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Bidding to Give: An Experimental Comparison of Auctions for Charity

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ABSTRACT:

We experimentally compare three mechanisms used to raise money for charities: first-price winner-pay auctions, first-price all-pay auctions, and lotteries. We stay close to the characteristics of most charity auctions by using an environment with incomplete information and independent private values. Our results support theoretical predictions by showing that the all-pay format raises substantially higher revenue than the other mechanisms.

KEYWORDS: Auctions; Lotteries; Charity; Laboratory Experiments

JEL CODES: C91; D44; H41

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1. Introduction

What do Eric Clapton's guitar, Margaret Thatcher's handbag, and Britney Spears' pregnancy test kit have in common? The answer: all were auctioned for the benefit of charity. Indeed, auctions are often used as a means to raise money for charities. They are not the only method, however. Charities also organize lotteries and voluntary contributions to raise money. This co-existence of various mechanisms gives rise to the obvious question of their relative performance. In this paper, we use a laboratory experiment to answer this question.¹

When the proceeds of an auction are donated to a charity, bidders may care about how much money is raised. Compared to the case where auctions or lotteries are only used as mechanisms to allocate private goods, cases where the proceeds matter to the bidders will affect the way in which they evaluate the outcome and the way they bid. Moreover, if the revenue constitutes a public good, the criteria used to evaluate mechanisms may be different from those used in the standard case. Whereas efficiency is a prime concern of a vast majority of the auction literature, mechanisms where the proceeds are dedicated to a charity are typically evaluated based on the revenue they generate.²

We consider the case where a single unit of a good is allocated by way of auction or lottery. The proceeds (revenue) are donated to a charity. Our focus is on the case where all participants care about the charity. *Ceteris paribus*, they attribute higher utility to higher revenue. Moreover, each individual attributes value to the good being offered. In this respect, note a second characteristic that the three collector's items mentioned above have in common: the value attributed to them may vary significantly across individuals. This is typically the case for charity auctions. In our analysis, we therefore assume that individuals attribute independent private values to the good.

Many theoretical results have been obtained for both private and common value settings where bidders positively value the proceeds. First of all, auctions and lotteries dominate voluntary contribution mechanisms (Morgan, 2000; Lange *et al.*, 2006; Orzen; 2005). The reason lies in the negative externality that occurs when a person bids [buys

¹ Alternatively, one could study this question in field experiments. As argued by Levitt and List (2006), however, the laboratory is the preferred environment to start investigations on this type of mechanism selection. We will return to this point in the conclusions.

² Cramton *et al.* (1987) study the efficiency effects of dividing an auction revenue (not necessarily equally) among bidders. They show that an efficient allocation is usually not possible with unequal division.

lottery tickets]: this decreases the chances of others winning the auction [lottery]. This negative externality mitigates the free-riding incentive compared to voluntary contributions.

Second, the equilibrium bidding strategies for first-price and second-price winner-pay auctions unbalance the traditional revenue equivalence result (Vickrey, 1961; Myerson, 1981), with higher prices expected in the second-price auction (Goeree *et al.*, 2005 (henceforth GMOT); Engelbrecht-Wiggans, 1994; Engers and McManus, 2006; Maasland and Onderstal, 2006).

Third, the first-price all-pay auction dominates the first-price winner-pay auction (Engers and McManus, 2006; GMOT) and the lottery (GMOT; Orzen, 2005), as well as the second-price winner-pay auction if the number of bidders is sufficiently large (Engers and McManus, 2006; GMOT). The underlying intuition why the all-pay auction performs better than the winner-pay auctions is based on the opportunity costs of raising one's bid in the latter: topping another bid implies elimination of the benefit from its contribution to the revenue, in contrast to the all-pay auction. Moreover, a lottery's inefficiency (the participant with the highest value may not win the object) will lead to less aggressive bidding and lower revenues than in an efficient mechanism (GMOT). A priori, auctions may provide a more efficient allocation and may therefore be expected to raise more money.³ Indeed, this turns out to be the case for the first-price all-pay auction.⁴

A few experimental and field studies have been undertaken to test these theories. Most of these empirical studies focus on situations in which the value of the prize is the same for all bidders, *i.e.*, the common value scenario. In line with the theory, these studies find that voluntary contributions generate less money than lotteries and auctions (Morgan and Sefton, 2000; Lange *et al.*, 2006 and Orzen, 2005 provide evidence from the laboratory, Landry *et al.*, 2006 use field data),⁵ and the lowest-price all-pay auction is

³ Moreover, in some auctions, losing bidders have an incentive and a possibility to drive up the price to be paid by the winner (*e.g.*, Cramton *et al.*, 1987; Graham and Marshall, 1987; McAfee and McMillan, 1992; Singh, 1998; Bulow *et al.*, 1999; Maasland and Onderstal, 2006).

