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Entry into winner-take-all and proportional-prize contests: An experimental study

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ABSTRACT

This experiment compares the performance of two contest designs: a standard winner-take-all tournament with a single fixed prize, and a novel proportional-payment design in which that same prize is divided among contestants by their share of total achievement. We find that proportional prizes elicit more entry and more total achievement than the winner-take-all tournament. The proportional-prize contest performs better by limiting the degree to which heterogeneity among contestants discourages weaker entrants, without altering the performance of stronger entrants. These findings could inform the design of contests for technological and other improvements, which are widely used by governments and philanthropic donors to elicit more effort on targeted economic and technological development activities.

1. Introduction

Government agencies and philanthropic donors often sponsor contests to reward socially desirable achievements, such as educational attainment or technological innovation.[1] Policymakers can also influence the value of rewards in private contests, by taxing or regulating the payoffs obtained from tournament-like competitions.[2] In this paper, we use controlled experiments to compare the degree of effort and achievement elicited by two contrasting payment structures, in an otherwise identical contest with the same stakes. The vast majority of previous work on contest payments focuses on winner-take-all or rank-order tournaments with fixed prizes.[3] Here, we contrast that traditional approach with an alternative contest design, in which payments are strictly proportional to measured achievement.

Winner-take-all competition is widespread, often because achievement is inherently indivisible or because the contest sponsor wishes to create strong effort incentives by providing the greatest possible reward for winning. Examples include competitions for leadership positions, medical discoveries, or athletic records. Lazear and Rosen (1981) predict that winner-take-all payments elicit greater maximum efforts when identical players pursue a fixed goal, but some contests in real life aim to attract diverse contestants whose efforts are cumulative. For example, a contest sponsor may wish to elicit greater educational achievement, environmental conservation, or productivity gains. Such competitions are not inherently winner-take-all, and their explicit goal may be to attract and reward the efforts of heterogeneous contestants.

Recent theoretical and experimental studies have identified several limitations of winner-take-all tournaments that might lead contest sponsors to seek different designs (Lazear, 1999; 2000).

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[1] A comprehensive review of government and philanthropic contests is available from McKinsey and Company (2009); a database of technology prizes is provided in Masters and Delbecq (2008).

[2] Many governments impose special taxes on income above certain thresholds, and also directly regulate specific kinds of contests. For example, attorneys in the United States can compete for contingency fees, but that type of tournament is often prohibited elsewhere.

[3] A review of this literature is provided in Falk and Fehr (2003) and Irlenbusch (2006).

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Relative to piece rate wages, winner-take-all incentives may lead to greater variance in effort by players (Bull et al., 1987; Nalbantian and Schotter, 1997; Eriksson et al., 2009) or sabotage among them (Münster, 2007; Chen, 2003; Harbring and Irlenbusch, 2008), and the outcomes are also affected by heterogeneity among players (Schotter and Weigelt, 1992; Harbring et al., 2007) as well as risk-sharing incentives (Krishna and Morgan, 1998). These considerations may discourage players from entry and distort performance, and thus reduce the total effort elicited in winner-take-all tournaments. Winner-take-all tournaments can also lead to a more unequal distribution of income (Frank and Cook, 1996). Moldovanu and Sela (2001) show that an alternative tournament design with multiple prizes elicits higher aggregate performance when the cost of effort is convex. One of their predictions is tested in a maze-solving contest by Freeman and Gelber (2010), who find that the multiple-prize structure does result in higher aggregate performance than the winner-take-all payment.[4]

This paper studies a new type of tournament: a proportional-prize contest, in which the prize is divided among participants in proportion to their achievement.[5] This type of contest imitates some forms of competition among firms, for example, whose effort may be rewarded through a share of industry profit. Shared prizes can also be awarded in lobbying contests, such as the allocation of import quota licenses among competing importers (Krueger, 1974). Proportional contests may also be used within firms to reward workers, or as a type of procurement contract to elicit effort among suppliers. For example, poultry meat processors in the United States use proportional-payment competitions among their suppliers to spur cost reductions; Zheng and Vukina (2007) study the case of one firm that switched to such contracts in 1984, and estimate the resulting increase in performance compared to the rank-order contests used previously.

Comparing contest designs could offer both positive and normative lessons. In terms of positive economics, our results show differences in behavior under proportional as opposed to winner-take-all incentives. On the normative side, our results could guide the design of government-sponsored and philanthropic contests, including competitions for educational achievement, health-care improvements, and many kinds of technological innovations. In a review of the history of such contests, Masters and Delbecq (2008) suggest how proportional payments could encourage innovation targeted at agricultural innovations for low-income farmers, building on the opportunities sketched in Masters (2005). In general, contest sponsors could use proportional payments whenever the contest objective can be measured in a cardinal (rather than ordinal) manner. Where cardinal measurement is feasible, paying incrementally for increased achievement uses all of the available information about relative performance. In contrast, winner-take-all contests provide no incentives for any result other than winning.

