mechanism becomes perfectly discriminatory: the player with the highest bid wins the contest for sure. This case corresponds to an all-pay auction (our FPA treatment). To analyze the equilibrium properties of this format the following definition is useful.

Definition: *The prize level R will be categorized as "low" if* $0 < R \leq (1/\alpha)(\alpha - \beta)A$, *as "medium" if* $(1/a)(\alpha - \beta)A < R \leq (1/\alpha)(\alpha - \beta)nA$, *and as "high" if* $R \geq (1/\alpha)(\alpha - \beta)nA$.

Proposition 2:

(a) If R is high, the all-pay auction has a symmetric pure strategy equilibrium where players contribute their full endowments.

(b) If R is not high, there is no symmetric Nash equilibrium in pure strategies.

(c) If R is low, there is a symmetric mixed strategy equilibrium in which players choose contributions from the cumulative distribution function (cdf)

$$F(x) = \left(\frac{\alpha - \beta}{\alpha R} x \right)^{\frac{1}{n-1}}$$

on the support $[0, u]$ *where* $u = \alpha R / (\alpha - \beta)$.

(d) If R is medium, there is a symmetric mixed strategy equilibrium in which players contribute their full endowment with probability $p_A > 0$, *where* p_A *is the (unique) solution of*

$$\frac{1 - (1 - p_A)^n}{p_A} = \frac{\alpha - \beta}{\alpha R} nA.$$

With probability $1 - p_A$ *an agent chooses her contributions from F(x) in the interval* $[0, w]$, *where* $w = (1 - p_A)^{n-1} \alpha R / (\alpha - \beta) < A$. *Thus, the equilibrium cdf in this case is*

$$G(x) = \begin{cases} F(x) & \text{if } 0 < x \leq w \\ 1 - p_A & \text{if } w < x < A \\ 1 & \text{if } x = A. \end{cases}$$

Proof. *See Appendix A.*

The intuition for Proposition 2 is as follows. If the prize is very high, players are willing to spend their entire endowment for the chance to win. If it is low, players always prefer outbidding their competitors to tying with them; however, if this requires a bid above a certain level the best response is actually bidding zero. Players balance this tension between different bid levels by randomizing their bids according to *F*(*x*). If *R* is medium, it is a best response to tie with some (but not all) competitors at *A*. Players then either choose *A* or randomize over an interval of lower bids.

Table 2 summarizes the equilibrium predictions for the all-pay auction.

Table 2: Theoretical predictions for the all-pay auction

Prize[*]	*Distribution*	*Support*	*Expected bid*
$R = 0$	—	0	0
$0 < R \le \Omega$	$\left(\frac{\alpha-\beta}{\alpha R}x\right)^{\frac{1}{n-1}}$	$\left[0, \frac{\alpha R}{\alpha-\beta}\right]$	$\frac{\alpha R}{n(\alpha-\beta)}$
$\Omega < R \le n\Omega$	$\left(\frac{\alpha-\beta}{\alpha R}x\right)^{\frac{1}{n-1}}$	$\left[0, \frac{(1-p_A)^{n-1}\alpha R}{\alpha-\beta}\right]; A$	$\frac{\alpha R}{n(\alpha-\beta)}$
$R > n\Omega$	—	A	A

[*] $\Omega = (1/\alpha)(\alpha-\beta)A$

Hence, if A is not binding, the provision level in the all-pay auction is, in expectation,

$$\Theta_{\mathrm{FPA}} = \frac{\beta}{\alpha-\beta}R. \quad [6]$$

and thus, for $n \ge 2$, $\Theta_{\mathrm{FPA}} = \Theta_{\rho=\tilde{\rho}} > \Theta_{\mathrm{LOT}}$.

Now consider intermediate values of ρ, where $\rho > \tilde{\rho}$ but finite.[4] For any such ρ the expected payoff in the symmetric mixed strategy equilibrium can be written as

$$\pi = \alpha A + (n\beta - \alpha)E(x) + \left(\frac{\alpha}{n} - \beta\right)R. \quad [7]$$

It is straightforward to show that the lower bound of the equilibrium support must be at zero and does not have a point mass there. The expected payoff from making a zero contribution can hence be written as $\pi_i(0) = \alpha A + (n-1)\beta E(x) - \beta R$ and must equal π. This implies that

$$\Theta_{\rho>\tilde{\rho}} = nE(x) - R = \frac{\beta}{\alpha-\beta}R \qquad (= \Theta_{\tilde{\rho}} = \Theta_{\mathrm{FPA}}). \quad [8]$$

A sketch of the relationship between ρ and the provision level is shown in Figure 1. With an infinite number of players $\tilde{\rho}$ approaches one, and the raffle, the lotteries with quantity discounts and the all-pay auction become revenue-equivalent.

[4] The literature on Tullock's rent seeking model (where $\beta = 0$) has devoted considerable attention to this case; see Baye, Kovenock and de Vries (1994).

[FIGURE 1 HERE]

3.3 The pay-the-lowest-bid rule (LPA and LCD)

In the analysis above, players pay what they bid. Alternatively, the contribution rule may stipulate that some bidders pay less than what they bid. Goeree et al. analyze the class of k^{th}-price all-pay auctions where the k highest bidders all pay the k^{th}-highest bid and all other bidders pay their own bids. Goeree et al. show that revenues are increasing in k. An intuitive argument suggests why this is the case. In a first-price all-pay auction a player's marginal cost of increasing her bid is always $\alpha - \beta$. In a k^{th}-price all-pay auction this is only the case if the player's bid is below the kth-highest bid. If the player's bid is higher than the kth-highest bid her marginal cost of raising her bid is zero. If the player's bid is equal to the kth highest bid and she is not tied with another player the marginal cost is $\alpha - k\beta$.

The optimal fundraising mechanism therefore is a last-price all-pay auction (LPA) where $g(x_i, \mathbf{x_{-i}}) = \min(x_1, \ldots, x_n)$. Consider equilibrium bidding under this rule. Note first that $x_i = 0 \; \forall i$ cannot be an equilibrium because a player could then grab the prize at zero cost by submitting an arbitrary positive bid. Similarly, if all other bidders choose $\tilde{x} > 0$, a player could profitably outbid his competitors at no additional cost. In contrast, a downward deviation would not pay off, because a lower bid would reduce the required contribution level for *all* players and thus fully internalizes the externality for that bidder. Consequently, we get

Proposition 3: *In the unique equilibrium of the last-price all-pay auction all players contribute their endowment (* $x_i = A \; \forall i$ *).*

This result also holds for heterogeneous agents who differ from each other in the marginal payoff they receive from the public good, as long as $n\beta_i > \alpha \; \forall i$. If this condition is not fulfilled for all i, the provision level becomes dependent on R and maximum contributions are obtained if $R > (1/\alpha)(\alpha - \min\{\beta_1, \ldots, \beta_n\})nA$.

Proposition 3 is driven by the last-price contribution rule, which effectively internalizes the externality—competing for the prize becomes almost secondary. In fact, the public good provision level in LPA does not depend on the value of the prize. As long as there *is* a prize, the equilibrium in Proposition 3 is sustained and unique. When the prize is zero, the equilibrium is no longer unique: in this case a symmetric pure strategy equilibrium exists at every contribution level. However, choosing A remains a weakly dominant strategy and if the Nash equilibrium is refined accordingly players still contribute their endowments, as long as this is socially optimal. Based on this refinement, we can therefore predict a fully efficient outcome for the lowest common denominator treatment (LCD), whereas in LPA efficiency is brought down, to some degree, by the cost of providing the prize.[5]

Note also that the LPA and LCD mechanism do not burden the fundraiser with strong commitment requirements: unlike provision point mechanisms they do not rely on the threat to refuse or return donations. Indeed, in the experiment subjects were allowed to contribute more than the lowest common bid in LPA and LCD if they wished to do so. This allows the fundraiser to accept additional voluntary donations and does not affect the equilibrium.

