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Single versus multiple-prize all-pay auctions to finance public goods: An experimental analysis

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ABSTRACT

This paper presents an experimental comparison of single and multiple-prize all-pay auctions as fundraising mechanisms to finance public goods. We consider a setting characterized by heterogenous incomes and incomplete information, where single and multiple-prize incentive mechanisms are predicted to raise the same overall contribution, but different contributions by income level. We find that overall, for a given total prize sum, a single large prize generates higher contributions to the public good than three smaller prizes. As predicted by the theory, a single prize provides a more effective incentive for high-income individuals. However, contrary to the theoretical predictions, multiple prizes do not provide a more effective incentive for low-income individuals.

1. Introduction

Prizes are commonly used as incentives in various spheres of human activity, from sports to education and research. The economic literature has analyzed extensively the use of contests as incentive mechanisms in different areas, such as rent-seeking activities, technological races and compensation schemes in labor markets, among others.[1] A number of recent papers have investigated, both theoretically and experimentally, the use of prize-based mechanisms to incentivize contributions to public goods. This literature has shown that contests, either lotteries or all-pay auctions, are effective ways to overcome free riding (e.g. Morgan, 2000; Morgan and Sefton, 2000; Goeree et al., 2005; Lange et al., 2007; Orzen, 2008; Schram and Onderstal, 2009; Carpenter et al., 2008; Corazzini et al., 2010; Faravelli, 2011). This paper presents an experimental investigation of the performance of single and multiple-prize all-pay auctions as incentive schemes to finance public goods.

A fundamental question regarding the use of contests is the optimal allocation of prizes. For a given total prize sum, is the award of a single prize more or less effective than multiple prizes? Providing an answer to this question is even more crucial when considering situations characterized by heterogenous agents, for instance individuals who face different budget constraints. In this case, intuitively, we would expect one large prize to give greater incentives to the rich than to

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[1] See, as examples, Lazear and Rosen (1981), Broecker (1990), Taylor (1995) and Fullerton and McAfee (1999).

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the poor. The findings in Corazzini et al. (2010) confirm this hypothesis in a fundraising experiment comparing an all-pay auction and a lottery with a single prize. As predicted, contributions are positively related to income. However, contrary to the theoretical prediction, the all-pay auction raises less contributions than the lottery. One of the factors driving this result is the significant percentage of subjects who abstain from taking part in the all-pay auction (i.e. they bid zero). Crucially, the abstention rate is higher among subjects with lower incomes. Carpenter et al. (2008) report similar results from a field experiment on charitable giving. They find that single-prize all-pay auctions fail to attract enough participation, resulting in lower total contributions than when winner-pay auctions are implemented.

While low participation may be due to several factors, theory predicts that, in the mixed strategy equilibrium, the bids of players with lower endowments are characterized by high density in the neighborhood of zero. This may explain the high frequency of abstention overall, and particularly the higher rate of zero bids among low-income individuals. On the contrary, by awarding multiple prizes, in equilibrium players would move their density to higher bids. This raises the question of whether awarding more than one prize would increase the participation rate and, more importantly, what the overall result would be. Furthermore, we are interested in exploring the effects of different prize configurations on subjects with heterogenous incomes.

Several theoretical studies have analyzed the use of multiple prizes in contests (see Sisak, 2009, for a review). The relative efficiency of single and multiple-prize contests is influenced by various features, which can be categorized into three main dimensions: the type of contest (i.e. whether or not it is a deterministic mechanism), agents' heterogeneity and their risk attitude. Expected effort is generally independent of the number of prizes, for a given prize sum, in all-pay auctions with symmetric, risk neutral agents. Barut and Kovenock (1998) analyze symmetric multiple-prize all-pay auctions with complete information, focusing on risk neutral bidders. Expected expenditures are maximized by driving the value of the lowest prize to zero, but are invariant across all configurations of prizes keeping the lowest prize constant. Moldovanu and Sela (2001) study a deterministic contest where agents have different abilities, which are private information. They demonstrate that a single prize maximizes effort when cost is either linear or concave, but it may be optimal to allocate more than one prize when the cost function is convex. Lange et al. (2007) analyze lotteries as a means to fund public goods, showing that effort is maximized by a single prize with symmetric, risk neutral agents, while multiple prizes may be optimal when agents either have asymmetric valuations or are risk averse.[2]

At the experimental level, there exists limited evidence on the relative performance of single and multiple-prize contests, and the results are not conclusive. Moreover, to the best of our knowledge, existing experiments have concentrated either on multiple-prize lotteries or on proportional-prize tournaments in which the prize is shared according to the relative effort. Schmidt et al. (2005) compare a proportional-prize contest with a single-prize and a three-prize lottery. In the multiple-prize treatment, a subject may win more than one prize, thus the three mechanisms are equivalent for risk neutral players. However the proportional-prize tournament raises higher revenue than the multiple-prize, which outperforms the single-prize treatment. Cason et al. (2010) compare a (deterministic) winner-take-all and a proportional-prize contest in a setting where agents have different abilities. The main finding is similar to the result in Schmidt et al. (2005), with the proportional-prize treatment outperforming the single-prize. Assigning proportional prizes elicits higher entry from low-ability subjects without discouraging the high-ability contestants from entering the tournament or diminishing the entrants' performance. A recent paper by Sheremeta (2010) compares, among other treatments, a single-prize lottery and two-prize lotteries, with equal and unequal prizes. In all treatments, each subject is awarded at most one prize. In this case, the theoretical predictions are confirmed, with the single prize performing better than multiple prizes, and the equal prize contest generating higher effort than unequal prizes. Nevertheless, when using contests to incentivize public good contributions, Lange et al. (2007) report no significant difference between single and multiple-prize lotteries, even when the latter are predicted to generate higher contributions due to the asymmetry of the (risk neutral) agents. When focusing on symmetric but risk averse agents, multiple prizes still fail to generate higher contributions. Similarly, in a field experiment on charitable giving, Landry et al. (2006) report slightly lower contributions with multiple-prize than with single-prize lotteries.