The potential value of using proportional prizes is in some ways similar to offering multiple prizes in a rank-order tournament, as studied by Lazear and Rosen (1981), Clark and Riis (1998), and Moldovanu and Sela (2001). The main difference is that, instead of an exogenously determined number of prizes and prize values, all players receive a payment which is endogenously determined by their individual efforts. Making proportional payments is also in some ways similar to the use of individual-specific handicaps to normalize incentives, as in Dickinson and Isaac (1998). Here the main difference is that each contestant endogenously competes against the average of all other contestants, with no need for the contest designer to evaluate entrants and impose handicaps.

In this paper, we compare the performance of winner-take-all and proportional-payment contests in attracting entry and eliciting real efforts by actual contestants. Experiments that make participation endogenous, such as those of Ahn et al. (2009), help bridge the gap between behavior in an exogenously-imposed setting and the results when that situation arises outside the laboratory. Unlike Clark and Riis (1998) or Moldovanu and Sela (2001), we do not address the general theoretical optimality of these contests. Our experimental design focuses on heterogeneity among contestants, by offering subjects the opportunity to enter contests against opponents of varying skill levels. Our main result is that, given identical circumstances and the same amount of prize funds available, a proportional-prize tournament elicits higher entry rates and also higher total achievement than the winner-take-all tournament. The advantage of proportional payments is in attracting entry and eliciting effort even where there is at least one very strong player, whose presence in a winner-take-all setting can discourage other subjects from entering. This robustness to heterogeneity among potential competitors is a key dimension of contest performance, particularly for government and philanthropic contest sponsors who seek to attract diverse new entrants into the pursuit of a common objective.

2. Experimental design and predictions

2.1. Experimental design

We conduct an experiment with alternative payment incentives and compare performance in a real effort task: adding up sets of five randomly generated two-digit numbers by hand, as quickly as possible. Achievement is measured as the number of correct sums computed in a five-minute period, with no assistance other than a pen and paper (no calculators). This task is commonly used in the experimental literature (Niederle and Vesterlund, 2007; Eriksson et al., 2008) because it is easy to explain, and there is substantial variability in individual performance that is due partly to skill and partly to effort. The task does not require previous experience and high performance is not associated with a particular gender, socio-economic background, or physical conditioning.[6]

We study three payment conditions: piece-rate payments, a winner-take-all tournament, and a proportional-prize tournament. In the simple piece-rate (PR) condition, subjects receive 2 experimental francs (equivalent to $0.40) per correct answer. In the winner-take-all (WTA) tournament, four subjects within a group compete for a prize of 100 francs ($20) paid to the one with the largest number of correct answers. In the proportional-prize (PP) tournament, four subjects within a group compete for a fraction of that same-sized prize, paid proportionally to all subjects according to their share of the group's total number of correct answers. Note that the contestant group size is held fixed at four in both cases.

The experiment used subjects drawn from the population of undergraduate students at Purdue University. Computerized experimental sessions were run using z-Tree (Fischbacher, 2007) at the Vernon Smith Experimental Economics Laboratory. A total of 93 subjects participated in eight experimental sessions. Upon arrival the subjects were randomly assigned to a computer. The experiment proceeded in four parts. All subjects were given written instructions, available in the Appendix, at the beginning of each part, and an

[4] In a chosen effort experiment, Müller and Schotter (2009) also find a general support for the theory developed by Moldovanu and Sela (2001). However, they find that low ability players drop out significantly more than predicted.

[5] A proportional-prize tournament is in some ways similar to the type of contest modeled by Tullock (1980), in which a contestant's effort influences their probability of winning a fixed prize. Making the prize itself proportional to effort allows us to separate risk concerns from contest design, as in Long and Vousden (1987), and allows direct comparison of winner-take-all versus proportional payments. Contests with proportional prizes are also related to the literature on profit sharing and labor productivity. For a review of this literature, see Weitzman and Kruse (1990).

[6] We are not aware of any evidence suggesting any learning effects in adding numbers task. Moreover, the results of our experiment indicate that there is no such learning.

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experimenter also read the instructions aloud. In the first part, subjects made 15 choices in simple lotteries, similar to Holt and Laury (2002), for the purpose of eliciting subjects' risk preferences.[7] In the second part, each subject participated in one period of adding up numbers under the PR treatment. Performance was recorded and subjects received 2 experimental francs for each correct answer at the end of the experimental session.

The third and fourth parts of the experiment involved WTA and PP contests. In two initial experimental sessions, employing a total of 24 subjects, each subject was randomly and exogenously assigned to compete in a WTA and a PP contest, in a varied sequence. In the next six sessions, employing a total of 69 subjects, each subject chose whether they wanted to enter a contest or be paid by PR.[8] Our main focus is on the choices and performance of subjects during those endogenous-entry sessions, in which their contest opponents were explicitly and deliberately drawn from the pool of subjects in the previous sessions. Having each subject compete against the pre-recorded scores of earlier contestants ruled out strategic interactions among subjects within the same session, and also eliminates the potential influence of social preferences. If we had not used historical competitors, social preferences could have affected behavior because entry and greater effort impose a negative externality on contemporaneous competitors. Competing against pre-recorded, historical performances also allowed us to assign each subject to a four-player group in which their three competitors had higher or lower performance, thereby exogenously manipulating their relative skill.[9] Before each entry decision, subjects were shown the actual piece-rate scores of the three previous subjects against whom they would compete, to inform their expectations about relative performance should they choose to enter. The opponents' prerecorded performance in the WTA and PP contests was not revealed, however, until the subject's performance was registered and their reward was computed.