3.4 Experimental design

A total of 180 undergraduate students from various subject areas took part in the experiment, which I ran at the University of Nottingham. The experiment consisted of fifteen sessions, three in each of five treatments, with twelve participants per session. At arrival subjects were randomly seated at computer terminals. During a session participants could earn "points" that were later converted to cash using an exchange rate of 10 points per penny. Each session lasted twenty-five periods. To avoid repeated game effects subjects were randomly and anonymously rematched (into three groups of four) at the beginning of each period.[6] No verbal or other form of communication was permitted.

At the beginning of a period subjects received 100 tokens each and then had to decide how to allocate these between their "private accounts" and the "group account".[7] A token allocated to the private account generated a return of two points for the individual, and a token allocated to the group account generated a return of one point for each of the four group members—thus, the marginal per capita return from the public good was 0.5.

The framing of the experimental environment differed slightly from the theoretical setup in that exogenous funds covered the cost of the prize *R* to ensure that that the provision level could not become negative. In other words, a common starting point for all treatments was that a fixed, exogenously provided amount was available which, depending on the treatment, was either used directly for public good provision or used as a means to fund a

[5] Note that the lowest common denominator property is not the same as the "weakest-link" technology (see Hirshleifer, 1983, and Harrison and Hirshleifer, 1989). In the case of weakest link public goods there are multiple equilibria too but there the efficient equilibrium is only "payoff dominant", not in weakly dominant strategies. The main difference is that the weakest link model considers a first-price contribution rule.

[6] Actual fundraisers might prefer not to impose anonymity to encourage giving via peer pressure or imitation, and Andreoni and Petrie (2004) find that disclosure indeed increases contributions significantly. However, the idea of this experiment is to examine specific incentive structures separately from such social processes.

[7] A copy of the instructions can be found in Appendix B.

prize to incentivize contributions. Thus, for the purpose of consistency, subjects in VCM and LCD received an additional lump sum payment of fifty points per period, which is equivalent to one hundred points invested in the group account. In the other three treatments the hundred points were transferred to the private account of the winner of the competition.

In each of the five treatments participants experienced just one of the mechanisms. The LPA and LCD mechanisms were implemented using a two-stage procedure. In stage one of LPA subjects were asked to state how many tokens they would be willing to allocate to the group account and the person willing to allocate the highest number to the group account received the prize. In stage one of LCD there was no prize and a slightly different wording was used. In the second stage of both LPA and LCD players were informed about the other group members' stage-one submissions and then decided how many tokens to actually contribute (the minimum being the lowest number submitted in stage one).

After subjects had submitted their choices, the computer calculated the outcomes according to the rules of the relevant treatment. Participants were then informed about the payoffs of all group members before new groups were formed for the subsequent period.

Obviously, the experiment abstracts from "realism" in several respects: the individual endowments, the group size and the benefits from private and public good consumption are identical across subjects and are common knowledge, and the prize, when it is present, has a common value, which is also known by all players. Everything is linear and the participants are given ample opportunity to familiarize themselves with the incentive structure each mechanism creates. Such a design has advantages and drawbacks. The advantages are simplicity, greater experimental control and comparability to existing laboratory research on public goods, where highly similar designs have been used. Hence, this experiment will provide clear-cut evidence about the extent to which the mechanisms cause behavioral changes and changes in outcomes *in the simplest possible world*. This allows a clean examination of their strategic incentive properties. The drawback, of course, is a potential loss of external validity, since many of the features of the experiment are atypical for natural fundraising scenarios. Accordingly, one should exercise caution with generalizing the results to such natural settings.

Within the given framework, equilibrium theory ranks LCD and LPA as the most effective mechanisms, followed by FPA, LOT and VCM. In the VCM the prediction is that not more than the initial supply of 100 points can be spent on public good provision. In LCD there are multiple equilibria, but via elimination of weakly-dominated strategies the efficient outcome emerges as the prediction (public good provision of 900 points). In LPA the equilibrium is unique and predicts maximum provision, although the cost of making the prize available must now be subtracted (leaving 800 points). Lower provision levels are predicted in LOT (150 points) and FPA (200 points).

Of course, based on known behavioral patterns from previous laboratory experiments on social dilemma games, one may expect positive contributions in the VCM. But if subjects are generally influenced by efficiency considerations, one might also expect a positive bias in some of the other treatments (which is a further justification for the equilibrium refinement used in the prediction for LCD). Even if efficiency considerations are of minor importance, the properties of the LPA and LCD mechanisms might appeal to people with a willingness to cooperate *conditionally*.[8] A player's pre-commitment in the first stage is only binding if all other group members *also* decide to pre-commit at the same or at a higher level. Thus, the notion of conditional cooperation is effectively incorporated into the incentive structure of these mechanisms. On the other hand, both LPA and LCD are vulnerable to other forms of "anomalous" behavior: the mechanisms effectively break down if only one of the players decides to submit a zero in stage one. Moreover, theoretically these mechanisms work because bidders expect that the lowest bid strictly *determines* the contributions of *all* players since agents are predicted to contribute the lowest permissible amount in stage two—however, if this prediction turns out to be empirically false, this will ease the burden of responsibility on the lowest bidder and may therefore facilitate downward deviations in bidding behavior.

4 Results

On average, subjects earned £8.33 (about $14.50 at the time) for sessions lasting about thirty-five minutes, including the time for instructions. Thus, the financial incentives were quite substantial.

In the first period, the outcomes deviate substantially from the theoretically predicted ranking. As shown in Table 3, average contributions in VCM, LOT, LPA and LCD are all clustered around the middle of the action space. The mechanism that sticks out is the first-price all-pay auction, and the difference between FPA and the other treatments is statistically significant.[9] In particular, contributions in FPA are more than 50% higher than in the VCM,

[8] See Keser and van Winden (2000) and Fischbacher, Gächter and Fehr (2001).

[9] Initial decisions can be viewed as independent of one another and so statistical tests are based on subject-level data: a Wilcoxon rank-sum test yields two-sided p-values of 0.001 (FPA vs. VCM), 0.010 (FPA vs. LOT), 0.001

the baseline treatment. However, because no prize is needed for the voluntary contribution mechanism, the level of *public good provision* in FPA exceeds that of the VCM by only about 19% and this difference is not statistically significant (using non-parametric methods). For the same reason the VCM is in fact more successful than the lottery and the last-price all-pay auction (although these differences are not significant either).

Table 3: Outcomes in period 1

Experimental treatment	*VCM*	*LOT*	*FPA*	*LPA*	*LCD*
*Average contribution level in tokens**	45.2 (31.4)	50.4 (33.3)	68.9 (27.1)	55.7 (34.9)	45.9 (26.2)
*Average public good provision in points**	461.6 (112.2)	402.9 (140.7)	551.1 (103.8)	445.6 (207.5)	466.9 (135.0)

* *Standard deviations in parentheses*

Result 1: *The equilibrium predictions do not organize the period 1 data well. Contributions are highest in the first-price all-pay auction and lowest in the VCM, but there is no clear ranking of the mechanisms in terms of the level of public good provision.*

Over time we observe some clear and diverse dynamic trends across treatments. Figure 2 shows average contributions over time in all five treatments. The contribution levels in all VCM, LOT and FPA sessions are lower in the second half (periods 14 to 25) than in the first half (periods 1 to 13), while there is an increase in all LPA and LCD sessions.

[FIGURE 2 HERE]

The ranking of the mechanisms that emerges towards the end of the experiment differs drastically from that in period one, and the initial superiority of the FPA mechanism does not last. Contributions in both FPA and LOT end up at around thirty percent of the endowment, while they collapse almost completely in VCM and reach the top of the strategy space in LPA and LCD. Table 4 reports the average contribution levels overall and for later periods.

Based on a nonparametric Wilcoxon rank-sum test at the session level, the difference in average contributions between the VCM benchmark and each of the other four treatments is significant at a 5% level, in every column of Table 4. Conversely, choices in LPA and LCD are consistently and systematically *higher* than in the other treatments (again in every column

(FPA vs. LCD) and 0.086 (FPA vs. LPA). A Kruskal-Wallis test based on the four treatments exclusive of FPA does not reject the null hypothesis of equal distributions (the p-value is 0.639).

of Table 4). Remarkably, in the final period of LPA and LCD *all the 72 subjects* who participated in these treatments choose to allocate *all* their tokens to the group account.