⁴ The optimal fundraising mechanism also has an 'all-pay' element: it is the lowest-price all-pay auction with entry fee and reserve price (GMOT). If an entry fee is not possible and sellers are committed to sell, the lowest-price all-pay auction is revenue maximizing (GMOT; Orzen, 2005).

⁵ There is a vast experimental literature on voluntary contributions to public goods. For surveys, see Ledyard (1995) and Zelmer (2003). The bottom line in this research is that free-riding, though not complete, does cause inefficiency in the provision of the good.

revenue maximizing (Orzen, 2005). However, the all-pay auction does not dominate the lottery (Orzen, 2005).

Fundraising mechanisms with private values have hardly been examined empirically. Two notable exceptions are Davis *et al.* (2006) and Carpenter *et al.* (2005).⁶ Davis *et al.* observe in a laboratory experiment that lotteries raise more money than the English auction. In contrast to our setting, they employ a perfect information environment where each bidder is completely informed about how much other bidders value the object for sale. This is unlikely to hold true for most charity auctions in the field, however. Carpenter *et al.* conducted a field experiment during fund-raising festivals organized by preschools in Addison County. Their data suggest that the first-price auction dominates both the second-price and all-pay auction. As a potential explanation for why their findings deviate from the theory, the authors argue that bidders were unfamiliar with the rules of the second-price and all-pay auction, so that many were reluctant even to participate in these auctions.⁷

All in all, we believe our study to be the first to empirically compare fund-raising mechanisms in a controlled environment with private values and imperfect information. We think that this environment best describes the situation for most charity auctions, including the three mentioned in our opening sentence.

We begin in Section 2 by describing our experimental design and constructing hypotheses on the basis of our private values model. Our theoretical results closely resemble the findings from the literature in that the all-pay auction dominates both the winner-pay auction and the lottery if bidders positively value the proceeds. Moreover, all mechanisms are predicted to generate more money with than without the charity. In addition, without a charity, the two auctions are revenue equivalent, and raise more revenue than the lottery.

We present our experimental findings in Section 3. These findings confirm the predictions from our theory about the relative performance of mechanisms used to raise money. Of our other predictions, only two are not supported: (1) without charity, the

⁶ Another is Isaac and Schnier (2005), who mainly focus on bidding behavior in ‘silent auctions’, jump bidding in particular. They do not compare mechanisms in terms of their revenue generating properties.

⁷ In our experiment, subjects could stay out of the auction by bidding zero. We will show below that this occurred much more often in the all-pay auction than in the other formats.

first-price winner-pay auction does not dominate the lottery, and (2) the first-price winner-pay auction and the lottery do not raise more money with than without the charity. One reason for the latter observation is that in all auctions, subjects systematically overbid [underbid] relative to the Nash prediction in the case with [without] charity.

2. Experimental Design and Hypotheses

2.1. Procedures and Parameters

We ran the experiments at the Center for Experimental Economics and political Decision making (CREED) of the University of Amsterdam in the fall of 2002. 180 students from the undergraduate population of the University were recruited by public announcement and participated in 12 sessions. On top of a show-up fee of €5, subjects earned on average €24.46 in sessions that lasted between 60 and 90 minutes. An example of the experimental instructions is given in the appendix.

In each of 28 rounds of a session, groups of 3 subjects are formed.⁸ Members of a group compete in an auction or lottery for a private good. Values and earnings are given in experimental ‘francs’, with an exchange rate of €1=300 francs. Subjects were given a starting capital of 1500 francs. In every round, subject i ’s value v_i for the good is independently drawn from a uniform distribution on $[0,500]$.⁹ We reallocate subjects to groups in every round. Unknown to subjects, we do so within sets of 6 subjects (two groups). These ‘matching groups’ constitute statistically independent units of observation.

A positively valued charity is introduced by making the revenue a public good for the participants. Each subject is paid a fraction α of the revenue of the auction or lottery she participates in, irrespective of her bid or value. In all sessions, $\alpha=0.5$, i.e., every subject

⁸ A restriction to group size 3 is an obvious limitation. Our aim at this stage, however, is to test for differences across mechanisms *per se*, guided by the theoretical predictions. An extension to larger n is an obvious candidate for future research. It is important to note that, theoretically, the all-pay auction dominates the winner-pay auction (Engers and McManus, 2006) and the lottery (GMOT), independently of n .

⁹ In theory, subjects could make a loss. They were told that their earnings would be set to zero and that the computer would take over their decision if this occurred but that they would have to remain seated. Other group members would be informed. This never happened, however: all subjects had positive earnings throughout the experiment.

earns €0.50 for every €1 her group contributes to revenue.¹⁰ We benchmark these ‘charity’ results in a within-subject design by including rounds where the revenue does not affect payoffs ($\alpha=0$). To do so, we split the 28 rounds in 4 blocks of 7 and alternate between blocks with and without public good. To check for order effects, we sometimes start with a public good and sometimes without.