Each subject participated in six five-minute periods, three with the opportunity to enter a WTA contest and three with the opportunity to enter a PP contest. The sequence was varied so that half the sessions had WTA contests offered first, and half had PP offered first. In each of these six periods, subjects were matched with a fresh group of three other subjects, and informed that their competitors' scores had been recorded from an experimental session run earlier in the year. The computer screen displayed the number of problems that each participant in the group had solved in their initial PR payment condition. Subjects could then choose to enter the contest available in that round (WTA or PP), or to be paid by PR for their own performance. We interpret the PR choice in this design as the opportunity cost of entry, which varies across subjects due to their heterogeneous skill. Non-entrants direct their effort to other activities, rather than whatever is being encouraged by the contest. At the end of each period the computer displayed the number of problems that each participant in the group solved correctly, and the earnings outcome of that period.

At the end of each session, subjects were paid privately in cash: a show-up fee of $5, their earnings from the risk elicitation task in part one, the piece-rate payments in part two, and the contests or piece-rate payments chosen in parts three and four. From the risk-aversion part of the experiment, one of the 15 lottery decisions was randomly selected for payment. From the second part of the experiment in which all payments were by piece rate, subjects were paid for each correctly solved problem. For the third and fourth parts, subjects were paid their earnings from one randomly selected period in part three and one randomly selected period in part four. All earnings were converted into US dollars at the rate of 5 francs to $1. On average the subjects earned $22 including the show-up fee, and sessions lasted about 75 min.

2.2. Predictions and hypothesis

Equilibrium effort in tournaments is typically modeled following Lazear and Rosen (1981) and Hillman and Riley (1989). The approach in Lazear and Rosen (1981) leads to a symmetric pure strategy Nash equilibrium. Their model includes random noise and convex costs, so that predicted efforts equate marginal costs with marginal gains. Hillman and Riley (1989) assume that individual performance is a function of only effort, so the winner is simply the player who expends the highest effort. In that setting, there is no pure strategy equilibrium, but there is a symmetric mixed strategy Nash equilibrium in which players randomize their efforts over some interval.

Entry into tournament contests has been addressed only recently. Fullerton and McAfee (1999) study a tournament where potential entrants have heterogeneous abilities and find that often the efficient tournament attracts only the two players with the highest abilities. Comparing different contests, Namoro and Mathews (2008) demonstrate that the high ability players do not necessarily participate in the contest with the largest prize, but may choose one with a lower prize instead.

To derive our main hypothesis, we consider a simple contest in which n risk-neutral players compete for a prize, normalized to $v=1$. Player i selects irreversible effort ei, with the marginal cost of effort $\frac{1}{c_i}$. Assume that all players have different costs (abilities) and that marginal costs can be ordered as $c1 \geq c2 \geq ...cn \geq 0$. The share of the prize (or probability of winning) for player i is defined by a contest success function:

$$p_i(e_i, e_{-i}) = \frac{e_i^r}{\sum_{j=1}^{n} e_j^r}. \tag{1}$$

where, r is the parameter which describes the degree of discrimination. The contest is perfectly discriminatory when $r=\infty$, i.e. the player with the highest effort receives the entire prize (winner-take-all contest). When $r=1$, each player receives the portion of the prize according to the relative performance (proportional-prize).[10] The expected payoff for a risk-neutral player i is equal to the expected prize (p_i, (e_i, e_{-i}) times the prize valuation 1) minus cost of effort, $\frac{1}{c_i} e_i$:

$$E(\pi_i) = p_i(e_i, e_{-i}) - \frac{1}{c_i} e_i. \tag{2}$$

The Nash equilibrium depends on the parameter r. For $r=1$, the derivation of the unique pure strategy equilibrium can be found

[7] Subjects were asked to state whether they preferred safe option A or risky option B. Option A yielded $1 payoff with certainty, while option B was a lottery with payoff of either $3 or zero. The series of 15 lotteries offered increasing odds of winning the $3 prize, from a 5% probability of winning to a 70% probability. The subject's willingness to forego option A in favor of option B reflects their risk preferences, at roughly the same scale of wealth effect as the rest of our experiment.

[8] Four sessions had 12 subjects each, one session had 11 subjects, and one session had 10 subjects. The number of subjects in each session does not have to be a multiple of 4 since subjects compete against pre-recorded scores.

[9] Assigning subjects to pre-determined group compositions obviously limits our ability to draw general conclusions about the performance of WTA and PP. This design choice, however, allows us to avoid other potential problems that arise when group size and composition are formed endogenously. For example, this approach controls for (unobserved) beliefs about the skill and contest-induced effort intensity of potential competitors. It is also guided by the theoretical properties of these two tournaments, summarized in the next section, which imply different entry choices for participants with different relative ability. It would be interesting for future research to investigate alternative designs in which subjects compete against others who have selected into the tournament, or can choose which of the two tournament schemes to enter.

