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Endogenous Entry in Contests

by

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July 2008

Abstract

We report the results of laboratory experiments on rent-seeking contests with endogenous participation. Theory predicts that (a) contest entry and rent-seeking expenditures increase with the size of the prize; and (b) earnings are equalized between the contest and the outside option. While the directional predictions offered in (a) are supported in the data, the level predictions are not. Prediction (b) is not supported in the data: When the prize is large, contest participants earn more than the outside option. When the prize is small, contest participants earn less. Previous studies of gender and contest competition suggest that females should (a) not perform as well in the contest; and (b) enter at a lower rate. We find some support for (a) but not for (b). Women participate in the contest at the same rate as men.

Keywords: Contests; Competition; Entry; Experiments

JEL Classification Numbers: C9; D4; D72

1. Introduction

Markets owe much of their strength to selection. Individuals *choose* to participate on the basis of their superior skills, optimistic beliefs, or unique access to resources. “Unfit” agents are outcompeted and ultimately driven from the market. A version of this argument suggests that certain non-optimizing heuristics and biases observed in decision-making experiments are likely to be of little consequence in practice owing to the power of sorting.

A pure expression of the idea of endogenous selection may be seen in market entry experiments. In these games, players can decide to enter, in which case they receive a payoff that is decreasing in the number of entrants, or not enter, in which case they receive a fixed outside option. In the first experimental market entry games, Kahneman (1988) found that the number of entrants was very close to the number predicted by theory. Although subsequent experiments have found slight tendencies toward excess entry when equilibrium predicts few entrants and under-entry when equilibrium predicts many entrants, overall there is remarkable support for equilibrium predictions (see Camerer, 2003, for a review).

In real world markets, the payoff to an entrant is obviously not a simple deterministic function of the number of rivals. Rather, competitive processes are shaped by both the number of rivals and, importantly, their post-entry strategies. In other words, payoffs depend crucially on what entrants *do*, not just on how many there are. However, while numerous laboratory experiments investigate behavior under various forms of competition, these studies typically confine attention to the case where the number of players is exogenous.

In this paper we report experiments where entry is endogenous and where entrants subsequently engage in competition, and ask how well the outcomes are captured by equilibrium theory. We distinguish between behavior—the choices made by players—and payoffs—the resulting earnings. While behavior might differ from equilibrium predictions, market forces exert strong pressure on earnings. In our experiments, players choose between entering a contest and accepting a fixed outside option. Contest entrants play a version of Tullock’s (1967, 1980) rent-seeking game.

Previous experiments on rent-seeking games, summarized in Section 2, exhibit substantial discrepancies between actual investment levels and equilibrium predictions. Indeed, the broad conclusion in this literature is that standard equilibrium analysis does a poor job in

describing behavior. As a result, actual payoffs differ widely from equilibrium payoffs. Can endogenous entry—the discipline of the market—restore equilibrium outcomes?

In Section 3 we describe theoretical properties of our endogenous entry game. Contests with endogenous entry provide an additional mechanism for bringing payoffs in line with equilibrium predictions—the force of entry. First, even if players overinvest in the contest, this overinvestment will be anticipated and “priced” into the entry decision. Profitable contests should attract more contestants and unprofitable contests should shed contestants, up to a point where the payoffs from opting into the contest and opting out are approximately equal. Second, players with a tendency to overinvest receive feedback in the form of lower returns relative to the safe outside option. With experience, these individuals will learn to avoid the “temptation” to overinvest by staying out of the contest in the first place, so that selection may align contest behavior and contest profits back with equilibrium predictions.

Section 4 describes our experiments. Key features that distinguish these from previous experiments are: i) entry into the contest is endogenous, and ii) the game is repeated fifty times. At the end of each round, all players—entrants and non-entrants—learn about contest expenditures and outcomes as well as how much non-entrants earn. These features give players opportunities to learn how the number of contestants and contest strategies affect contest payoff, and also give players opportunities to react to over- or under-investment by exit/entry decisions.