In order to study the effect of fund-raising mechanisms on revenue, we examine three institutions in a between-subject design. Our selection of mechanisms is inspired by the theoretical results in GMOT. They distinguish three qualitatively different mechanisms: winner-pay auctions, lotteries, and all-pay auctions. Within the auction institutions, one can distinguish between first-price, second-price, etc. Because we wish to focus on the main effects, we restrict our attention to the first-price versions of the two auction types. Lower-price auctions can be studied in future research.

Hence, we distinguish three allocation mechanisms:

- 1) *First-price winner-pay auction (WP)*. Each of the three subjects submits a bid, b_i . The highest bidder wins the object and pays her bid. The winning bidder w earns $v_w - b_w$ from the private good. Other bidders’ payoff from the private good is 0. The auction revenue is b_w . In rounds with public good, each bidder additionally receives $0.5b_w$.
- 2) *First-price all-pay auction (AP)*. Each of the three subjects submits a bid, b_i . The highest bidder wins the object and each bidder pays her bid. Revenue is $b = b_1 + b_2 + b_3$. The winning bidder w earns $v_w - b_w$ from the private good. Private good payoff for $i \neq w$ is $-b_i$. In rounds with public good, each bidder receives an additional $0.5b$.
- 3) *Lottery (LOT)*. Each of the three bidders buys b_i tickets for a raffle. One of the $b = b_1 + b_2 + b_3$ tickets is randomly drawn and determines the winner, w , who earns $v_w - b_w$ from the private good. Private good payoff for $i \neq w$ is $-b_i$. In rounds with public good, each bidder receives an additional $0.5b$.

Table 1 summarizes our treatments including the number of observations per cell.

¹⁰ Note the resemblance to a linear public good game with a marginal per capita return equal to 0.5 (Isaac *et al.*, 1984). An important difference is the private value that a player can obtain by winning the auction. There are, of course, other ways to model the fact that the auction revenue matters to the bidders. We chose this ‘public good scenario’ for two main reasons: (1) it mirrors the setup of the theories we are testing; (2) it allows us to capture the ‘public good’ characteristic of charity donations in a way that has a long tradition in experimental economics.

TABLE 1: Summary of the treatments

Mechanism		Order of rounds*	# sessions	# groups	# independent observations
First-price winner-pay	WP	NC-C-NC-C	2	12	6
		C-NC-C-NC	2	8	4
lottery	LOT	NC-C-NC-C	2	12	6
		C-NC-C-NC	2	8	4
First-price all-pay	AP	NC-C-NC-C	2	12	6
		C-NC-C-NC	2	8	4

*NC-C-NC-C: rounds 1-7 and 15-21 without charity; rounds 8-14 and 22-28 with charity.

C-NC-C-NC: rounds 1-7 and 15-21 with charity; rounds 8-14 and 22-28 without charity.

2.2 Hypotheses

Let each individual value €1 raised for the charity by € α . Hence, auction revenue R is considered to be a public good, adding αR to each individual's net earnings from the auction. Excluding the cases of a public bad ($\alpha < 0$) and those where individuals care more about the charity than about themselves ($\alpha > 1$), we assume α to lie in the interval $[0, 1]$.

The equilibrium bidding strategies for the auctions can be straightforwardly derived from GMOT. For WP (first price winner-pay), the (risk-neutral) symmetric Nash equilibrium bid is:

$$b_i^{WP} = \frac{2v_i}{3 - \alpha} . \quad (1)$$

By substituting $\alpha=0$, this simplifies to the standard Nash equilibrium bid for the three-bidder case: bidding $2/3$ of one's value. For $\alpha=0.5$, this gives $b_i^{WP} = 0.8v_i$. In equilibrium, the expected revenue of this auction is found by evaluating (1) at the expected value of the highest of the three draws, which gives:

$$R^{WP} = \frac{3}{6 - 2\alpha} * 500 \quad (2)$$

Thus, $R_{\alpha=0}^{WP} = 250$ without, and $R_{\alpha=0.5}^{WP} = 300$ with the public good.

For AP, the symmetric equilibrium bid is:

$$b_i^{AP} = \frac{2}{3(1 - \alpha)} * 500 * \left(\frac{v_i}{500} \right)^3 \quad (3)$$

For $\alpha=0$, this gives $b_i^{AP} = \frac{2v_i^3}{750,000}$.¹¹ For $\alpha=0.5$, we have $b_i^{AP} = \frac{2v_i^3}{375,000}$. Expected

revenue in the all-pay auction is given by:

$$R^{AP} = \frac{1}{2} * \frac{1}{1-\alpha} * 500, \quad (4)$$

which gives $R_{\alpha=0}^{AP} = 250$ and $R_{\alpha=0.5}^{AP} = 500$.