[10] Technically speaking, the winner-take-all contest is an all-pay auction of Hillman and Riley (1989) and the proportional-prize contest is a lottery contest of Tullock (1980). Che and Gale (2000) provide a link between an all-pay auction of Hillman and Riley (1989) and a winner-take-all tournament of Lazear and Rosen (1981).

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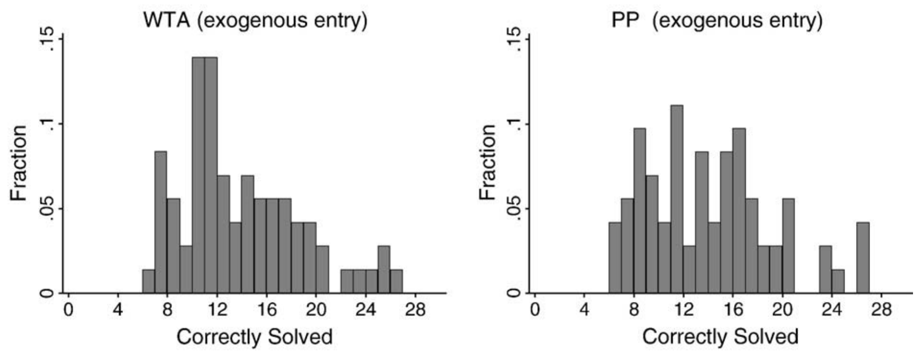

Fig. 1. Distribution of performance with exogenous on tournament entry.

in Fang (2002). In such a case, the equilibrium effort for player i is given by:

$$e_i^{PP} = \frac{n-1}{\sum_{j=1}^{n}\frac{1}{c_j}} - \frac{1}{c_i}\left(\frac{n-1}{\sum_{j=1}^{n}\frac{1}{c_j}}\right)^2. \quad (3)$$

For $r = \infty$, the player who expends the highest effort wins the entire prize. The equilibrium in such a winner-take-all contest is quite different from the proportional-prize contest (Baye et al., 1996). In equilibrium all weaker players with marginal costs above $\frac{1}{c_3}$ expend effort of zero with probability one. The two strongest players use mixed strategies, which are characterized by cumulative distribution functions that describe the distribution of efforts on the support $e \in [0, c_2]$,

$$F_1^{WTA}(e) = e / c_2 \text{ and } F_2^{WTA}(e) = (c_1 - c_2 + e) / c_1. \quad (4)$$

It is easy to verify that the expected payoffs Eq. (2) are positive for all players participating in the proportional-prize contest and the expected payoff is positive only for the strongest player in the winner-take-all contest (Baye et al., 1993, 1996; Fang, 2002; Ryvkin, 2007)[11]. Therefore, if players have an outside option, as they do in our experiment, then the low ability players should always choose not to enter the winner-take-all contest and instead choose the outside option. The highest ability player will choose to participate in the winner-take-all contest if the outside option is relatively small. We thus hypothesize that low ability players will enter PP significantly more than WTA, while there should be no significant difference in entry decisions of high ability players. Note that our experimental design tests this hypothesis directly, in that each potential entrant's outside option involves exactly the same skills and efforts as the tournament, but is rewarded on a piece-rate basis instead of PP or WTA prizes.

Hypothesis. Subjects with a relatively low ability enter PP significantly more than WTA, while there is no difference in entry for high ability subjects.

3. Results

Fig. 1 illustrates the distribution of performance for the two preliminary sessions when subjects were placed exogenously in each type of contest. The primary purpose of those preliminary sessions was to obtain some historical performance scores against which our subjects would compete in the main experiment. There are two noticeable features of the data. First, the average number of problems solved by subjects in the WTA and PP is very similar (13.4 versus 13.6), which indicates that both tournaments generate similar incentives for subjects' performance. Second, both histograms in Fig. 1 indicate substantial variability in individual performance (Niederle and Vesterlund, 2007; Eriksson et al., 2008). This highlights an important feature of this real effort task: subjects have different abilities and therefore they may have different incentives to enter tournaments.

3.1. Aggregate performance

Table 1 summarizes the number of entry decisions, the total number of problems solved correctly, and the total number of problems attempted in all treatments, conditional on whether the subject chose to enter the tournament or accepted the outside option of a piece-rate payment. A total of 85 entries were made when tournament payoffs were WTA, and jointly these subjects solved 1077 problems correctly. By contrast, a total of 129 entries occurred with PP tournaments, and the total number of problems they solved was 1509. Total achievement in the tournament was thus 40% larger with PP payment than in WTA.

Result 1. PP attracts more subjects and has higher total performance than WTA.

The rightmost column of Table 1 indicates that the WTA contest tended to attract more able subjects. On average, the WTA entrants solved one more problem than the PP entrants. This 8.5% advantage in individual performance for WTA is noticeably smaller than the 40% advantage in aggregate total performance for the PP tournament. Even more importantly, as we show in the next subsection the PP

Table 1
Conditional statistics in PR, WTA and PP (endogenous-entry sessions).