We present a linear public good game in which contributions are incentivized through prizes. We compare two extreme scenarios, for a given total prize: a single-prize all-pay auction (winner-take-all) versus a three-prize all-pay auction (three highest bids receive an equal prize). Differently from the experiments conducted by Lange et al. (2007) and Cason et al. (2010) we introduce asymmetry in income, instead of ability. Subjects have heterogenous endowments, which are private information. In the single-prize contest, because of the different budget constraints, in equilibrium individuals with higher income should contribute more in expectation than those with lower income. Vice versa, in the three-prize mechanism the symmetric equilibrium identified by Barut and Kovenock (1998) emerges, with different agents contributing the same amount. The intuition is that, with smaller prizes, all agents are effectively unconstrained. Despite this difference, the two mechanisms are predicted to generate the same expected total contribution (revenue equivalence).

Consistently with the theoretical predictions, we find that contributions rise with income in the single-prize all-pay auction, while they are relatively flatter in the three-prize all-pay auction. However, on aggregate, multiple prizes raise lower contributions than a single prize. This difference is mainly explained by two factors. First, as predicted by the theory, high-income subjects contribute significantly more in the single-prize treatment than with three-prizes. Second, contrary

[2] The role of risk aversion and asymmetry is also analyzed by Glazer and Hassin (1988) and Szymanski and Valletti (2005), respectively, with both studies showing the optimality of multiple prizes in these settings.

to the theoretical predictions, multiple prizes do not provide a more effective incentive than a single prize for low-income individuals. Interestingly, when looking at individual contributions, we find that assigning more than one prize significantly increases the level of participation, i.e. it guarantees a lower percentage of zero bids. Nevertheless, the higher participation rate is more than offset by the lower average contribution.

The under-performance of multiple prizes as fundraising schemes confirms the findings related to lotteries reported by Lange et al. (2007) in the laboratory, and by Landry et al. (2006) in the field. Our experiment extends this evidence to all-pay auctions. Moreover, it allows us to discern the differential effect that distinct prize configurations have on individuals with different incomes. This suggests that reducing the incentives for the rich, in order to increase them for the poor, may end up being too costly for the fundraiser.

The rest of the paper is organized as follows. Section 2 describes the experimental design and procedures. Section 3 presents the theoretical predictions and hypotheses to be tested. Section 4 illustrates the experimental results. Section 5 discusses possible interpretations of the results. Section 6 concludes with a summary of the main findings and a discussion of the implications of the analysis.

2. The experiment

The experiment, based on a standard linear public good game, is designed to compare between subjects the performance of two incentive mechanisms that differ only with respect to the number of prizes: a one-prize all-pay auction (1PA) and a three-prize all-pay auction (3PA). The total prize sum is the same in the two treatments.

The experimental task is as follows (see Appendix A for the instructions). Each session consists of 20 rounds. In each round, every subject has to allocate entirely a given endowment between two accounts, an "individual account"and a "group account".[3] Subjects privately benefit from what they allocate to the individual account, whereas contributions to the group account are multiplied by two and shared equally among the four members of a group. In order to avoid decimals, returns from both accounts are multiplied by two and expressed in points. Therefore, a subject receives 2 points for each token he allocates to the individual account, while he receives 1 point for each token allocated by him, or by any other member of his group, to the group account.

Income heterogeneity is introduced by using a variant of the strangers matching procedure used by Andreoni (1988). At the beginning of each round, subjects are randomly and anonymously rematched in groups of four players. Hence, in each round, subjects ignore the identity and endowment of the other group members: they only know that the endowment of each of the other members can be either 120, 160, 200, or 240 tokens with equal probabilities. Group matching for each round is determined randomly before the beginning of the experiment in the following way. Four pools of four subjects are formed, each containing one subject for each of the four income types (120, 160, 200 or 240 tokens). Each of the four groups is formed by randomly drawing one subject from each pool. As a consequence, within every group, each member can have an endowment of 120, 160, 200, or 240 tokens with equal probability. Having formed the four groups for each round in this way, the same sequence of group matchings for the twenty rounds is used in each session of both treatments.

The incentive mechanisms in the two treatments imply the same financial commitment (total prize) for the fundraiser, but differ in the way prizes (extra points) can be obtained by the subjects. In 1PA, the member of the group who allocates the highest amount to the group account wins the single prize of 240 points. In 3PA, each of the three group members who allocate the highest amounts to the group account wins a prize of 80 points. In both treatments, in case of ties the winner is determined randomly.

The experiment was run in the Experimental Economics Lab of the University of Milan Bicocca, using the *z*-Tree software (Fischbacher, 2007). We ran three sessions for each treatment, with 16 subjects participating in each session, for a total of 96 subjects. Participants were undergraduate students of Economics recruited through an on-line system. In each session, subjects were randomly assigned to a computer terminal at their arrival. To ensure public knowledge, instructions were distributed and read aloud. Moreover, to ensure individual understanding of the public good game and the incentive mechanism, sample questions were distributed and the answers privately checked and, if necessary, explained to the subjects. At the end of each round, subjects were informed about their payoffs from the group account, individual account and prize. At the end of the last round, subjects were informed of their final payoff in points, determined as the sum of their payoffs from all rounds of the experiment. They were then paid in private using an exchange rate of 1000 points per euro. On average, subjects earned 12.25 euros for sessions lasting about 50 min.