For the lotteries, no closed form solution for the optimal bid can be derived for the case with private values.¹² Numerically, one can derive the Nash bid for any given value, however. We did so for values starting at 0, with increments of 10. We then estimated a 4th-order polynomial for the equilibrium bid function:

$$b_i^{LOT} = \frac{500}{1-\alpha} * \left(0.0000353 - 0.0774619 \left(\frac{v_i}{500} \right) + 1.125996 \left(\frac{v_i}{500} \right)^2 - 1.395296 \left(\frac{v_i}{500} \right)^3 + 0.5727756 \left(\frac{v_i}{500} \right)^4 \right) \quad (5)$$

We will use these estimated Nash bids in our data analysis. Evaluation at the expected values gives $R_{\alpha=0}^{LOT} = 156.28$ and $R_{\alpha=0.5}^{LOT} = 312.57$.

Table 2 summarizes expected equilibrium revenue for our treatments. Expected revenue without a charity is lowest for LOT while WP and AP are revenue equivalent. With the charity, expected revenue of LOT is approximately equal to that of WP. For both cases, expected revenue is higher in AP than in LOT.

TABLE 2: Expected revenue in equilibrium

	Winner-pay (WP)	All-pay (AP)	Lottery (LOT)
Without charity ($\alpha=0$)	250	250	156
With charity ($\alpha=0.5$)	300	500	313

¹¹ See also Krishna and Morgan (1997), theorem 2.

¹² In the case where the prize has a common value, v , to all participants, it can be shown that in equilibrium each participant will buy $(n-1)v/(n^2(1-\alpha))$ tickets, giving revenue of $(n-1)v/(n(1-\alpha))$ (e.g., Orzen, 2005).

Table 2 serves as a basis for the hypotheses that we will test in Section 3.¹³ The first concerns our main research question: the relative performance of these mechanisms for raising revenues for a charity:

H1: With the charity, revenue is higher in the all-pay auction than in either of the other two mechanisms: $R_{\alpha=0.5}^{AP} > R_{\alpha=0.5}^{WP}$; $R_{\alpha=0.5}^{AP} > R_{\alpha=0.5}^{LOT}$.

In addition, the predictions allow us to formulate the following hypotheses:

H2: Without a charity, revenue is higher in either auction format than in the lottery: $R_{\alpha=0}^{WP} > R_{\alpha=0}^{LOT}$; $R_{\alpha=0}^{AP} > R_{\alpha=0}^{LOT}$;

H3: For each mechanism, revenue is higher with the charity than without: $R_{\alpha=0.5}^{WP} > R_{\alpha=0}^{WP}$; $R_{\alpha=0.5}^{AP} > R_{\alpha=0}^{AP}$; $R_{\alpha=0.5}^{LOT} > R_{\alpha=0}^{LOT}$.

3. Experimental Results

We will start our presentation of the experimental results with a general overview of observed efficiency and revenue in Section 3.1. Section 3.2 gives test results for our hypotheses on treatment effects. In Section 3.3, we analyze bidding behavior in our data and use this to explain the treatments effects we observe.

3.1. Efficiency and Revenue

The observed relative efficiency¹⁴ and revenue are given in table 3, distinguishing both between mechanisms and order of rounds. Of course, the revenue in the case of equilibrium bidding will vary across rounds and treatments, depending on the actual values drawn. For comparison to observed revenue, table 3 also gives the average revenue per treatment for the equilibrium bids.

From table 3 it appears that *efficiency* is highest in the winner-pay auctions and lowest in the lottery. All pairwise differences are significant at the 5%-level (Mann-Whitney tests, using matching groups as unit of observation). The inefficiency of lotteries

¹³ Formally, each hypothesis will serve as an alternative to the null that there is no difference in revenue.

¹⁴ To avoid extreme numbers due to low value draws, the efficiency is calculated relative to the lowest of the three draws in a group: relative efficiency = (winner's value – lowest value)/(highest value – lowest value).

TABLE 3: Efficiency and Revenue (all rounds)

			Efficiency	Revenue	Nash-Revenue
Winner-pay	NC-C- no charity		0.94	301	256
	NC-C charity		0.88	282	301
	C-NC- no charity		0.90	285	255
	C-NC charity		0.89	271	300
All-pay	NC-C- no charity		0.83	373	247
	NC-C charity		0.85	373	441
	C-NC- no charity		0.81	322	228
	C-NC charity		0.79	404	502
Lottery	NC-C- no charity		0.70	290	149
	NC-C charity		0.69	330	318
	C-NC- no charity		0.81	343	150
	C-NC charity		0.70	346	301

Note: NC-C-NC-C: rounds 1-7 and 15-21 without charity; rounds 8-14 and 22-28 with charity.
C-NC-C-NC: rounds 1-7 and 15-21 with charity; rounds 8-14 and 22-28 without charity.