	Total Number of			Average Number of Correctly Solved Problems
	Entry Observations	Correctly Solved Problems	Attempted Problems	
PR	69	661	893	9.6
WTA	85	1077	1342	12.7
PR (WTA)	122	1440	1796	11.8
Combined	207	2517	3138	12.2
PP	129	1509	1912	11.7
PR (PP)	78	1071	1281	13.7
Combined	207	2580	3193	12.5

Note: The first row shows unconditional PR results, required for all 69 subjects before the contests were offered. The third and sixth rows show subjects' PR performance, conditional on having declined participation in the contest.

[11] It is possible that some players, whose costs are sufficiently high, may decide not to participate in the contest and instead expend the effort of. For specific condition under which such situation may occur see Fang (2002).

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contest attracts entry by high performers at a (statistically) equivalent rate as the WTA contest. The difference in individual performance arises only because the WTA format discourages entry of relatively weaker performers.

For certain applications, such as a labor market context in which managers may be selecting between alternative incentive schemes to motivate employees, the overall effort performance comparison should include the PR effort. By this measure (labeled "Combined" in Table 1) the two tournaments have nearly identical achievement. For our research objective to evaluate the tournaments' ability to redirect effort to specific activities by attracting entry into a contest, the most relevant performance metric is the problems solved when participating in the tournament.

3.2. Entry and individual performance

The overall achievement advantage of the PP tournament depends on subjects' decision to enter the tournament, which in turn depends on what they believe about their relative performance vis-à-vis the competitors they would face. We assigned subjects to three kinds of matches. In one third of cases, subjects were placed into a group with a "superstar" contestant, defined as a subject whose PR scores were among the highest in the preliminary sessions. In another third of the cases, subjects were placed in a group of relatively weak contestants, whose PR scores were somewhat lower than the subject's own initial PR score. In the remaining third they were placed in a group of relatively strong contestants.

Table 2's first two columns show the matches, in terms of the maximum and the mean of the three other contestants' pre-recorded scores. The second two columns show entry decisions, in terms of the fraction of subjects who chose to compete under each tournament option. The most dramatic difference is seen when subjects know they face a superstar. In those cases, only 7% of subjects chose to enter contests with WTA payments, whereas 51% chose to enter when the same prize amount was to be paid proportionally. When matched against weaker groups, more than 90% of subjects entered both types of contests. When matched against a stronger group (but no superstar), 25% entered the WTA contests and 43% entered the contests with proportional payment. In total subjects enter 62% of the PP contests but only 41% of the WTA contests.

The entry decision could be influenced by learning over time, and could vary across different types of subjects. Table 3 reports results of various probit random effect models to evaluate this influence. Each one tests the influence of PP compared to WTA payment on subjects' decision to enter the contest. The regressions control for learning using the time trend 1/period and a dummy-variable controlling for the sequence in which the treatments were run. Specification (1) uses all subjects in the endogenous entry condition, while specifications (2) to (5) are based on different subsets of the data. Controlling for the time trend and sequence, the probability of entering the contest is significantly higher when payment is PP rather than WTA. This increase in entry likelihood for the PP contest is especially pronounced for the subjects whose performance in the preliminary PR rounds was the lowest of their contest comparison group (specification 3) or below the group's average (specification 5). No significant difference in entry likelihood is found for the subjects whose performance is the highest or higher than average (specifications 2 and 4). This finding supports the main hypothesis of this study.

Table 3
Entry into PP and WTA contests by initial performance.

Condition	All	Performance in PR treatment			
		is Max	is Min	is ≥Mean	is<Mean
Dependent variable, Entry into Tournament	(1) RE probit	(2) RE probit	(3) RE probit	(4) RE probit	(5) RE probit
PP dummy	0.54**	−0.15	0.60*	0.26	0.83**
[1 if PP treatment]	(0.13)	(0.40)	(0.23)	(0.18)	(0.18)
1/period	0.44*	−0.87	0.55	0.52	0.37
[time trend]	(0.22)	(0.70)	(0.41)	(0.32)	(0.32)
sequence dummy	0.06	0.37	0.02	0.04	0.11
[1 if WTA is before PP]	(0.13)	(0.42)	(0.25)	(0.18)	(0.18)
constant	−0.52**	2.00**	−1.02**	−0.56*	−0.52*
	(0.18)	(0.63)	(0.36)	(0.25)	(0.25)
Observations	414	94	146	198	216
Number of subjects	69	50	68	33	36

Note: All results are from probit models with random subject effects. Standard errors in parentheses. Asterisks indicate * significant at 5%; ** significant at 1%.

Result 2. PP encourages significantly more entry among low ability subjects than WTA without discouraging the entry of high ability subjects.

Another question of interest is whether subjects' performance depends on the type of the contest or the contestants with whom they were matched. To address this we estimated several random effect models with individual subject effects. The estimation results are shown in Table 4. The estimates in column (1) are based on the initial sessions with exogenous, compulsory contest entry, and the other columns report estimates for those who chose to enter the contest.[12] The dependent variable is the number of correctly solved problems (performance) and the independent variables are the treatment dummy variable and controls for the time trend and learning. The conclusion from all specifications is that subject's performance is not influenced by the type of the contest, since the PP dummy variable never even approaches statistical significance.