3. Theoretical predictions

We assume that players are risk neutral and choose their contributions in order to maximize their expected utility. Recall that in either treatment, for a given prize sum $\Pi = 240$ points, a subject can win at most one prize, which we call π. In 1PA

[3] The language used in the instructions does not refer to contributions or public goods.

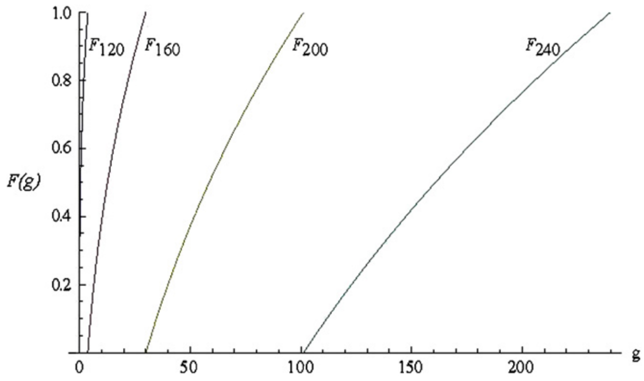

Fig. 1. Cumulative distributions of contributions by income type, 1PA.

$\pi = 240$, while in 3PA $\pi = 80$. Thus, the payoff for a player with endowment $\omega_i \in \{120, 160, 200, 240\}$ who contributes g_i is given by

$$2(\omega_i - g_i) + E[\pi, g_i, g_{-i}] + g_i + G_{-i}, \tag{1}$$

where the second term is the expected prize, g_{-i} is the vector of contributions of the other group members, while G_{-i} is their sum.

Let us first focus on 1PA. Rearranging (1) and considering that $\pi = 240$, we obtain

$$2\omega_i + G_{-i} + E[240, g_i, g_{-i}] - g_i.$$

Notice from the above expression that solving the 1PA game is equivalent to solving an all-pay auction without public good where bidders endowed with either 120, 160, 200 or 240 units compete for a prize of 240 units, and where budgets are private information. As demonstrated in Corazzini et al. (2010), such a game has neither pure strategy equilibria, nor symmetric equilibria, in which all players behave identically independently of their endowment. Given this result, it is natural to concentrate on quasi-symmetric mixed strategy equilibria (i.e. players of the same type randomize according to the same distribution). More specifically, we characterize an equilibrium in which different agents randomize on different supports and expected bids rise with income.

Proposition 1. *There exists a quasi-symmetric Bayesian Nash equilibrium in which:*

- *players with endowment* 120 *choose their contribution according to the distribution function* $F_{120}(g) = (4g/15)^{1/3}$ *on the interval* $[0, 15/4]$*;*
- *players with endowment* 160 *choose their contribution according to the distribution function* $F_{160}(g) = (4g/15)^{1/3} - 1$ *on the interval* $[15/4, 30]$*;*
- *players with endowment* 200 *choose their contribution according to the distribution function* $F_{200}(g) = (4g/15)^{1/3} - 2$ *on the interval* $[30, 405/4]$*;*
- *players with endowment* 240 *choose their contribution according to the distribution function* $F_{240}(g) = (4g/15)^{1/3} - 3$ *on the interval* $[405/4, 240]$.

Total expected group contribution is equal to 240 *tokens.*

Proof. See the proof of Proposition 2 in Corazzini et al. (2010). □

Fig. 1 displays the cumulative distributions of contributions for each income type in 1PA. The distributions show how players with endowments 120 and 160 place high density on very low bids. In particular, agents endowed with 120 tokens randomize on a very narrow support and their bids are extremely close to zero with a very high probability. From Proposition 1 we can calculate the expected value of each income type's contribution to the public good. In equilibrium, the expected contributions of players with endowment 120, 160, 200 and 240 are (approximately) equal to 1, 14, 61, 164 tokens, respectively.

We now provide the predictions for 3PA. Given $\pi = 80$, expression (1) can be rearranged as

$$2\omega_i + G_{-i} + E[80, g_i, g_{-i}] - g_i.$$

Hence, solving the 3PA game is equivalent to solving an all-pay auction without public good, where budgets are private information and bidders endowed with either 120, 160, 200 or 240 units compete for 3 equal prizes of 80 units each. Any contribution $g > 80$ is dominated by $g = 0$. Since the lowest possible endowment is greater than 80, budget constraints are not binding for any agents. Therefore, the game is equivalent to one of complete information in which players are unconstrained, and can be solved as such.

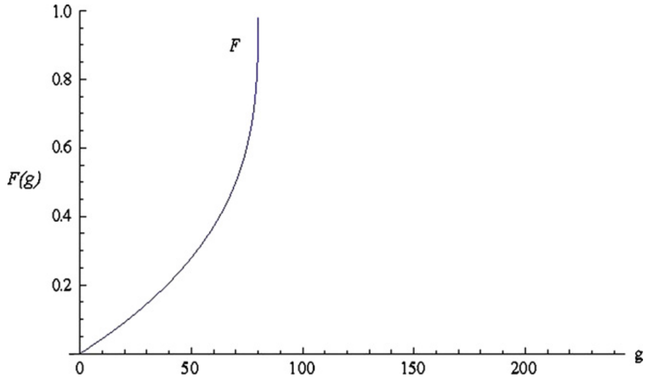

Fig. 2. Cumulative distribution of contributions, 3PA.