is as expected, because any number of tickets gives a positive probability of winning, so even bidders with low values may win the good, in equilibrium. As for the order in which the rounds with and without charity are presented, there is no systematic effect: for each auction type differences are statistically insignificant at the 10%-level (Mann-Whitney tests).¹⁵

In charity auctions, one is typically more interested in *revenue* than in efficiency. First note that the revenues in the case of Nash bids are close to the predictions of table 2, indicating that the realized value draws did not cause severe deviation from these predictions. The only exception is for the all-pay auctions starting with no-charity rounds. For the rounds with charity, realized values were relatively low, leading to an equilibrium revenue of 441 instead of 500. Perhaps as a consequence of these low draws, the realized revenue in this case is equal to that without charity. More generally, the charity seems to boost revenues for the all-pay auctions starting with a charity round and lotteries starting without charity. Comparing mechanisms, revenues seem to be highest in the all-pay auctions. A statistical analysis of revenue differences is presented below.¹⁶

¹⁵ To avoid flooding the text with pairwise test results, we summarize the Mann-Whitney tests in this way. Detailed test results are available from the authors upon request.

¹⁶ Pairwise Mann-Whitney tests show a significantly higher revenue for the all-pay auction than for the first-price winner-pay auction ($p < 0.01$). Other differences are not significant. We will observe more differences in our more detailed analysis, below.

FIGURE 1: Revenue +/- Nash Revenue

Observed average revenue may be affected by erratic behavior in early rounds. To see if learning takes place over time, figure 1 shows how the difference between average revenue and the average Nash-revenue develops. It appears that in the last two blocks of 7 rounds, revenue is only slightly closer to the equilibrium level than in blocks 1 and 2. In aggregate, the average deviation from equilibrium is 45 in the first 14 rounds and 38 in rounds 15-28. At the same time, the standard deviation decreases from 170 to 163, indicating a slightly lower volatility in later rounds. Though convergence is slow and limited, we will correct for possible learning effects in our statistical analysis below.

A number of other patterns are also visible in figure 1. First of all, for both auctions, revenue is generally above the equilibrium level in rounds without charity and below equilibrium in rounds with charity (causing a smaller difference in revenue than predicted by theory). In the lotteries, revenue is close to the equilibrium level in rounds with charity and much higher than predicted by equilibrium when there is no charity. Finally, the figure shows that by the time subjects reach the last 14 rounds, it does not seem to matter anymore whether they started in rounds with charity or without. In each panel, the solid line in the third block converges more or less smoothly into the dashed line in the last block, and *vice versa*. In aggregate, the average deviation from equilibrium in the non-charity rounds after round 14 is -29 , both if these rounds are first (15-21) and when they are last (22-28). With charity, these deviations are 90 and 104, respectively. Therefore, we conclude that the order of rounds does not affect our results after round 14.¹⁷

3.2 Testing our Hypotheses

We test the hypotheses on revenue presented in Section 2.2 using regressions explaining observed revenue by treatment variables. Random effects are included at the level of statistically independent matching groups (of 6 individuals).¹⁸ Dummy variables representing the order of rounds and the second half (rounds 15-28) of the session are added to correct for learning effects. The model to be estimated is given by:

¹⁷ This is confirmed by the regression results below.

¹⁸ Contrary to the non-parametric tests discussed in footnote 15, these allow us to correct for order effects.

$$R_{it}^k = \beta_0^k + \beta_1^k D_{1i} + \beta_2^k D_{2i} + \beta_3^k Order_i + \beta_4^k Experience_i + u_j^k + \varepsilon_{it}^k, \quad (6)$$

$$k=\text{charity, no-charity}; i=1,\dots,60; j=1,\dots,30; t=1,\dots,28,$$

where k distinguishes between rounds with and without charity, i ($\in j$) denotes the group of 3 subjects competing for the object; j represents the group of 6 subjects that interact over time¹⁹; t gives the round; D_1 and D_2 are dummies representing the mechanism (the third is absorbed in the constant term); $Order=0$ [1] if the session started with a (no) charity round; $Experience=0$ [1] for rounds 1-14 [15-28]; and β_i^k are coefficients to be estimated. The random terms u_j^k and ε_{it}^k are normally distributed. u_i^k captures the panel structure in the data. Table 4 presents the maximum likelihood estimates for the coefficients in (6). These results confirm that the order of rounds does not affect revenue. Having experience does have an effect, however: lower revenues are observed in the second block of (seven) non-charity rounds than in the first.²⁰

First, consider our main research question, that is, the performance of the various formats for raising revenues for a charity. The theoretical prediction is given by $H2$:

$$R_{\alpha=0.5}^{AP} > R_{\alpha=0.5}^{WP}; R_{\alpha=0.5}^{AP} > R_{\alpha=0.5}^{LOT}. \text{ Both inequalities are confirmed by the results in the last}$$