Result 3. Individual performance is not significantly different in PP and WTA tournaments, regardless whether the entry is exogenous or endogenous.

Results 1, 2, and 3 can be summarized as follows: as long as potential entrants expect to face capable competitors, a proportional-prize tournament elicits higher entry rates and higher total achievement than the winner-take-all tournament, by avoiding the discouragement effect associated with contestant heterogeneity without otherwise altering individual performance.

Note also that, by design, the proportional-prize tournament reduces earnings inequality relative to the winner-take-all tournament. Fig. 2 displays the distribution of payoffs for the WTA and PP tournaments,

Table 2
Fraction of subjects entering the tournament.

Matching	Performance in PR by other contestants		Fraction of Entry	
	Maximum of others	Average of others	WTA	PP
Against Superstar	22.0	11.5	0.07	0.51
Against Weaker Group	8.4	7.4	0.91	0.93
Against Stronger Group	16.4	14.1	0.25	0.43
Total	15.6	11.0	0.41	0.62

[12] We also estimated an alternative set of models following Heckman's (1979) two-step estimation procedure to account for the endogenous selection into the tournament. In the first stage, we estimate the probit model as in Table 3, where the dependent variable is whether or not the subject chose the contest payment scheme. In the second stage we use the results from the first stage to estimate the determinants of performance as in Table 4. Gender and the subject's estimated degree of risk-aversion were used as the identifying variables responsible for the selection effect, based on theoretical predictions (for risk) and previous research documenting different tournament entry rates for men and women (Niederle and Vesterlund, 2007). To conserve space we do not report these estimation results, however, since they are very similar to the results reported in Table 4. We also estimated specifications that included the abilities (initial piece rate performance) of the competitors, and this revealed that performance does not depend on competitors' abilities.

Table 4
Performance in PP and WTA contests.

Condition	Exogenous Entry	Endogenous Contest Entry (columns 2–6) Performance in PR treatment				
		All	is Max	is Min	is ≧ Mean	is<Mean
Dependent variable, Performance	(1) RE	(2) RE	(3) RE	(4) RE	(5) RE	(6) RE
PP dummy	0.22	−0.04	−0.09	−0.62	0.21	−0.26
[1 if PP treatment]	(0.30)	(0.22)	(0.31)	(0.53)	(0.30)	(0.30)
1/period	−0.50	−0.31	−2.27**	−0.91	−0.91	0.05
[time trend]	(0.53)	(0.40)	(0.75)	(0.91)	(0.60)	(0.52)
sequence dummy	−2.22	0	−0.09	−0.21	−0.11	−0.28
[1 if WTA is before PP]	(1.96)	(0.82)	(0.96)	(1.01)	(1.00)	(0.76)
constant	14.83**	12.53**	14.85**	12.25**	15.29**	10.35**
	(1.43)	(0.66)	(0.86)	(1.00)	(0.86)	(0.65)
Observations	144	214	87	55	92	122
Number of subjects	24	69	49	36	33	36

Note: All results shown are estimated using random subject effects. Standard errors in parentheses. Asterisks indicate * significant at 5%; ** significant at 1%.

including PR payoffs received by subjects who chose not to enter the contests. The stark win-or-lose structure of payoffs in the WTA tournament results in a few winners who entered and earned all 100 francs, while a larger fraction of entrants lose and are left with nothing. The contrast with the distribution of payoffs in the PP tournaments is striking. The average payoff for the WTA periods (32.7) is higher than in the PP periods (26.1), but the payoff standard deviation is almost five times higher in the WTA (34.2 compared to 7.3).

3.3. Entry decisions

The decision to enter a contest depends on the outside option and the payoff from entry. In our experiment, the outside option is a piece-rate payment (PR): subjects receive a relatively safe reward that depends only on their own performance. The payoff from entry depends on performance relative to other contestants.

Table 5 examines subjects' entry choices, separately considering each type of tournament, using a series of random effect probit models. The significantly positive coefficient on the subject's own PR score in model (1) indicates that higher ability subjects enter WTA contests more frequently than do low ability subjects, whereas no such skill selection effect appears in model (2) for PP contests. Opponents' skills also matter. With WTA payment, the maximum_other score discourages entry, whereas in the PP contest the average_other score discourages entry. This result is consistent with other players' actual influence on the entrant's payoff based on these different contest structures. Although risk-averse subjects enter WTA less frequently on average, the coefficient on a risk_averse dummy variable is not statistically significant. As expected, no correlation exists between risk-aversion and entry into the PP contests. Consistent with Niederle and Vesterlund (2007), the male dummy coefficient indicates that men enter contests more frequently than women. This entry difference is only statistically significant in the PP tournament, which had the larger number of entrants.