Focusing on mixed strategy equilibria,[4] we prove the existence of a symmetric equilibrium in which all players randomize according to the same distribution function.

Proposition 2. *There exists a symmetric mixed strategy equilibrium in which all agents choose their contributions from the distribution function* $F(g) = \sqrt[3]{((g/80) - 1)} + 1$ *on the interval* [0, 80]. *Each player's expected contribution is equal to* 60 *tokens and total expected contribution is* 240 *tokens.*

Proof. Suppose that in equilibrium no agent earns a strictly positive expected surplus. Assume that three agents choose their contributions from the distribution function $F(g)$ on the interval [0, 80]. In order for this to be an equilibrium the remaining player i must be indifferent to play any $g \in [0, 80]$. Hence his expected payoff from playing g must be

$$80\left[(F(g))^3 + 3(F(g))^2(1 - F(g)) + 3F(g)(1 - F(g))^2\right] = g.$$

The above equation has a unique real root root given by $F(g) = \sqrt[3]{(g - 80)/80} + 1$. It is easy to calculate that each player's expected contribution equals 60 tokens. □

Fig. 2 illustrates the cumulative distribution of contributions in 3PA. Note that, relative to 1PA, low-income individuals place much less density on very low bids.

The revenue equivalence result follows from the assumptions of risk neutrality and symmetry among the bidders. However, while expected contributions rise with income in 1PA, they are independent of income in 3PA. Intuitively, the reason is that budget constraints are not binding for *any agents* in 3PA, while they are not binding *only* for players with 240 tokens in 1PA.

Summing up, in 1PA expected contributions are 1, 14, 61, and 164 tokens for players with endowment 120, 160, 200 and 240, respectively, while in 3PA they are 60 tokens for all players. Total expected group contribution is 240 tokens in both treatments. The experiment is designed to test the following hypotheses:

H1 Total contributions: For a given total prize sum, total expected contributions to the public good are the same irrespective of the number of prizes (revenue equivalence).

H2 Contributions by income level: For a given total prize sum, expected contributions are higher with three prizes than with one prize for low-income individuals, while the opposite holds for high-income individuals.

4. Results

This section presents the experimental results. We start with a comparison of contributions between treatments on aggregate. Next, we examine treatment effects by individual income level. Finally, we focus on individual behavior.

4.1. Overall contributions

Fig. 3 compares average contributions over rounds in 1PA and 3PA. In both treatments, average contributions start relatively high and converge towards the theoretical prediction (60 tokens) in the first ten rounds. However, the effects of repetition are quite different across treatments: in 1PA, contributions remain stable, close to the predicted level, after the first 10 rounds; in 3PA, contributions fall steadily throughout the first 18 rounds, then stabilize well below the predicted

[4] It is easy to show that there exists a unique (uninteresting) equilibrium in pure strategies, such that three agents bid 80 tokens and the remaining player bids zero. Note that, even in this equilibrium, total contribution is the same as in 1PA.

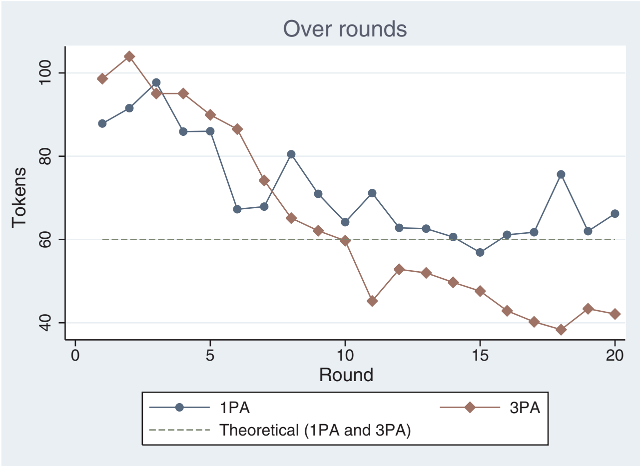

Fig. 3. Average absolute contributions, by treatment.

level. Therefore, in our analysis, treatment effects will be assessed both over the whole session and focusing on the final 10 rounds.

Fig. 4 displays average contributions by treatment. Over the whole session (left panel), average contributions are 72 tokens in 1PA and 64.2 tokens in 3PA. This result is indeed much stronger if we focus on the second half of the sessions, when subjects are more experienced. In the last 10 rounds, average contributions are 64.1 and 45.4 tokens in 1PA and 3PA, respectively.