TABLE 4: Revenue and Mechanism

	Without Charity	With Charity
Constant	325.17 (15.86)**	379.91 (15.90)**
Winner-pay	-16.85 (0.67)	-107.56 (3.64)**
All-pay	41.19 (1.64)*	--
Lottery	--	-48.95 (1.66)*
Order	-4.27 (0.20)	11.98 (0.49)
Experience	-24.55 (2.07)**	0.91 (0.07)
LR-test for random effects	p<0.001	p<0.001
Test of $\beta_1=\beta_2$	$\chi^2(1)=5.34$ (p=0.02)	$\chi^2(1)=3.94$ (p=0.05)

Note: The table gives maximum likelihood estimates of the coefficients in eq. (6) with t-values in parentheses (*,** denote that the coefficient is statistically significantly different than 0 at the 10%-, and 5%-level, respectively). In each equation, one mechanism dummy is dropped and included in the constant term. The dummy dropped is the mechanism for which a different equilibrium revenue is hypothesized than

¹⁹ In every round each group j is randomly split in two groups i . Table 1 shows that there are 6 sessions with 18 participants (3 independent groups j) and 6 sessions with 12 participants (2 independent groups j) for a total of 30 independent groups (and 60 auctions per round).

²⁰ The effect of experience does not depend on the mechanism involved. If we add interaction terms between mechanism and experience to (6), none of these terms obtains a significant coefficient at the 10% levels. Moreover, the qualitative conclusions with respect to other coefficients are unaffected.

for the other two. A test for equality of the coefficients of the other two mechanisms is presented in the last row. The LR-test for random effects tests $\sigma_u=0$, which is strongly rejected in both cases.

column of table 4 (the former at the 5%-level, the latter at the 10%-level). Hence, the all-pay format is the preferred mechanism to raise proceeds for charities. In addition (and contrary to the equilibrium prediction), the last row of table 4 shows that revenue in WP is significantly (5%) lower than in LOT, when there is a charity. Though the equilibrium prediction is more or less equal for these two mechanisms (at 300), figure 1 shows that this level is overshoot by much more in the lotteries than in the winner-pay auctions.

Our additional hypothesis about the case without charity reads *H1*: $R_{\alpha=0}^{WP} > R_{\alpha=0}^{LOT}$; $R_{\alpha=0}^{AP} > R_{\alpha=0}^{LOT}$. The second column shows that equality of revenue in WP and LOT cannot be rejected.²¹ The second comparison (higher revenue in AP than in LOT) is supported at the 10% -level, however.²² Finally, in equilibrium, we do not expect a difference in revenue between AP and WP. The last row of table 4 rejects equal revenues in favor of higher revenue in AP at the 5%-level, however.²³ All in all, when there is no charity, revenue in the winner-pay auction in comparison to the other two formats is lower than expected. From figure 1, we observe that this is caused by revenue in AP and LOT ‘overshooting’ equilibrium revenue by much more than in WP.

Finally, *H3*: $R_{\alpha=0.5}^{WP} > R_{\alpha=0}^{WP}$; $R_{\alpha=0.5}^{AP} > R_{\alpha=0}^{AP}$; $R_{\alpha=0.5}^{LOT} > R_{\alpha=0}^{LOT}$ predicts that revenues are higher when there is a charity. To test this, we regress revenue on a variable distinguishing between rounds with and without charity. For each of the three mechanisms, we estimate the coefficients of:

$$R_{it}^k = \beta_0^k + \beta_1^k \text{Charity}_t + \beta_2^k \text{Order}_i + u_j^k + \varepsilon_{it}^k, \quad (7)$$

$$k=\text{WP,AP,LOT}; i=1,\dots,60; j=1,\dots,30; t=1,\dots,28,$$

where $\text{Charity}_t=1$ [0] if a charity was [not] provided in round t. When estimating the coefficients of this equation, we need to take account of the results in table 4. These show that *Experience* has a (significantly) negative effect on revenue for rounds without

²¹ As far as we know, we are the first to experimentally compare winner-pay auctions and lotteries in a setting without charity.

²² Davis and Reilly (1998) and Potters *et al.* (1998) also observe that revenue in an all-pay auction dominates that of a lottery, albeit that these studies use a common value environment in their experiments.

²³ Noussair and Silver (2006) find the same in their experiment.

charity, but no effect for rounds with charity. When estimating (7), this interaction between $Experience_t$ and $Charity_t$ may cause spurious results.²⁴ For this reason, we only use data from the second half of the experiment ($t \mid Experience_t=1$) to estimate the coefficients in (6). Table 5 presents the results.²⁵

TABLE 5: Revenue and Charity

	WP	AP	LOT
Constant	286.40 (33.30)**	363.31 (12.62)**	278.40 (7.64)**
Charity	-3.21 (0.31)	56.15 (2.04)**	26.30 (1.35)
Order	-6.92 (0.64)	-71.17 (1.78)*	60.51 (1.09)
All-pay	---	---	---
Lottery	---	---	---
LR-test	p=0.45	p=0.04	p<0.001

Note: The table gives maximum likelihood estimates of the coefficients in eq. (6) with absolute z-values in parentheses (*, ** denote that the coefficient is statistically significantly different than 0 at the 10%-, and 5%-level, respectively). The LR-test for random effects tests $\sigma_u=0$, which is rejected for AP and LOT, but not for WP.