To determine whether subjects' entry decisions are optimal, we need to model their expectations of their contest payoff conditional on the information they have when making this entry choice. At the time of their entry decisions, subjects know the initial piece rate performances for themselves and for the three other contestants with whom they have been matched. From that, they can observe the difference between their own initial piece rate score and the highest of the others (for a WTA contest), and the difference between their own and the average of the others (for a PP contest). These comparisons would influence an optimizing subject's beliefs about their expected payoff from entry. In making that forecast, a subject might also consider how they and others are likely to perform in subsequent rounds given those initial piece rate scores. To ensure that these predictions turn out to be unbiased, we model subjects' beliefs using rational expectations by regressing the payoff each subject would actually have earned through contest entry in each round on their own and their competitors' initial piece rate performances.

For example, before his first entry choice subject 25 knew that his own piece rate performance was 14 correctly solved problems, and that his three potential competitors solved 13, 15 and 21 problems on their initial piece rate task. It turns out that this subject then solved 20 problems correctly in the following period, while his three rivals solved 20, 20, and 23 problems. If those results had occurred in a PP contest, the subject would have earned a share $20/(20+20+20+23)=0.24$ of the 100 prize, or 24 experimental francs. If he had not entered, he would have earned the piece-rate payment of $2\times20=40$ experimental francs. For our regression, we calculate the payoffs that would have been realized in the PP contest for all 207 potential entry choices, and combine them in an OLS regression of PP payoffs on the piece rate information available at the time of the entry choice. The coefficient estimates from this regression and initial piece rate performances tell us that subject 25 in this example period would have an expected payoff of 22.54 experimental francs from PP contest entry, whereas with non-entry he would have earned an expected payoff of 32.27 experimental francs. For this period, an entry decision would not have been optimal.

We employ a similar calculation to compute expected earnings from entering WTA contests, except that we use a logit regression since the dependent variable is a binary indicator for whether a subject would have actually won. The model estimates indicate the probability of winning based on piece rate information available at the

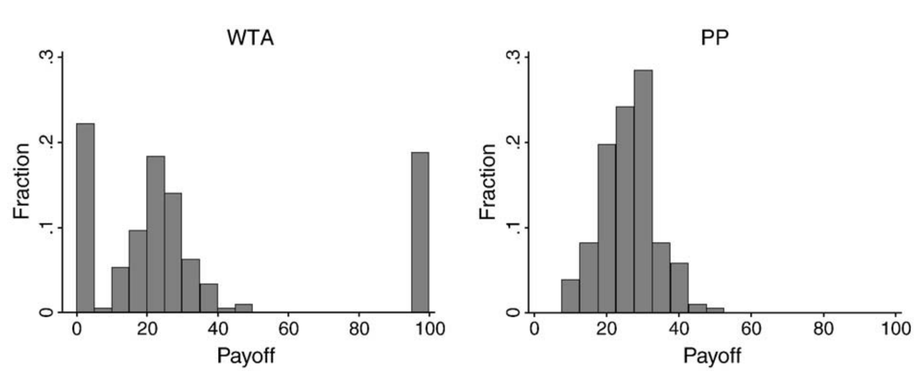

Fig. 2. Distribution of payoffs under WTA and PP.

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Table 5
Entry into different contest formats by initial own and competitor abilities.

Dependent variable	Entry into Tournament		
	WTA	PP	WTA + PP
Specification	(1) RE probit	(2) RE probit	(3) RE probit
own	0.17**	−0.01	0.16**
[own piece rate performance]	(0.05)	(0.03)	(0.04)
maximum_other	−0.20**	−0.05	−0.19**
[max of the other three piece rates]	(0.04)	(0.02)	(0.03)
average_other	−0.08	−0.19**	−0.08
[average of the other three piece rates]	(0.06)	(0.05)	(0.06)
PP dummy			1.29
[1 if PP treatment]			(0.67)
own x PP dummy			−0.17**
[own if PP]			(0.05)
maximum_other x PP dummy			0.15**
[maximum_other if PP]			(0.04)
average_other x PP dummy			−0.11
[average_other if PP]			(0.07)
1/period	0.23	0.37	0.29
[time trend]	(0.44)	(0.36)	(0.27)
male dummy	0.24	0.59**	0.44**
[1 if male]	(0.26)	(0.21)	(0.16)
risk_averse dummy	−0.17	0.00	−0.07
[1 if # of safe options A>8]	(0.26)	(0.21)	(0.16)
sequence dummy	0.4	−0.01	0.16
[1 if WTA is before PP]	(0.27)	(0.21)	(0.16)
constant	2.07**	2.81**	1.69**
	(0.63)	(0.54)	(0.50)
Observations	207	207	414
Number of subjects	69	69	69

Note: All results shown are RE probit estimates, with subjects as the random effect. Significance levels are: *Significant at 5%; and **significant at 1%. Standard errors are in parentheses.

time of the entry choice, which we multiply by the prize value (100) to determine expected profits from entry. For example, using this logit model subject 25 would have expected to win his third potential WTA contest (which was against some relatively weak opponents) with probability 0.841, leading to an expected contest payoff of 84.1. This exceeds what he would have expected to earn (30.97) from a PR payment, making entry optimal in that period.