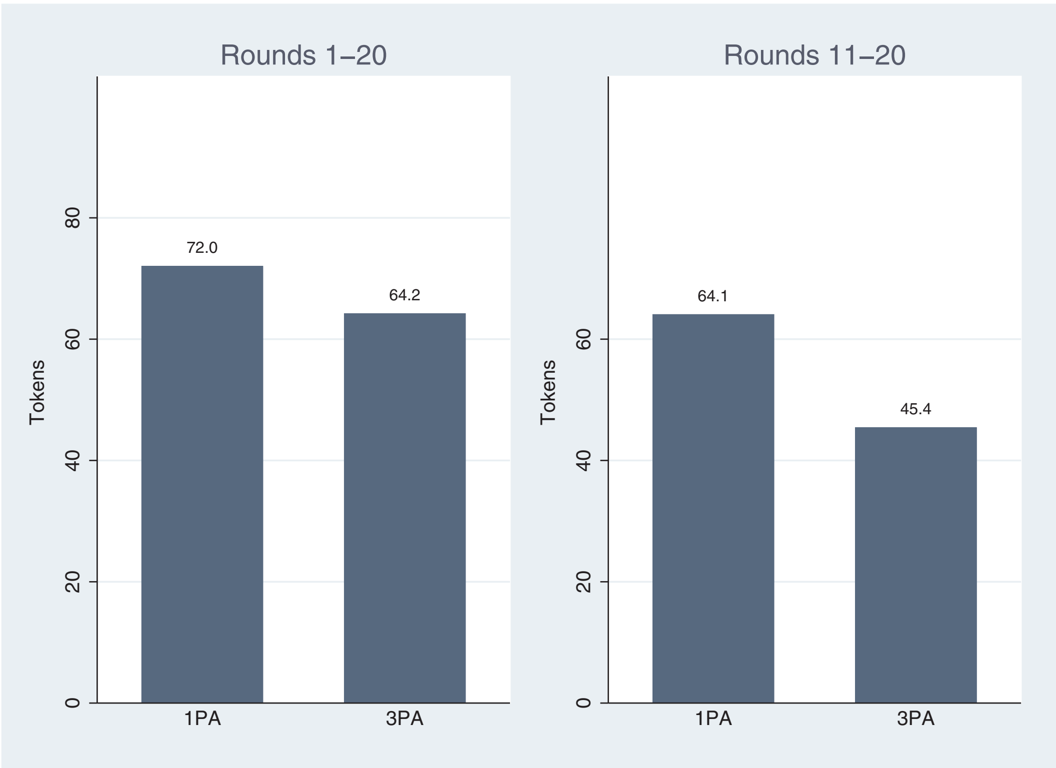

Fig. 4. Average absolute contributions, by treatment.

Table 1
Tests of revenue equivalence hypothesis.

	Rounds 1–20		Rounds 11–20	
	OLS	*Tobit*	OLS	Tobit
3PA–1PA	−7.80 (6.32)	−1.90 (2.92)	−18.65** (6.57)	−12.03** (3.91)
Number of observations	1920	1920	960	960

Note: Dependent variable: individual contribution in round *t*. The set of regressors includes dummy variables for the four income types and time fixed effects. Standard errors clustered at subject level reported in parentheses.
* $p < 0.05$ for the hypothesis $\delta = 0$ in Eq. (2).
** $p < 0.01$ for the hypothesis $\delta = 0$ in Eq. (2).

In order to assess the statistical significance of treatment effects, we estimate the difference in average contributions across treatments while conditioning on subjects' endowment type. We also include time fixed effects to account for the overall declining trend over successive rounds. The resulting specification can be written as follows:

$$g_{it} = \alpha + \delta D_{3PA} + \sum_{k=1}^{4} \beta_k E_k + \sum_{s=1}^{T} \gamma_s R_s + \varepsilon_{it} \tag{2}$$

where g_{it} is subject *i*'s contribution in round *t*, D_{3PA} is a dummy for treatment 3PA, E_k is a dummy for endowment type *k*, R_s is a dummy for round *s*, and ε_{it} is an idiosyncratic error term. We estimate Eq. (2) using either OLS or a Tobit estimator in order to account for the censoring of contributions at 0 and 240. Hypothesis 1 can be tested as $H_0 : \delta = 0$ against $H_1 : \delta \neq 0$.

The panel structure of the data implies that repeated observations from the same individuals are not independent. In order to account for this, we use standard errors adjusted for clustering at the subject level. In addition, because of repeated interactions with a shared feedback under a random rematching protocol, the assumption of independent observations across subjects within sessions might also be violated. However, the characteristics of the experimental design are such that this correlation can be considered negligible: at the end of each round subjects only learn about the total contribution to the group account, so that it is difficult for them to infer individual absolute contributions; moreover, since subjects do not know the endowments of other group members, it is even more difficult for them to infer other subjects' relative contributions. Nevertheless, in order to account for the possibility of cross-subject dependence, we also examine test results obtained with standard errors clustered at the session level (Cooper and Kagel, 2009) or, alternatively, by conditioning on the information available to the subjects, thus including among regressors past realizations of contest outcome and total group members' contributions (Faravelli and Stanca, 2011).

Table 1 reports the results. Over the whole session (columns 1–2), the difference between 1PA and 3PA is negative but not statistically significant. This reflects the fact that average contributions are relatively similar across treatments in the initial rounds, whereas they converge to markedly different levels in the second half of the sessions. Focusing on rounds 11–20 (columns 3–4), the difference between 1PA and 3PA is much larger and strongly significant using both OLS ($p < 0.01$) and Tobit estimation ($p < 0.01$).

The results are qualitatively unchanged when using standard errors corrected for clustering at the session level: the difference between 1PA and 3PA is negative and significant with both OLS ($p < 0.02$) and Tobit estimation ($p < 0.09$). When controlling for cross-subject dependence by conditioning on past realizations of both contest outcome and group contributions, the difference between 1PA and 3PA is large and strongly significant irrespective of the selection of rounds and estimation method.

Overall, the results indicate that, contrary to the theoretical prediction of revenue equivalence, contributions to the public good are higher in 1PA than in 3PA.

> **Result 1**: For a given total prize sum, a single-prize all-pay auction generates higher contributions to the public good than a multiple-prize all-pay auction.