Table 4: Average contributions (in tokens)

	Periods				
Treatment	*All*	*Last 15*	*Last 10*	*Last 5*	*Last*
VCM	16.9	10.3	7.3	5.5	3.2
LOT	40.6	33.1	30.8	29.5	29.8
FPA	37.7	30.0	28.4	27.2	28.8
LPA	76.9	83.8	84.7	90.4	100.0
LCD	68.5	82.8	89.2	95.3	100.0

In LOT, FPA and LPA bidding is stimulated by the presence of the prize, the cost of which must be covered by the players' contributions before the fundraiser makes any net revenue. As Table 5 shows, the net effect relative to the baseline treatment is still positive. Averaged over all periods, the provision level in the first-price all-pay auction is 28% higher than in the VCM, in the lottery the difference is +38% and in LPA it is +162%.

Table 5: Average public good provision (in points)

	Periods					
Treatment	*All*	*Last 15*	*Last 10*	*Last 5*	*Last*	*Prediction*
VCM	235	183	158	144	125	100
LOT	325	265	246	236	238	150
FPA	302	240	227	218	230	200
LPA	615	671	677	723	800	800
LCD	648	762	814	862	900	900

When we focus on the late periods, the results are even more clear-cut, due to the fact that the provision levels move closer to the predicted levels over time.[10] Looking at Table 5, the differences between LOT/FPA and the baseline are statistically significant from the "Last 10" column onwards (at a 5% significance level), whereas LOT and FPA cannot be

[10] Indeed, this is the case in all 15 sessions. The probability for such a pattern—under the null hypothesis that contributions are equally likely to move closer to or further away from the equilibrium level from the first half to the second—is less than 0.001. In most treatments the provision levels approach values close to the relevant predictions even in absolute terms, though in LOT they exceed the theoretical value by a substantial amount.

statistically separated from each other.[11] The LPA mechanism produces significantly more net revenue than either LOT or FPA (in all columns of Table 5, again based on a 5% significance level). The LCD format is in turn significantly more successful than LPA, based on the last three columns and using the same level of significance. This last difference is not rooted in any *behavioral* difference between the two treatments; it is explained by the efficiency loss due to the cost of making a prize available in LPA.

Result 2: *With experience subjects contribute systematically less in the VCM than under any of the incentive mechanisms, while contributions in the last-price all-pay auction and the lowest common denominator scheme are higher than in any other format. The highest level of public good provision is attained in LCD. The LPA mechanism is slightly less effective. There is little difference between LOT and FPA, but both outperform the VCM in terms of public good provision.*

From a practitioner's viewpoint an important question is how much 'hands-on' experience with the mechanisms is necessary before this ranking develops. To investigate this question, consider the period averages (across all groups and sessions) for each treatment. After period 11, both FPA and LOT generate higher average provision levels than the VCM, in every period without exception until the end of the experiment. However, LPA and LCD already achieve this after the very first period, and after period 7 they also always outperform FPA and LOT. Thus, although the complete final ranking of the treatments takes some time, the two last-price mechanisms appear to take the lead early on. Ultimately, LCD becomes the most successful mechanism (it dominates LPA from period 14 onwards).

It should be noted, however, that in all sessions there is considerable variability in choices at the individual level, particularly in early periods where individual contributions are typically located all over the [0, 100] range. Although, as we have just seen, these fluctuations at the individual level average out at the treatment level, one may wonder how likely it is that a particular mechanism performs well when we consider a randomly composed group of four. The results from such an analysis are presented in Tables 6 and 7.

Most importantly, the mechanisms should be reliable in the sense that the cost of providing a prize to incentivize giving can be expected to be more than outweighed by additional contributions. Since no prize is supplied in VCM and LCD, there is no such risk of

[11] Contrary to the theoretical prediction, subjects contribute on average a little more in LOT than in FPA.

failure for these. However, Table 6 shows that the other mechanisms are also quite reliable. Remarkably, the risk of failure in the last-price all-pay auction is practically zero.

Table 6: Chances of breaking even†

Rounds	*VCM*	*LOT*	*FPA*	*LPA*	*LCD*
1–5	100%	99%	99%	99%	100%
6–10	100%	96%	89%	100%	100%
11–15	100%	91%	83%	100%	100%
16–20	100%	88%	77%	100%	100%
21–25	100%	86%	80%	100%	100%

† Probability that the contributions from a group of four (randomly composed from the subjects in the relevant treatment) exceed the cost of providing the prize

Another aspect of reliability is how likely the four alternatives to the VCM outperform the VCM. This is reported in Table 7. As the table shows, net revenues under any of the mechanisms are more likely to exceed the VCM contributions than fall short, from the start. Amazingly, after the first ten periods the superiority of LCD and LPA is virtually guaranteed.

Table 7: Chances of outperforming the VCM‡

Rounds	*LOT*	*FPA*	*LPA*	*LCD*
1-5	72%	75%	78%	70%
6-10	66%	55%	90%	88%
11-15	65%	56%	99%	99%
16-20	70%	62%	100%	100%
21-25	73%	68%	100%	100%

‡ Probability that a randomly composed group of four in a treatment contributes more than a randomly composed group of four in VCM.

Overall, the reliability figures are lowest for FPA. Perhaps, one could point out, this should not be too surprising since equilibrium theory predicts that FPA players randomize between different contributions, whereas the solutions for all other treatments are in pure strategies. Does the theoretical incentive to mix manifest itself in the FPA data? Based on all rounds the standard deviation of individual contributions in FPA is 39.6—higher than the expected value of 28.3 that would emerge if all players made i.i.d. draws from the theoretical distribution. In the other treatments, where there is no mixing in equilibrium, the standard deviations are lower but not by much (LOT: 36.6, LPA: 36.3, LCD: 35.3, VCM: 25.7). Thus, the evidence is mixed. However, we will return to this question below.

Result 3: *The complete final ranking of the mechanisms in terms of average provision levels takes time to develop. However, LPA and LCD quickly emerge as the superior methods of raising funds, both in terms of their average performance and in terms of their reliability. In the second half, LCD becomes the most successful mechanism.*

To study these dynamics further I ran a number of regressions to examine in how far individuals make their current contributions (VCM, LOT, FPA) or their submissions regarding their willingness to contribute (LPA, LCD) dependent on decisions from the preceding round. As explanatory variables I included subject *i*'s own lagged contribution (or willingness to contribute, WTC) and the lagged contributions (or WTCs) of the other three members of subject *i*'s group (this information is displayed on the computer screens at the end of a period), as well as the current period number to control for the time trends noted above. In the treatments with a prize (LOT, FPA, LPA) a dummy variable indicating whether or not subject *i* has won the prize in the preceding period is also included. The results are reported in Table 8.

Quite clearly, the regressions pick up the already noted divergent time trends: the *Period* coefficient is negative and significant for VCM, LOT and FPA, and positive and significant for LPA and LCD. The coefficients for own lagged contributions/WTCs are all positive and highly significant, indicating a considerable degree of path dependency. Focusing on the VCM column, it appears that the example set by the "relative free rider" among the other group members does not as such depress individuals' willingness to contribute: the coefficient for the lowest other contribution in *i*'s group is *negative*. Thus, lower contributions from the relative free rider have some tendency to encourage an individual to contribute *more* in the next period. Conversely, higher contributions from the relative free rider appear to produce some crowding out of contributions.[12] The *top contributors*, on the other hand, do play an exemplary role: the more they contribute the more an individual tends to contribute subsequently. The effect is quite small, however.

[12] The coefficient is not statistically significant; thus one has to be cautious with interpretations. However, note that the data here encompass both individuals whose contribution is and individuals whose contribution is not the lowest in the group. When the regression is run only for those who are not *themselves* the lowest contributor in their group, the magnitude of the coefficient increases (to –0.278) and it becomes significant at the 10% level.