¹The difference between All-pay and Lottery is not statistically significant (p=0.12).

The coefficients for *Charity* support *H3* for all-pay auctions, but not for WP (which even has the wrong sign, though not significantly so) and LOT. Apparently, for WP and LOT, a charity does not boost revenue to the extent predicted.²⁶ To investigate why this is the case, we take a closer look at bidding behavior.

3.3. Bidding Behavior

To start, we consider participation in the various mechanisms. Recall that bidders can ‘withdraw’ from the auction by bidding 0. For both auctions with and without charity, we observe highest participation in the winner-pay auction (>99% in both cases) and lowest in the all-pay case (80% without charity and 84.1% with charity). Participation in the lottery is in between these two (92.9% without charity and 90.6% with charity). All

²⁴ This problem is not solved by adding the variable $Experience_t$ to the right hand side of (6). The second half of each session includes rounds with and without charity and $Experience_t$ affects these differently.

²⁵ The results show a (mild) order effect for AP. This disappears if we estimate the coefficients using all rounds, however. Hence, it is not expected to affect the results in table 4 (which are based on all rounds).

²⁶ This contrasts to recent findings by Elfenbein and McManus (2006) and Popkowski et al. (2006), who observe (in internet auctions) that bidders bid more in winner-pay auctions if the auction’s revenue is (partly) donated to charity. On the other hand, Chua and Berger (2006) observe that bidders bid less in these auctions when the revenue is donated.

pairwise differences are significant at the 5%-level (Mann-Whitney tests at the independent group level). Hence, as in Carpenter *et al.* (2005), the all-pay format suppresses participation. Contrary to their results from the field, however, we nevertheless find highest revenue for this auction format.

Next, take a closer look at the way bidders bid. For each of the mechanisms, we estimated a 3rd-order polynomial, fitting the bids as a function of the data. We did so separately for the environments with and without charity. To minimize noise due to learning, we decided to use only data from experienced subjects (after round 14). More specifically, we estimate the bid functions:

$$b_{it}^{kl} = 500 * \left(\beta_0^{kl} + \beta_1^{kl} * \left(\frac{v_{it}}{500} \right) + \beta_2^{kl} * \left(\frac{v_{it}}{500} \right)^2 + \beta_3^{kl} * \left(\frac{v_{it}}{500} \right)^3 \right) + u_i^{kl} + \varepsilon_{it}^{kl}, \quad (8)$$

$$k=WP,AP,LOT, l=charity, no charity, i=1, \dots, 30, t=15, \dots, 28,$$

where k denotes the mechanism, l distinguishes between environments with and without charity, i gives the individual and t is the round. The bid is given by b and the value by v . The random terms u_i^{kl} and ε_{it}^{kl} are normally distributed. u_i^k captures the panel structure in the data, where random effects are now included at the level of individuals. Coefficients β are estimated with Maximum Likelihood.

Instead of giving the estimates of β (which are difficult to interpret), we present the results by showing graphs of the estimated functions. These are shown in figure 2, distinguishing between the no charity (top panel) and charity (bottom panel) cases. In both graphs, gray lines show the Nash bid functions (*cf.* Section 2.2) and black lines show the estimated functions. Mechanisms are distinguished by the type of line: dashed (WP), solid (AP) or bold (LOT).

A first thing to note about the figure is that the general shape of the estimated bid functions correspond quite closely to the Nash benchmarks. The WP functions are almost linear, those estimated for AP are more or less convex and the LOT bid functions are convex for low values and concave for high values. The only deviations from this observation are that for WP and AP with charity (see panel b), there appears to be a slight ‘concave bend-off’ for very high values (>450). Nevertheless, the correspondence with the shape of the benchmark functions is quite remarkable. The deviations from Nash that we observe appear to occur not because of the shape of the bid functions but due to their

FIGURE 2: Estimated Bid Functions

location. In 5 out of 6 cases, the estimated bid function lies at or above the Nash benchmark for all values. Only the AP function with charity is estimated to lie below the Nash bids for values larger than approximately 325. Interestingly, this contains the area where Nash predicts that bids will exceed values.

For the winner-pay auctions overbidding increases slightly with value, both with and without charity.²⁷ Recall that we observed when testing *H3* that the predicted higher revenue with charity is not supported. The reason appears to lie in the non-linearity for high values (starting at approximately $v_i=400$). Apparently, bidders with high values shy away from making the corresponding (very) high bids when there is a charity.²⁸ The consequences for revenue occur because the highest of three draws is likely to be in the concave range, which affects revenue strongly.