4.2. Contributions by income level

Fig. 5 displays average contributions in tokens, by treatment, for each of the four income types. Over the 20 rounds, average contributions are relatively similar across treatments for low income levels. They are indeed virtually identical, as predicted by the theory, for subjects with an income of 200. The difference is instead very large for the highest income level (98.6 and 65.3 for 1PA and 3PA, respectively). Focusing on the final 10 rounds, the findings are more clear-cut: 1PA outperforms 3PA for each income type, with the size of the difference being positively related to the income level.

Table 2 provides an assessment of the statistical significance of the treatment effects by income level. Equation (2) is estimated by Tobit separately for each income type, with standard errors adjusted for clustering at subject level. The difference between 1PA and 3PA is strongly significant for high-income individuals ($p < 0.02$), while not significant for all other income types. The results are qualitatively unchanged, and more clear-cut, when focusing on the last ten rounds ($p < 0.00$ for the highest income type). An identical pattern is obtained when clustering errors at session level or conditioning on the information available to the subjects in order to account for possible cross-subject dependence within sessions.

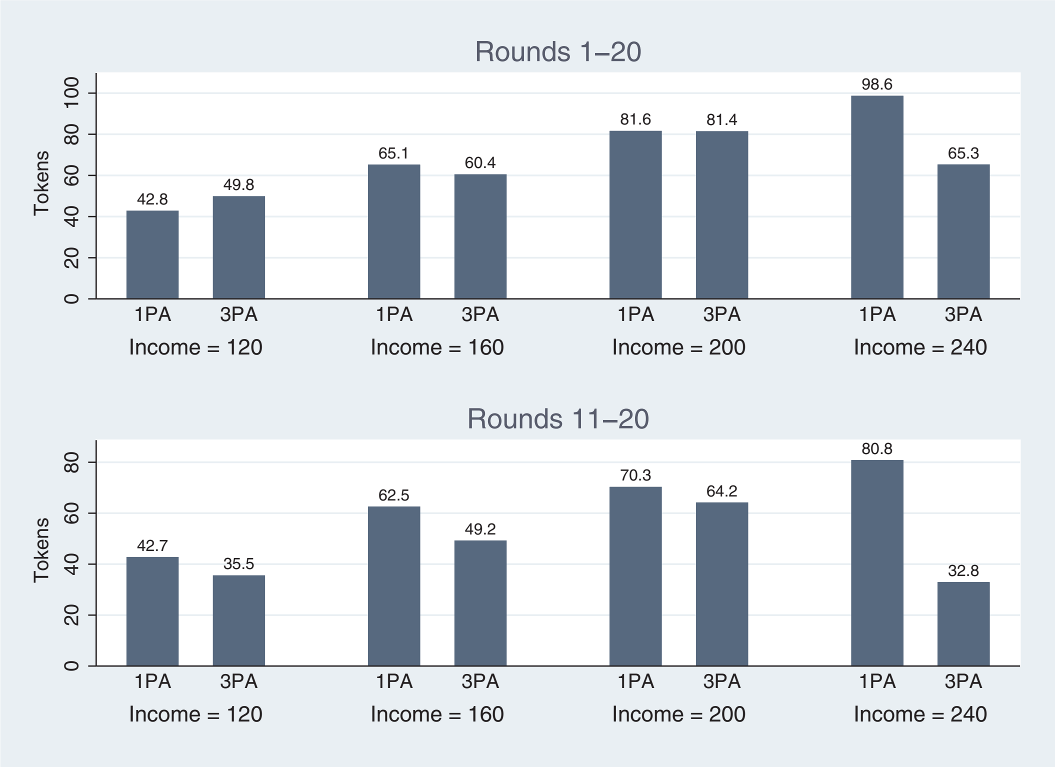

Fig. 5. Average absolute contributions, by treatment.

These findings indicate that, as predicted by the theory, a single larger prize provides a more effective incentive than three smaller prizes for high-income individuals. On the other hand, contrary to the theoretical predictions, three smaller prizes do not provide a more effective incentive for low-income individuals.

Result 2: High-income individuals contribute more with a single prize than with multiple prizes. Low-income individuals do not contribute more with multiple prizes than with a single prize.

4.3. Individual behavior

Fig. 6 compares across treatments the cumulative distribution functions of contributions, focusing on rounds 11–20. On aggregate (left panel), subjects choose to contribute zero much more frequently in 1PA (23.3%) than in 3PA (2.9%). On the other hand, contributions are clustered around very low levels in 3PA, and this more than offsets the higher participation rate. The same pattern can be observed for individual income types (right panel). The opposite effects of the number of prizes on participation and size of contributions are particularly pronounced for high-income subjects.

Table 3 presents tests of treatment effects on participation rates (non-zero contributions). We estimate the marginal effect of 3PA, relative to 1PA, on the probability of contributing, using a probit model with the same set of controls as in Eq. (2) and standard errors clustered at subject level. The results indicate that, irrespective of the sample considered,

Table 2
Significance of treatment effects, by income level.

	Income = 120	Income = 160	Income = 200	Income = 240
	Rounds 1–20			
3PA–1PA	17.15 (11.86)	−2.46 (15.15)	2.71 (17.07)	−30.45* (13.63)
Observations	480	480	480	480
	Rounds 11–20			
3PA–1PA	0.13 (9.61)	−12.40 (19.11)	−2.47 (18.88)	−42.72** (10.70)
Observations	240	240	240	240

Note: Dependent variable: individual contribution in round t. Each equation is estimated by Tobit allowing for the relevant censoring. The set of regressors includes a set of dummy variables for income types and time fixed effects. Standard errors clustered at subject level reported in parentheses.