Table 8: Determinants of individual contributions in period *t* †

Treatment	*VCM*	*LOT*	*FPA*	*LPA*	*LCD*
Dependent variable	Contrib.	Contrib.	Contrib.	WTC	WTC
Constant	5.272**	25.576***	43.393***	33.199	15.551*
	[2.3414]	[6.1183]	[6.9628]	[27.3594]	[9.0614]
Period	–0.199*	–0.675***	–0.850***	0.353**	0.354**
	[0.0905]	[0.1856]	[0.2132]	[0.1496]	[0.1446]
Individual *i*'s own contrib./ WTC in period $t-1$	0.517***	0.508***	0.461***	0.294***	0.562***
	[0.0659]	[0.0634]	[0.0688]	[0.0959]	[0.0596]
Lowest of the other contrib./ WTCs in *i*'s group in $t-1$	–0.106	0.065	0.081	–0.003	0.042
	[0.1299]	[0.0769]	[0.0638]	[0.0197]	[0.0286]
Median of the other contrib./ WTCs in *i*'s group in $t-1$	0.082	–0.051	–0.042	–0.059	0.057
	[0.0805]	[0.0457]	[0.0484]	[0.0435]	[0.0556]
Highest of the other contrib./ WTCs in *i*'s group in $t-1$	0.095***	0.048	–0.122**	0.321	0.107
	[0.0414]	[0.0397]	[0.0556]	[0.3117]	[0.0872]
1 if *i* has won the prize in $t-1$, 0 otherwise		1.796	–12.159***	1.632	
		[2.3617]	[4.2558]	[3.4745]	
Observations	864	864	864	864	864
Prob > F	0.000	0.000	0.000	0.001	0.000
R-squared	0.416	0.322	0.181	0.139	0.455

† The dependent variable is either individual *i*'s contribution in period *t* (VCM, LOT, FPA) or *i*'s minimum willingness to contribute (LPA, LCD). Correspondingly, the lagged independent variables also represent either contributions or minimum willingness to contribute. The lowest, median and highest contributions/WTCs refer to the decisions of the other three members of *i*'s group in $t-1$. Numbers in square brackets are robust standard errors clustered on individuals. Significance at the 10%, 5% and 1% level is denoted by *, ** and *** respectively.

In the lottery treatment, where the incentives (and the relevant normative benchmarks) are more ambivalent, the regression does not detect any clear patterns of response to other group members' decisions, and the same is true for the LPA and LCD mechanisms. Hence, there is no indication that the dynamics in these treatments are rooted in learning via the direct imitation of others. A priori, it did not seem obvious that the role of imitation learning would be so limited, since at the end of a given round participants were informed about the choices of all group members and also about how much each group member had earned in that round. Thus, the design made it easy for subjects to copy successful strategies if they wished to do so.

The analysis for first-price all-pay auction reveals that subjects respond extremely strongly to winning the prize: the average contribution of a winner drops by more than 12 tokens in the subsequent round! This is unique to the FPA treatment—in particular, there is no such effect in the closely related LOT treatment. Interestingly, one would expect such a pattern if players choose their contributions randomly (as the equilibrium solution in FPA requires), since winning bids are likely to be high numbers and therefore likely to be followed by a lower number if the next number is selected at random.[13] On the other hand, the regression also shows that that there is path dependency in bids and that subjects systematically lower their contribution when the top contributor among the other group members makes a high bid (unlike in any of the other treatments), and this is of course a pattern that should *not* occur if players choose their contributions randomly. Nevertheless, the FPA subjects appear to recognize the incentive to vary their contributions. One interpretation of these results is that they wait for the right moment to seize the prize, holding back when others bid highly and contributing more when they see others becoming more passive, striking occasionally with a very high bid in an attempt to surprise others.[14]

In this sense there is a lot of "gaming" in the FPA treatment. This could be viewed as weakness of this mechanism and may partly explain its reduced reliability and its failure to outperform the lottery as predicted. It seems that the nature of the strategic interaction, implying either pure or mixed equilibrium strategies, is the cause for the distinct behavior in FPA compared to LOT and the other treatments. While the absence of gaming in the LOT treatment may be put down to the non-deterministic contest success function there is no gaming in the LPA mechanism either, despite its deterministic winning rule. The equilibrium solutions in LOT and LPA are both in pure strategies, of course.

For the two-stage mechanisms, LPA and LCD, the question arises to what extent subjects make their second-stage decision (their actual contributions) dependent on what they observe in the first stage. By construction they are bound below by the lowest submitted stage-one value. However, as shown in Figure 3, average contributions often exceed this mandatory level, to a similar (and over time decreasing) extent in both treatments. Choices are very heterogeneous in this respect: 86% (77%) of contributions in LPA (LCD) are exactly at the required minimum, while in the remaining cases subjects contribute on average 44.6 (28.7) tokens more than required. Those group members who in stage one indicated a higher willingness to contribute than what ultimately emerged as the group-specific lower boundary

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[13] When first seeing this remarkable difference between FPA and LOT, I suspected that it might arise simply because in FPA the winner dummy variable invariably picks out the top contributor in a group while in LOT there is a wider distribution of winners. Hence, even if the LOT bids were all identical to the FPA bids, one might see differences in the regression results with respect to the winner variable. To check this, I ran an additional regression for LOT in which I replaced the winner dummy variable with a dummy variable that identifies the top contributor in a group. The coefficient for this new variable is –0.033 and it is not significant. Thus, there really *is* an important behavioral difference between LOT and FPA.

[14] While the average bid in FPA over all rounds is 37.7, the average winning bid is 77.2, more than twice as high. Furthermore, the winners appear to *jump* to this level: in the period before they win the prize they contribute only 52.8 on average.

for stage two, usually (83% of the time in LPA, 92% in LCD) decide to contribute less than what they originally submitted in the first stage. However, the higher an individual's indicated willingness to contribute ranks within a group, the more this individual tends to contribute in the second stage. In LPA, the group member with the lowest declared willingness to contribute subsequently *actually* contributes on average 2.1 tokens more than the required minimum, the second-lowest gives on average 12.0 extra tokens, the second-highest 20.5 and the highest 25.6 extra tokens. The corresponding figures for the LCD treatment are 2.1, 9.2, 14.4 and 19.0, from lowest to highest. Overall, both mechanisms rely quite heavily on voluntary extra contributions in the early rounds of the experiment: in the first 10 periods they make up 42% of the amount raised in LCD (31% in LPA). Over time, however, the importance of the extra contributions diminishes: in the last 10 periods they make up only 4% of the amount raised in LCD (10% in LPA).

[FIGURE 3 HERE]

Result 4: *In all treatments the evolution of choices is characterized by path dependency: the level of an individual's contribution in a given round affects (positively) how much that individual contributes in the subsequent round. There is very little indication that the dynamics over time are due to subjects copying the behavior of low or high contributors, with the exception of the VCM treatment where high contributors seem to stimulate increased contributions (to a small extent). The relatively high volatility in the FPA data appears to be caused by subjects actively varying their decisions over time, somewhat in the spirit of mixed strategies but clearly not literally as i.i.d. draws from a random distribution. Individual voluntary extra contributions in the second stage of the LPA and LCD treatments correlate with what the individuals indicated as their minimum willingness to contribute.*

5 Discussion and conclusions

During the fiscal year 2006 U.S. state-operated lotteries have raised a total of $57.4 billion.[15] Much of this money is used to finance public goods, either through general governmental funds or by providing extra funding for dedicated purposes. Many private charities also make use of different forms of "charitable gambling" and auction mechanisms in an attempt to entice people to give. It is interesting to speculate how private charitable fundraising will

[15] Data from the North American Association of State and Provincial Lotteries (NASPL).

develop in the future—as monetary transactions on the Internet have become so ubiquitous and safe, new fundraising formats become available which can be implemented at low costs.

This paper considers a particular class of fundraising mechanisms that utilize different forms competition as a means to generate incentives to give. As Morgan (2000) has shown, equilibrium theory predicts that a simple lottery format will generate positive net revenues as long as players attach sufficient value to the cause supported. However, other specifications of all-pay competition can be more effective. For example, net-revenues increase if players receive an exponentially increasing number of lottery tickets relative to their donation. In the limit, the player donating the most receives the prize for certain. Introducing some disconnect between initial bids and final contributions via a *k*th-price all-pay format (see Goeree et al.) can raise revenues even further. When bidders know that a low bid may determine not only their own but also other players' contributions, they carry much of the responsibility for the overall success of the fundraising effort. In theory, this consideration almost outweighs the importance of the competitive aspect of the mechanism: in the last-price all-pay auction it becomes virtually unnecessary to provide any substantial prize to incentivize giving.