For the all-pay auctions our testing of *H3* does yield support for the prediction that revenues are higher with charity. Here, the estimated curve lies consistently above the benchmark in absence of a charity,²⁹ whereas it crosses from above to below the curve (at a value of approximately 300) with charity. In the latter case, bidders do not increase their bid with value to the extent that the benchmark would have them do. Especially the idea of bidding above one's value seems to scare bidders off. Nevertheless, this is compensated by low value bidders overbidding, even when there is a charity. Because all bids add to revenue in this case, the aggregate results supports the prediction.

For lotteries, finally, significant overbidding takes place without charity,³⁰ whereas bidding follows the benchmark closely when there is a charity. As a result, there is no support for the theoretical result of increased revenue when there is a charity.

4. Conclusions

²⁷ In the absence of charity, many other empirical studies also observe overbidding in the first-price winner-pay auction. See *e.g.* Cox *et al.* (1982); Kagel *et al.* (1987); Kagel and Levin (1993).

²⁸ For example, a bidder with value 450 is predicted to bid 300 without charity and 360 with charity.

²⁹ This is also in line with earlier studies. See *e.g.* Davis and Reilly (1998); Noussair and Silver (2006). Potters *et al.* (1998) do not observe significant divergence from the Nash prediction, however.

³⁰ We are not the first to observe this. See also Davis and Reilly (1998) and Potters *et al.* (1998).

Charities often organize raffles or auctions to raise money. Staggering amounts are involved (reported estimates are that over \$240 billion was raised by charities in the U.S. in 2003; see Isaac and Schnier, 2005).³¹ There has recently been considerable interest in studying the performance of various mechanisms used. Yet, this is the first experimental investigation for the arguably most realistic case where the prize to be won is characterized by independent private values and where there is incomplete information about others' values. Our study compares winner-pay (first-price) auctions, lotteries and all-pay (first-price) auctions in this environment. The theoretical analysis derived from GMOT provides testable hypotheses for this scenario. Note that we have not attempted to find the optimal method. Given the theoretical results in GMOT this would involve adding second-price elements (or lower) to the all-pay auction. However, for many bidders, first-price auctions are much easier to understand. The formats we have compared are easy to implement and are easily understood by the bidders.³²

Our main result provides support for the theoretical predictions: all-pay auctions are the preferred mechanism to raise money for charities. With three bidders and independent private values in the range [0,500] our results show that compared to all-pay auctions winner-pay auctions are expected to reduce revenues by more than 100 and lotteries by almost 50. Extrapolating this to auctions in the field gives an indication of the potential gains to be made. For example, on June 24, 1999, Eric Clapton's legendary *1956 Fender Stratocaster* 'Brownie' raised \$497,500 for the 'Crossroads Centre' in a winner-pay auction.³³ Our estimates indicate that the proceeds of this one guitar could have been at least \$100,000 higher, had an all-pay format been used.

Needless to say, such extrapolations should be considered with all the necessary *caveats*. For instance, to which extent can theoretical results and observations in the lab be extrapolated to the field? At least Carpenter *et al.*'s (2005) field experiment shows that the all-pay auction may not always dominate the winner-pay auction. New experiments, both in the lab and in the field, may reveal under which circumstances the all-pay auction

³¹ Of course, a large proportion of this was not raised by way of lotteries or auctions. Still, Morgan and Sefton (2000) report that in the U.S. in 1992, at least \$6 billion was raised by lotteries. We have not been able to find numbers for auctions, but a google search with the terms "charity auction" and "charity auctions" gives about 2 million hits.

³² For example, the all-pay auction can be implemented as follows. People are invited to donate money to charity. It is announced that the person who donates the most, wins the prize.

³³ http://www.collectors.com/articles/article_view.shtml?artid=980&universeid=273&type=1.

is the preferred fundraising mechanism. We believe that our study provides a suitable starting point for such endeavors. As argued by Levitt and List (2006), laboratory experimentation is a useful tool for providing qualitative evidence, and is often the preferred first step when ranking mechanisms: "... the lab can be used to rank mechanisms within broad areas, such as charitable fundraising" (Levitt and List, 2006, p. 41). This is precisely what we have done in this paper.

There are at least two other potentially interesting avenues for further research. First, we modeled charity in the experiment by having each subject receive €0.50 for every €1 of revenue. It would be interesting to know to which extent our results carry over to a situation where the proceeds of the auction or lottery are transferred to a charitable organization such as Greenpeace. Second, we have restricted the analysis to the case where everyone values the proceeds equally. People who are not interested in the charity know a priori that in an auction, someone with the same value for the good, who does care about the charity, would outbid them. In some auction formats this would lead them to abstain from participation, in others they may still participate. It may be interesting to study whether this type of asymmetry would change our revenue ranking.

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