* $p < 0.05$ for the relevant hypotheses, as described in Section 3.

** $p < 0.01$ for the relevant hypotheses, as described in Section 3.

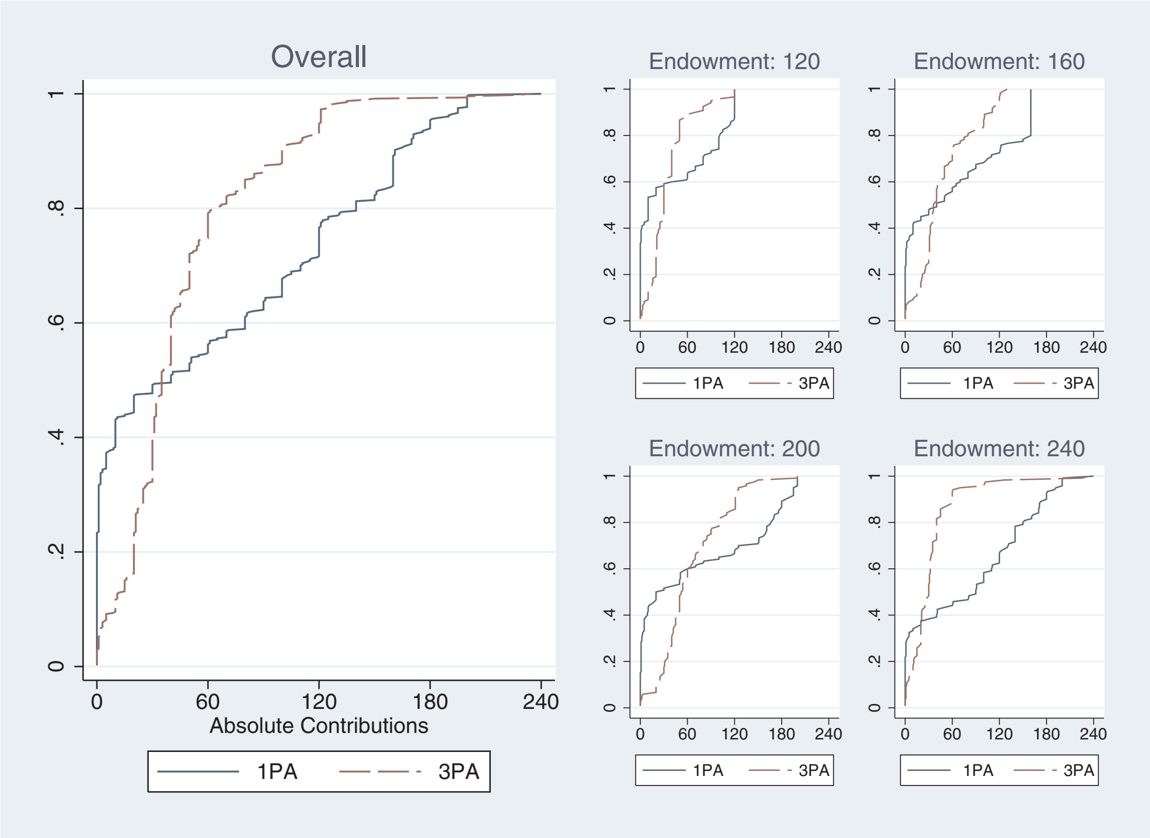

Fig. 6. Cumulative distribution of relative contributions, by treatment.

participation is significantly increased by the use of three smaller prizes, both overall and for individual income types. Quantitatively, the effect of multiple prizes on participation is less strong for subjects with higher income. The results are virtually unchanged when using standard errors clustered at session level or conditioning on the information available to the subjects.

Overall, these findings indicate that the use of multiple prizes is effective in increasing participation, and the effect is stronger for subjects with low income. However, the effect of multiple prizes on participation is more than offset by the fall of the average contributions of participating subjects.

Result 3: For a given total prize sum, multiple prizes significantly increase participation relative to a single prize.

Table 3
Treatment effects on participation.

	Overall	Incomes			
		120	160	200	240
	Rounds 1–20				
3PA–1PA	0.16** (0.03)	0.28** (0.08)	0.17** (0.06)	0.15** (0.04)	0.12* (0.06)
Observations	1920	480	480	480	480
	Rounds 11–20				
3PA–1PA	0.20** (0.03)	0.32** (0.08)	0.21* (0.09)	0.14** (0.04)	0.18** (0.06)
Observations	1920	480	480	480	480

Note: Dependent variable: binary decision to contribute in round *t*. Probit estimates (marginal effects). The set of regressors includes a set of dummy variables for income types and time fixed effects. Standard errors clustered by subject reported in parentheses.

* $p < 0.05$.

** $p < 0.01$.

Table 4
Predicted and observed contributions within treatments.

Contributions	Incomes				Overall
	120	160	200	240	
1PA					
Predicted	1	14	61	164	240
Observed	43	65	82	99	288
3PA					
Predicted	60	60	60	60	240
Observed	50	60	81	64	256

Note: Contributions are rounded to the nearest integer. Predictions refer to expected contributions, observed contributions are averages over the 20 rounds.

5. Discussion

Our key finding is that the prediction of revenue equivalence for single and multiple-prize all-pay auctions is rejected by the data: contributions are on average higher with a single prize, despite lower participation, than with multiple prizes. In this section, we discuss possible explanations, focusing on the departures from the theoretical predictions within treatments.