Five specific fundraising mechanisms were subjected to an empirical test in a controlled laboratory setting. In all treatments the dynamics of the data follow a clear pattern: over time average choices move closer to the equilibrium predictions. This may reflect adjustment processes which, in the end, lead to "roughly" mutually best responses. The incentives induced by the mechanisms clearly matter and affect behavior in a systematic way. As a result, contributions in the sessions with these incentives exceed those in the benchmark voluntary contribution mechanism (VCM), notwithstanding the fact that the participants in the baseline treatment already over-contribute relative to the standard prediction. Although the cost of providing a prize to encourage giving creates a potential obstacle to the success of alternatives to the VCM, this turns out to be unproblematic: subjects contribute sufficiently much to cover the prize and to attain an efficiency gain relative to the VCM baseline. The ranking of the alternative mechanisms according to contributions and provision levels is mostly consistent with the theoretical analysis—with the exception of the comparison of the lottery (LOT) and the first-price all-pay auction (FPA), which perform both very similarly. The data suggests that LOT is particularly "over-successful" relative to the theoretical benchmark. However, by far the most effective schemes are, as predicted, the last-price all-pay auction (LPA) and the lowest common denominator format (LCD), where full efficiency is reached in the final period of the experiment.

Two potential candidates to explain the often observed over-contributions in public good games are the notions of altruism and/or "warm-glow giving" (Andreoni, 1990). However, this cannot account for the fact that the public good provision levels in LPA and LCD are often substantially *below* the efficient level, which even perfectly selfish agents would achieve in this case. The observed behavior appears to fit better to a simple learning story: in all sessions subjects start off with intermediate contributions, but then seem to develop a feeling for payoff-improving adjustments, which lead to the observed evolution of choices over time. LPA and LCD emerge quite quickly as the dominant mechanisms, perhaps because their properties promote conditional cooperation.

The results leave no doubt that the manipulation of the incentive structures through all-pay competition makes a significant difference, resulting in substantial shifts in contribution levels. Despite the fact that the laboratory simplifies many aspects of real-world settings and that in light of this the results should be viewed with some caution, it seems conceivable that new formats like all-pay auctions could be implemented by private charitable initiatives. Some related experimental research that has emerged subsequently to earlier versions of this study provides further grounds for optimism. Duffy and Kornienko (2007) report experiments on the dictator game, examining to what extent the dictators are inclined to compete to give. Remarkably, dictators often do engage in "competitive altruism", i.e. they compete to give even when outperforming other dictators has no payoff consequences. More closely related to the paper here is the study by Schram and Onderstal (forthcoming) who experimentally investigate the performance of a first-price winner-pay auction, a first-price all-pay auction and a lottery, with and without the presence of a public good. Using a setting where the value of the prize differs between individuals and is private information they find strong evidence that all-pay competition is the superior fundraising method and, with somewhat less clarity, that the first-price all-pay auction outperforms the lottery mechanism when a public good is present. Corazzini, Faravelli and Stanca (2007) also compare a lottery and a first-price all-pay auction, and furthermore consider an all-pay auction with multiple (three) prizes as well as a VCM benchmark. In their design, motivated by Faravelli's (2008) theoretical work, subjects draw their initial financial endowments randomly and do not know their co-players endowments. Unlike in Schram and Onderstal the lottery emerges as the most successful fundraising mechanism (contrary to theoretical predictions). The paper by Lange, List and Price (2007) analyzes single- and multiple-prize lotteries (but no all-pay auctions), focusing particularly on the role of individual risk preferences and individual valuations of the public good. In their experiment, they find that the lotteries outperform two benchmark VCMs and some evidence that the relative performance of the single-prize versus three-prize lottery depends on the degree of risk aversion among subjects. In absolute terms, however, provision levels are highest in the single-prize lottery.

To the best of my knowledge, no other experimental study has thus far examined mechanisms similar to the LPA and LCD treatments. Given their remarkable success here, it seems warranted to further explore behavior in such settings in future research. There may be a role for "wind tunnel experiments" to examine how this type of mechanism could be developed to become useful in field applications. I suspect that a major hurdle for anyone who wishes to implement a version of the LPA format in the field is that it may very often not be feasible to sufficiently familiarize potential contributors with the mechanism in the way it was done in the experiment here. This may be particularly problematic in settings where the format must effectively compete against more established mechanisms, which may attract larger numbers of participants (an important conclusion from the field study on all-pay versus winner-pay auctions by Carpenter, Holmes and Matthews, 2008). To end on a more positive note, it seems to me that a version of the LPA format could be easily employed in some situations as an alternative to a voluntary donations system at low costs and risks. The prize can be small and allows people to make additional voluntary contributions; the mechanism does not require a threat to refuse donations as provision point mechanisms do. The experimental results here indicate that the potential of this mechanism is considerable.