These estimates of expected contest payoffs reveal that subjects have made correct entry choices a substantial majority of the time in both contests, with 86.05% correct in the WTA contest and 68.6% correct in the PP contest. There is a bias towards over-entry rather than under-entry in both contests. Subjects incorrectly enter the contest when an unbiased expectation suggests that they would have earned more from the PR in 36% of their entries, but they incorrectly stay out of the contest in only 8.5% of their non-entry choices. Thus, similar to previous research (e.g., Camerer and Lovallo, 1999), subjects tend to overestimate their chances of relative success and enter too frequently into tournaments.

Niederle and Vesterlund (2007) document that when choosing between compensation schemes men selected tournament compensation twice as often as women.[13] We find a smaller but still significant difference. Overall men selected the tournament 56% of the time, compared to 45% of the time for women.[14] One possible explanation is that women enter the tournament less than men because they tend to be more risk-averse (Eckel and Grossman, 2002; Powell and Ansic, 1997; Croson and Gneezy, 2009). In our experiment 60% of women and 52% of men are classified as risk-averse, but this difference is not significant (Wilcoxon p-value = 0.52). Furthermore, the Table 5 estimates control for risk-aversion and yet still find a significant gender difference on entry. Note also that the gender difference for entry is larger and is statistically significant for the less risky PP contest. Thus, it appears that some alternative explanation for this gender difference, such as greater overconfidence among men as suggested by Niederle and Vesterlund (2007), may be behind the more frequent entry by men. Our analysis of over- and under-entry summarized in the previous paragraph does not reveal any gender differences for the WTA contest; however it does indicate a marginally significant difference for the PP contest, indicating less frequent entry by women when the contest provides higher expected profit than the PR payment.[15]

4. Conclusions

McKinsey and Company (2009) describe how philanthropic and government-sponsored contests have become increasingly widespread instruments used to elicit efforts targeting many social goals and public goods. Almost all of these contests are winner-take-all in nature. Market incentives may also resemble such contests: in a book titled The Winner-Take-All Society, Frank and Cook (1996) argue that in the 1980s and early 1990s the U.S. economy became increasingly dominated by a stark win-or-lose structure of payoffs. Such "high powered incentives" are sometimes desirable, and are sometimes inevitable, but in some cases offering rewards to more winners might lead to preferable outcomes. That possibility has been explored in theoretical and experimental studies such as Moldovanu and Sela (2001, 2006), Che and Gale (2003), Müller and Schotter (2009), and Sheremeta (forthcoming).

This paper introduces a new type of tournament in which every contest entrant wins a prize, the value of which is strictly proportional to their share of total achievement. We find that such a proportional-prize contest elicits higher entry rates and thus higher total performance in the contest than an equivalent winner-take-all tournament. The proportional-prize tournament performs better because of greater participation by subjects with relatively low ability, with no change in the entry rates or performance of high ability subjects. Moreover, the proportional-prize tournament also substantially reduces earnings inequality relative to the winner-take-all tournament.

Our experiment varies the relative skill of each subject by exogenously matching them with prerecorded scores from a pool of previous competitors. This isolates the impact of relative skills, to test whether a proportional-prize design can overcome the discouraging effect of heterogeneity in winner-take-all contests. Future work might consider other important issues, such as strategic interaction among contestants, or the effect of voluntary entry on subsequent performance. Regarding relative skills, consistent with theory we find that

[13] While several studies replicate the result that women are less willing to enter contests (e.g., Niederle et al., 2008; Gneezy and Rustichini, 2005), this should not be interpreted as evidence that women are on average not as competitive as men. In fact, the majority of studies in the auction literature that consider gender effects find that women overbid more than men, suggesting more competitive behavior once in a competition (Chen et al., 2005; Ham and Kagel, 2006; Casari et al., 2007; Charness and Levin, 2009). Similar over-bidding behavior is found in studies of lottery contests (Sheremeta, forthcoming).

[14] Wilcoxon two-tailed p-value = 0.02. This smaller gender effect does not contradict Niederle and Vesterlund's (2007) result, since many differences besides the subject pool exist between the two experimental environments even though both feature the same real-effort task. For example, in our study we manipulate subjects' information about the relative abilities of their opponents; subjects compete for a single (total $20) prize rather than a piece rate prize; and they had no knowledge about the gender of their competitors.

[15] When the PP contest offered subjects a higher expected profit than PR payment, men actually entered the contest 87% of the time (in 62 out of 71 such cases), whereas women actually entered only 70% of the time (in 19 of 27 such cases). This gender difference is marginally significant (p-value = 0.052), when the entry choice for these cases is modeled as a logit function of gender and a time trend, for the subset of cases where the PP contest has a higher expected profit.

subjects are indeed discouraged from entering winner-take-all contests when they face a single much stronger (or luckier) potential opponent, whereas with proportional prizes their entry decision is influenced by the average performance of all other competitors.

At least for this laboratory contest environment, the proportional-prize contest is just as effective as the winner-take-all contest in identifying top performers because they enter both contests at the same rate and perform equally well conditional on entry. If a contest sponsor, employer or governing body has the additional goal to raise total aggregate performance – rather than just identifying the top performer – our results suggest that the higher entry rates in the proportional prize contest give it a distinct advantage over the winner-take-all format.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jpubeco.2010.05.006.

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