Table 4 compares predicted and observed contributions within each treatment. In 3PA, contributions are overall slightly higher than the theoretical predictions, and relatively close to the predictions for individual income types. The hypothesis that contributions are equal to the theoretical prediction cannot be rejected on aggregate ($p < 0.32$) and is only marginally significant when tested jointly for individual income types ($p < 0.07$).[5] In 1PA, instead, contributions are overall substantially higher than the theoretical predictions, and the difference is statistically significant ($p < 0.04$). Across income types, contributions are positively related to income, but the relationship is less steep than predicted. Differences with respect to the theoretical predictions for the four income types are jointly strongly significant ($p < 0.00$).

One possible interpretation of these departures from the theoretical predictions is based on attitudes towards risk. The predictions derived in Section 3 are based on the assumption of risk neutral agents. If agents were risk seeking, expected contributions would be higher than under risk neutrality in both treatments. In addition, the effect of risk seeking behavior on contributions would be stronger in the single-prize treatment than in the multiple-prize treatment. This is indeed what is observed in our experiment. As shown in Table 4, contributions are overall slightly higher than predicted in 3PA and substantially higher than predicted in 1PA. Therefore, on aggregate, both the direction of departure from revenue equivalence and the contributions observed *within* treatments are consistent with risk seeking behavior. Note also that a preference for risk is consistent with the relatively small size of monetary prizes in our experiment.[6]

While risk seeking behavior is consistent with our results on aggregate, it cannot fully explain the observed contributions of individual income types. In particular, as shown in Table 4, the overall treatment effects are mainly driven by the fact that in 1PA low-income subjects contribute substantially more than predicted by the theory. One possible interpretation of this finding is the tendency of agents to overreact to low probability events, generally referred to as overweighting of small probabilities (Kahneman and Tversky, 1979; see Starmer, 2000, for a review).

To illustrate, consider subjects with the lowest income. Their expected contribution is predicted to be close to zero in 1PA because, in a quasi-symmetric equilibrium where bids are positively related to income, low-income subjects can only win the prize if they are matched with *three* other individuals with the lowest income. If subjects overestimate the small probability of interacting with three other low-income subjects, their expected bid is higher. Note, on the other hand, that a similar argument does not apply to high-income subjects. For them, given a quasi-symmetric equilibrium, it is sufficient to be interacting with only *one* other high-income subject to face the possibility of not winning the prize. Since this scenario has a relatively high probability, the contributions of high-income subjects would not be affected by the overweighting of small probabilities.

The two interpretations discussed above are not mutually exclusive. The interplay of risk seeking behavior in the presence of small potential monetary gains and the asymmetric effects of overweighting small probabilities on the contributions of agents with heterogeneous incomes, might be able to account for the observed departures from the theoretical predictions, both on aggregate and by individual income type.

6. Conclusions

A number of recent papers have analyzed the use of prize-based mechanisms as incentive schemes for the private provision of public goods. One of the most relevant questions regarding the use of contests and tournaments is whether, for a given

[5] Test results are based on OLS estimation of Eq. (2) separately for each treatment, with standard errors clustered at subject level.
[6] The fact that people tend to be risk seeking in the presence of small stakes has been documented in various experiments (see, for instance, Weber and Chapman, 2005; Haisley et al., 2008; Lefebvre et al., 2010).

prize sum, using a single prize is more effective than multiple prizes. Besides analyzing the overall effect, it is also interesting to explore the implications that distinct prize configurations have on the behavior of agents who differ with respect to some characteristics. We addressed these questions with an experiment that focuses on the use of all-pay auctions as fundraising mechanisms, differently from other papers in this literature that analyze lotteries. We considered a situation in which agents have heterogenous incomes, which are private information. In such a setting, the two questions we have just posed are actually closely related and acquire even more relevance. Indeed, experimental findings have shown that single-prize all-pay auctions perform less well than other schemes, mainly because they fail to attract enough participation (Carpenter et al., 2008; Corazzini et al., 2010). Hence, we investigated whether awarding more prizes may increase participation and, ultimately, result in higher total contributions.

We studied a linear public good game and compared two extreme scenarios, with equal total prize sum: a single prize and a multiple-prize all-pay auction with equal prizes. Overall contributions are predicted to be equal, although, in equilibrium, they should rise with income in the single-prize case and be independent of income in the three-prize treatment. In accordance with the theoretical predictions, contributions are positively related to income in the winner-take-all treatment, while the relationship is less strong when three prizes are awarded. Nevertheless, the hypothesis of revenue equivalence is rejected. While high-income subjects contribute significantly more when only one prize is awarded, low-income subjects do not contribute more with multiple prizes than with a single prize. At the individual level, assigning multiple prizes significantly increases participation, but this effect is more than compensated by the drop in the average contribution of participating subjects. This results in the single-prize all-pay auction being a more effective mechanism to raise public good contributions.

Although not directly comparable, our results are consistent with the findings in Lange et al. (2007) and Landry et al. (2006), who examine single and multiple-prize lotteries as fundraising mechanisms in the laboratory and the field, respectively. Overall, they indicate that assigning more than one prize in order to attract higher participation may be costly for a fundraiser who is interested in maximizing total contributions. However, it is important to highlight the extremity of the treatments we considered. When exploring new mechanisms and hypotheses for the first time, it is useful to start by analyzing scenarios that are at the opposite ends of the spectrum. Hence, we compared a winner-take-all treatment with one in which all but one of the subjects are awarded an equal prize. It is possible that an intermediate prize configuration may guarantee higher total contributions. This hypothesis indicates an interesting extension for future research.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jebo.2011.10.007.

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