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Figures

Figure 1: Expected public good provision as a function of ρ

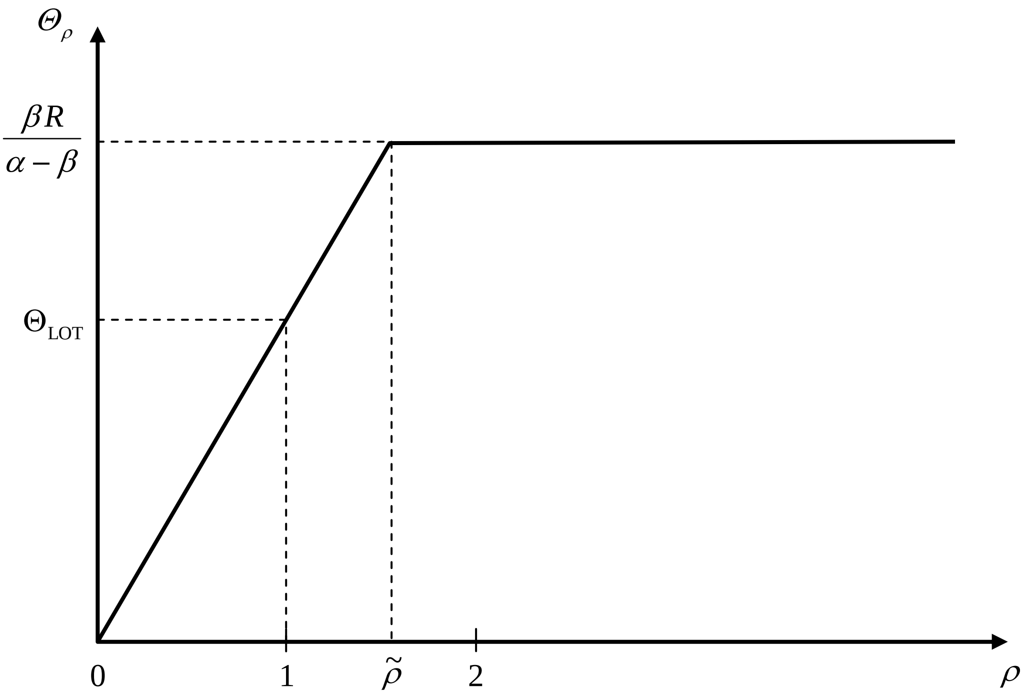


Figure 2: Average contributions over time

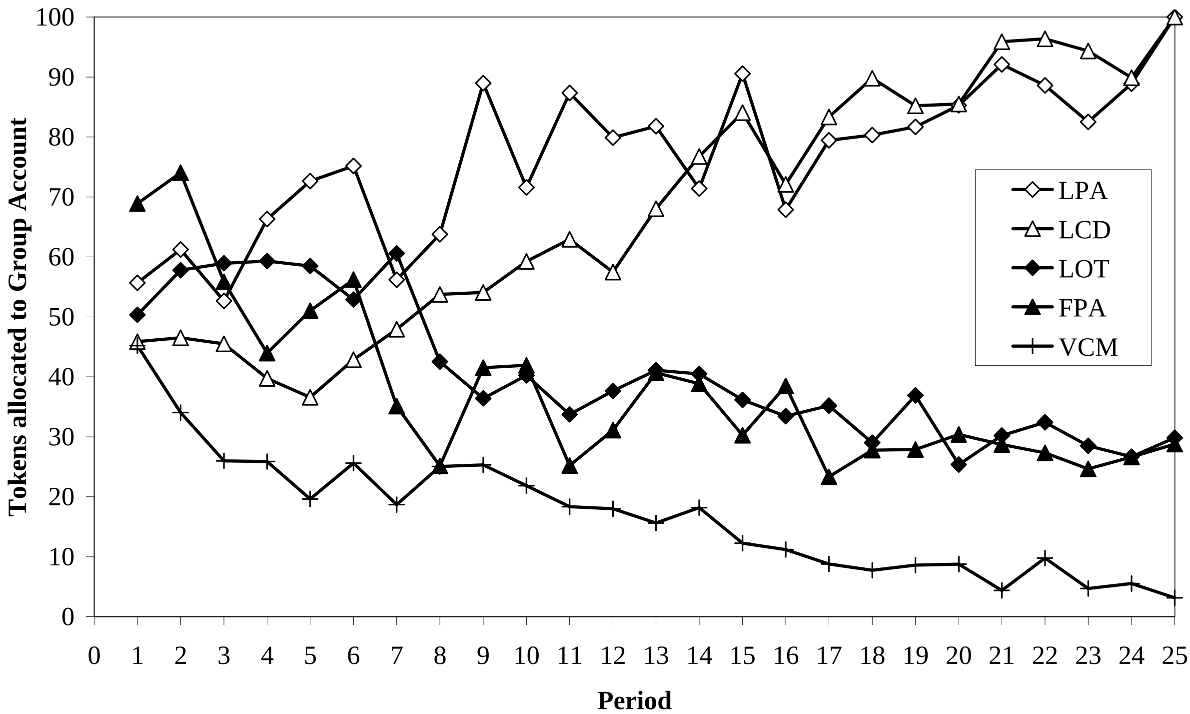


Figure 3a: WTCs and actual contributions in LCD

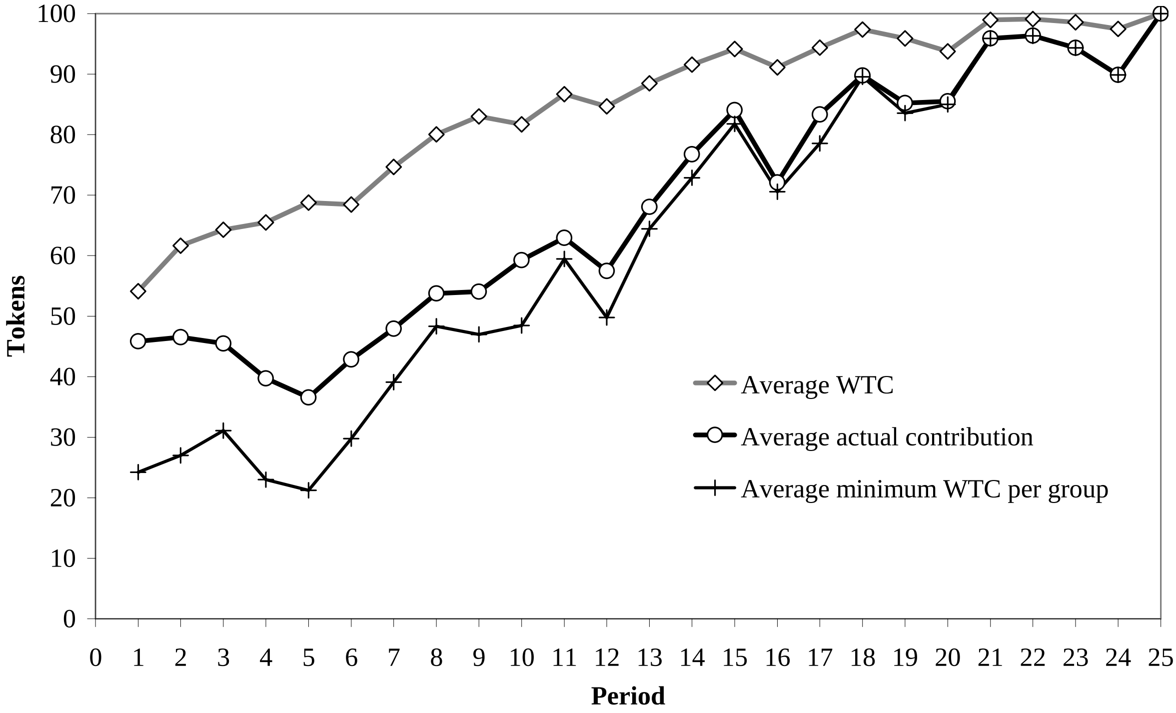
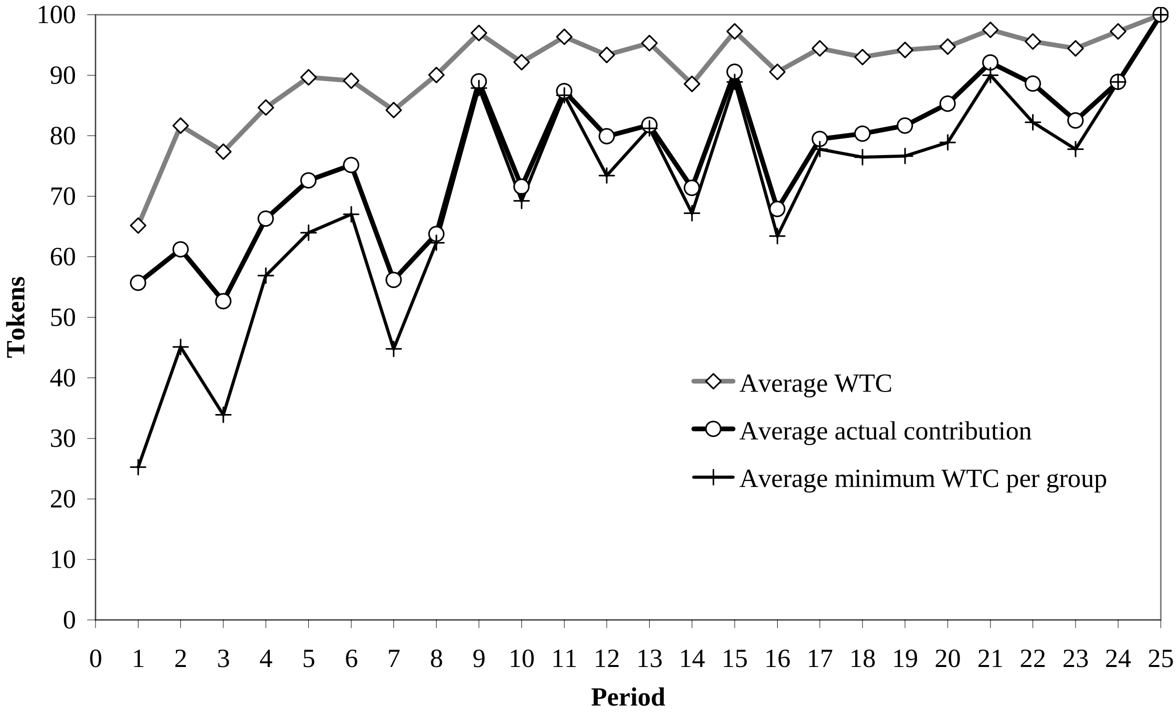


Figure 3b: WTCs and actual contributions in LPA



Appendix A

Proof of Proposition 1:

Player *i*'s expected payoff can be written as

$$\pi_i(x_i) = \begin{cases} \alpha\left(A + \frac{1}{n}R\right) - \beta R & \text{if } x_j = 0\ \forall j \\ \alpha(A - x_i) + \beta\left(\sum_{j=1}^{n} x_j - R\right) + \left(\frac{x_i^\rho}{\sum_{j=1}^{n} x_i^\rho}\right)\alpha R & \text{otherwise.} \end{cases}$$

The first-order conditions yield $x_i = x^* \ \ \forall i$ (see main text) as an equilibrium candidate. Suppose that $n-1$ players choose x^*. For this to constitute an equilibrium we require that

$$\pi_i(x_i \mid x_j = x^*\ \forall j \neq i) = \alpha(A - x_i) + \beta x_i + (n-1)\beta x^* + \left(\frac{x_i^\rho}{x_i^\rho + (n-1)(x^*)^\rho}\right)\alpha R$$

has a global maximum at $x_i = x^*$ on the support [0, *A*]. The following derives the necessary conditions for this to hold.

Let $h(x) = \pi_i(x_i \mid x_j = x^*\ \forall j \neq i)$. Note that if $\rho > n/(n-1) \equiv \tilde{\rho}$ we get $h(0) > h(x^*)$ and so x^* does not constitute an equilibrium. Now consider the opposite case, $\rho \leq \tilde{\rho}$. The second derivative of *h* is

$$\frac{\partial^2 h(x_i)}{\partial x_i^2} = \frac{\alpha R\rho(n-1)(x^*)^\rho}{\left(x_i^\rho + (n-1)(x^*)^\rho\right)^3}\left[(\rho-1)(n-1)(x^*)^\rho - (\rho+1)x_i^\rho\right]$$

which is negative at $x_i = x^*$ iff $\rho < n/(n-2)$. Hence, *h* has a local maximum at x^*, which gives an expected payoff at least as high as the payoff from using the entire endowment for private consumption. To see that x^* is also the global maximum in this parameter range, consider again the second derivative of *h*. The first part of the expression (the fraction) is positive for any x_i; the sign of the second part depends on ρ. If $\rho \leq 1$, $\partial^2 h(x_i) \big/ \partial x_i^2 < 0$ and so *h* is strictly concave; consequently x^* is the global maximum. If $\rho > 1$ we find a point of inflexion at

$$\tilde{x} = \left(\frac{(\rho-1)(n-1)(x^*)^\rho}{(\rho+1)}\right)^{\frac{1}{\rho}},$$

indicating that *h* is convex for $x_i < \tilde{x}$ and concave for $x_i > \tilde{x}$. Again, this implies that the function has a global maximum at x^*.

Proof of Proposition 2:

(a) *The all-pay auction has a symmetric pure-strategy equilibrium where players contribute their full endowments if, and only if,* $R \geq (1/\alpha)(\alpha - \beta)nA$.

Proof. Suppose all *n* agents contribute *A*. Then players earn

$$\pi_i(A) = n\beta A + \frac{\alpha R}{n}. \qquad \text{[A1]}$$

Now consider possible deviations from this strategy. Players cannot bid more than *A*. If a player decides to bid less than *A*, she loses her share of the prize and will thus be best off by reducing her contributions to zero. Hence, $x_i = A \; \forall i$ is an equilibrium iff $\pi_i(A) \geq \pi_i(0)$ (where $\pi_i(0) = \alpha A + (n-1)\beta A$), which is equivalent to the condition in (a).

(b) *For* $0 < R < (1/\alpha)(\alpha - \beta)nA$ *there is no symmetric Nash equilibrium in pure strategies.*

Proof. Suppose all *n* players contribute the same amount $\tilde{x} < A$. Then player *i*'s payoff is

$$\pi_i(\tilde{x}) = \alpha(A - \tilde{x}) + n\beta\tilde{x} + \frac{\alpha R}{n}. \qquad \text{[A2]}$$

By raising his bid slightly, player *i* could secure the prize for himself. This pays off if $\pi_i(\tilde{x} + \varepsilon) > \pi_i(\tilde{x})$, which can always be guaranteed for an arbitrarily small ε. Hence, for any given positive *R* a common contribution level $x_i = \tilde{x} \; \forall i$ cannot be an equilibrium.

(c) *For* $0 < R \leq (1/\alpha)(\alpha - \beta)A$ *there is a symmetric equilibrium in mixed strategies with players choosing contributions from F*(*x*) *on the support* $[0, u]$.

Proof. The proof consists of four parts.

(i) *No point masses*. The proposition implies that the equilibrium distribution is atom-free. To prove this claim, suppose that there *was* a point mass at $\tilde{x} < A$. Then player *i*'s expected payoff from choosing $\tilde{x}$ is

$$\pi_i(\tilde{x}) = \alpha(A - \tilde{x}) + \beta\left(\tilde{x} + \sum_{j \neq i} E[x_j]\right) + \alpha R \sum_{k=1}^{n} \binom{n-1}{k-1} \frac{(p_{\tilde{x}})^{k-1} \cdot prob\{x < \tilde{x}\}^{n-k}}{k}. \qquad \text{[A3]}$$

The term $\alpha R \sum(.)$ represents *i*'s expected payoff from winning the prize ($k = 1$) or a share of it ($k > 1$). The probability that other players choose $\tilde{x}$ is denoted by $p_{\tilde{x}}$. Player *i* receives the full prize ($k = 1$) if all other players choose a contribution below $\tilde{x}$, which occurs with probability $prob\{x < \tilde{x}\}^{n-1}$. Player *i* receives a *k*th share of the prize if he is tied with $k - 1$ other participants and if all remaining agents choose contributions below $\tilde{x}$. There are

$$\binom{n-1}{k-1} = \frac{(n-1)!}{(k-1)!(n-k)!} \quad \text{[A4]}$$

possible player combinations for this event. If one (or more) of the other agents choose contributions *above* $\tilde{x}$, player *i* does not receive any share of the prize.

Player *i* may consider raising his bid slightly by ε. Because the number of point masses must be finite, player *i* can choose ε such that there is no point mass at $\tilde{x}+\varepsilon$. In all cases, in which he would have been tied with other players at $\tilde{x}$, he now overbids those players and receives the full prize. In addition the possibility exists that other players choose effort levels in between $\tilde{x}$ and $\tilde{x}+\varepsilon$. Hence,

$$\pi_i(\tilde{x}+\varepsilon) \geq \alpha(A-\tilde{x}-\varepsilon)+\beta\left(\tilde{x}+\varepsilon+\sum_{j\neq i}E[x_j]\right)$$

$$+\alpha R\sum_{k=1}^{n}\binom{n-1}{k-1}\frac{(p_{\tilde{x}})^{k-1}\cdot prob\{x<\tilde{x}\}^{n-k}}{1}. \quad \text{[A5]}$$

Subtracting [A3] from [A5] yields

$$\pi_i(\tilde{x}+\varepsilon)-\pi_i(\tilde{x}) \geq -(\alpha-\beta)\varepsilon+\alpha R\sum_{k=1}^{n}\binom{n-1}{k-1}\frac{k-1}{k}(p_{\tilde{x}})^{k-1}\, prob\{x<\tilde{x}\}^{n-k}$$

$$>0 \quad \text{for sufficiently small } \varepsilon. \quad \text{[A6]}$$

Thus, given there was a point mass at $\tilde{x}$ a player could improve his payoffs by choosing $\tilde{x}$ with zero probability and by choosing $\tilde{x}+\varepsilon$ with a positive probability instead. Therefore there cannot be a point mass at $\tilde{x}<A$ in the equilibrium cdf.

(ii) *No lower bound* $v>0$ *in the support*. The proposition also claims that zero is the lower bound of the support of *F*. To prove this claim, suppose there was a lower bound $v>0$. It has been shown in (i) that there cannot be a point mass at *v*. Hence, the probability of winning a share of the prize when choosing *v* is zero. Consequently an agent would always prefer zero to *v*, and *v* cannot mark the lower bound of the equilibrium distribution.

(iii) *Upper bound u*. A further claim is that *u* is defined as suggested in the proposition. To see this, note first that in equilibrium any contribution level in the support must yield the same expected payoff. It can easily be checked that choosing *u* yields the same expected payoff as choosing zero—which is in the support because of (ii)—under the presumption that player *i* wins the prize with probability one when he contributes *u*. Any choice above *u* yields an expected payoff below the expected payoff from choosing zero. Consequently, *u* must be the upper limit of the support. Note, however, that to be a feasible choice the upper bound must not exceed *A*. Hence, the equilibrium is only valid if $u \leq A$ or

$$R \le \frac{\alpha - \beta}{\alpha} A \qquad [A7]$$

as required in the proposition.

(iv) *Cumulative distribution function*. Expected earnings can now be written as

$$\pi_i(x_i) = \alpha(A - x_i) + \beta\left(x_i + \sum_{j \ne i} E[x_j] \right) + \alpha R \cdot F(x_i)^{n-1}. \qquad [A8]$$

The equilibrium solution requires that bids be chosen according to a distribution function $F(.)$ that makes players indifferent between contribution levels in the interval $[0, u]$. By solving $\pi_i(x_i) = \pi_i(0)$ for $F(x_i)^{n-1}$ it can be easily checked that the only distribution meeting this criterion is the *cdf* given in the proposition.

(d) *If R is medium, there is a symmetric mixed strategy equilibrium in which players contribute A with probability* $p_A > 0$ *and choose contributions from F*(x) *in the interval* $[0, w]$ *with probability* $1 - p_A$.

Proof. The proof consists of six parts.

(i) *No point masses below A*. Proof as above in (c) i.

(ii) *No lower bound* $v > 0$. Proof as above in (c) ii.

(iii) *Making maximum bids*. The proposition claims that players contribute *A* with a positive probability. Suppose this was not the case. Then player *i* could make a bid $u \le A$ that would guarantee her the prize and that would therefore yield an expected payoff of

$$\pi_i(u) = \alpha(A - u) + \beta\left(u + \sum_{j \ne i} E[x_j] \right) + \alpha R. \qquad [A9]$$

If *u* was the upper bound of the equilibrium support then we must have $\pi_i(u) = \pi_i(0)$, which implies that $R = (1/\alpha)(\alpha - \beta)u$. However, from $u \le A$ it would then follow that $R \le (1/\alpha)(\alpha - \beta)A$, which in turn violates the initial condition of Proposition (d).

(iv) *Value of* p_A. By (iii), the maximum is chosen with a positive probability p_A. When player *i* chooses *A*, her expected share of the prize is therefore

$$\sum_{j=0}^{n-1} \binom{n-1}{j} \frac{(p_A)^j (1 - p_A)^{n-1-j}}{j+1},$$

which, by applying regular binomial rules, can be transformed into

$$\frac{1 - (1 - p_A)^n}{np_A}.$$

Hence, the expected payoff from contributing *A* is

$$\pi_i(A) = \beta\left(A + \sum_{j \neq i} E[x_j]\right) + \frac{1-(1-p_A)^n}{np_A}\alpha R\,. \qquad \text{[A10]}$$

The proposition also claims that only one value for $0 < p_A \leq 1$ solves Equation [A10]. This can be shown by converting the equation into

$$1 - Kp_A = (1-p_A)^n \qquad \text{[A11]}$$

where $K = (1/\alpha R)(\alpha - \beta)nA$. The restrictions on *R* given in the proposition imply that $1 \leq K < n$. The left hand side of Equation [A11] is linear with a slope of –*K* and the right hand side is convex. At $p_A = 0$ both sides are equal to 1 and the slope of the right hand side is –*n*, thus steeper than the left hand side. At $p_A = 1$ the right hand side becomes zero and the left hand side is either zero or negative. Hence, there must be a unique solution for Equation [A10] in the interval $(0,1]$.

(v) *Upper bound w*. The proposition states that players either choose *A* or they choose a bid from the interval $[0, w]$ with $w < A$. In other words, values in between *w* and *A* are not part of the equilibrium. To see this, consider what would happen if a player made a bid at $A - \varepsilon > w$ where ε is very small. This player would lose the expected payoffs she receives from possible ties at *A* with other players. These losses would outweigh the small gains from reallocating some resources to her private account. However, the more the player reduces her contributions the more the importance of private consumption grows. At some point, namely at $w = (1-p_A)^{n-1}\alpha R/(\alpha - \beta) < A$, the losses and gains balance out and $\pi_i(w) = \pi_i(A)$. Note also that by (i) there cannot be a point mass at *w*.

(vi) *Distribution function* $\text{Prob}\{x \leq t\}$. Proof as above in Proposition c (iv).

Appendix B: Instructions

[ALL TREATMENTS]

General rules

Welcome! This is an experiment on how people make decisions. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money. The experiment consists of 25 periods, in each of which you can earn “points”. The points you earn will be converted to cash using an exchange rate of 10 points = 1p. You will be paid at the end of the experiment, in private and in cash.

It is important that from now on you do not talk to, or in any way try to communicate with, any of the other participants until the experiment is over.

At the beginning of each of the 25 periods you will be matched with three other people, randomly selected from the participants in this room. You and the people you are matched with form a *group*. Your point earnings will depend on your decisions and on the decisions of the other members of your group. Because the composition of groups is randomly determined at the beginning of each period, the identity of the people you are matched with will change from period to period. Otherwise, all 25 periods are identical.

What you have to do and how your point earnings are determined

In each period you receive 100 tokens. Your task is to decide how many of these tokens to allocate to your PRIVATE ACCOUNT and how many to allocate to the GROUP ACCOUNT. Likewise, the other three group members can allocate tokens to their Private Accounts and to the Group Account.

Your point earnings are calculated as *points from your Private Account* plus *points from the Group Account* plus *bonus points:*

1. *Points from Private Account*

   For each token that you allocate to your Private Account you receive 2 points.

2. *Points from Group Account*

   For each token that is allocated to the Group Account (by you or by any of the other members of your group) *every* group member receives 1 point.

3. *Bonus points*

[VCM TREATMENT]

In each period you receive 50 bonus points.

[LOT TREATMENT]

In each period you have the chance to win 100 bonus points according to the following rules.

For each token that you allocate to the Group Account you receive a lottery ticket. Likewise, the other group members receive lottery tickets for the tokens they allocate to the Group Account. Each lottery ticket has a unique 3-digit number (“001”, “002”, “003” and so on). Your ticket numbers will be displayed on your screen.

Then the winning ticket is drawn at random out of all the tickets that have been given to you and to the other group members. The person holding that ticket wins the 100 bonus points.

Thus, your chances of winning the bonus is equal to the number of tokens you allocate to the Group Account, divided by the total number of tokens allocated to the Group Account. For example, if half of the tokens allocated to the Group Account come from you, you have a 50% chance of winning the bonus.

To make your decision you will be asked to enter a number between 0 and 100. By entering a number you decide how many tokens you place in the Group Account. The remainder of the 100 tokens will then automatically go into your Private Account.

[FPA TREATMENT]

The group member who allocates most tokens to the Group Account in a period receives 100 bonus points. (If there is a tie, the bonus points are divided equally among the tied group members.)

[LPA TREATMENT]

In each period you have the chance to get up to 100 bonus points (see below).

The decision how many tokens the group members allocate to their Private Accounts and to the Group Account is made in two steps.

(a) First, the computer will ask you how many tokens you are willing to allocate to the Group Account. The other group members are asked the same question. The 100 bonus points go to the group member who is willing to allocate the highest number of tokens to the group account. (If there is a tie, the bonus points are divided equally among the tied group members.)

(b) All four replies submitted in step (a) will be listed on your screen, from highest to lowest. Then you make your real decision. However, you (as well as the other group members) must allocate no less than the *lowest of the submitted numbers of tokens in step (a)* to the Group Account.

[LCD TREATMENT]

In each period you receive 50 bonus points.

The decision how many tokens the group members allocate to their Private Accounts and to the Group Account is made in two steps.

(a) First, the computer asks every group member to suggest a minimum number of tokens that everybody in the group should allocate to the Group Account.

(b) All four suggestions will be listed on your screen, from highest to lowest. Then you make your real decision. However, you (as well as the other group members) must allocate no less than the *lowest suggested number of tokens* to the Group Account.

[ALL TREATMENTS]

To make your decisions you will be asked to enter a number between 0 and 100. By entering a number **[**in (b)**]** you decide how many tokens you place in the Group Account. The remainder of the 100 tokens will then automatically go into your Private Account.

At the end of each period your terminal will display how many tokens each group member has allocated to the Group Account in that period. It will also show each group member’s point earnings from his or her Private Account, from the Group Account and from bonus points. Furthermore it will display your accumulated point earnings from all periods.