Section 5 describes our results. When a small contest prize is offered, there is initially too much entry and investment relative to equilibrium predictions. Over time, both entry and investment are reduced but remain above equilibrium levels. As a result, subjects choosing to participate in the contest earn about 5% less on average and at greater risk than if they had chosen the outside option. When a large contest prize is offered, there is initially too little entry and too much investment compared to equilibrium predictions. Investment gets close to equilibrium levels over time but entry is consistently too low. As a result, subjects opting for the contest earn about 10% more than those opting for the outside option.

Our design also allows us to examine the relationship between gender, decisions to enter contests and contest strategies. Consistent with the previous literature, women, on average, obtain lower earnings in the contest than men. With respect to entry, our findings diverge from the earlier literature. Despite their lower earnings, women opt into the contest at roughly the same rate as men.

Concluding comments, including some suggestions for further research are offered in Section 6.

2. Previous experiments

Several experiments have studied rent-seeking contests with exogenous numbers of participants. In strictly one-shot games, Anderson and Stafford (2003) find substantial over-dissipation. With two players rent-seeking expenditures are almost twice the predicted level, and for more than two players they find that total rent-seeking expenditures exceed the prize. In contrast, Schmidt, Shupp and Walker (2006) find that with four players expenditures are 30% below predicted levels.

One might expect that these discrepancies between actual and predicted expenditures would be eliminated by experience. However, even in experiments where subjects play repeatedly substantial discrepancies remain after many periods. Shupp (2004) introduces repetition into the Schmidt et al. design and finds some tendency for rent-seeking to increase over time, but, averaging over all periods, rent-dissipation is still around 30% lower than the Nash prediction. In two-player contests with thirty periods Potters, de Vries and van Winden (1995) and Fonseca (2006) find rent-seeking expenditures 68% and 100% above equilibrium respectively.

Table 1 summarizes results from experiments with symmetric contests where a contestant's probability of winning an exogenous prize is equal to her expenditure as a fraction of total expenditure. We normalize the parameters used in each study so that each study can be represented by the expected earnings function $w + x_i P / X - x_i$, where w is the endowment (and maximum permissible individual investment), $x_i \in \{0, 1, \dots, w\}$ is the individual investment, X is the group investment, and P is the prize. The last column shows rent-seeking expenditures as a percentage of those predicted by equilibrium (assuming risk neutrality). The main lesson conveyed in Table 1 is that when an exogenous number of players compete in a contest, one can find substantial rates of overinvestment or underinvestment relative to equilibrium.

Table 1. Summary of previous contest experiments

Study	Treatment	Group size	Number of periods	Matching	Number of subjects	Endowment	Prize	Expenditure as % of Equilibrium Expenditure
Millner and Pratt (1989, 1991)	$r = 1$; less risk averse	2	20	Random	32	120	80	122.5 (last 5 pds)
	$r = 1$; more risk averse	2	20	Random	30	120	80	101.5 (last 5 pds)
Shogren and Baik (1991)		2	32	Fixed	20	24	32	101.4 (last 10 pds)
Davis and Reilly (1998)	baseline; inexperienced	4	15	Fixed	20	cash balance of \$6 to cover losses	200	146.6
	baseline; experienced	4	15	Fixed	20		200	110.5
Potters, de Vries and van Winden (1998)	$r = 1$	2	30	Random	66	15	13	168.3 (150 in last 10 pds)
Anderson and Stafford (2003)	homogeneous costs; small prize	2	1	-	31 in total	20	20	193.2
		3						180.5
		4						240.0
		5						356.3
		10						294.4
	homogeneous costs; large prize	2	1	-	47 in total	40	40	179.2
		3						198.5
		4						187.5
		5						302.1
		10						246.3
Kong (2008)	more loss averse	3	30	Fixed	30	300	200	127.9 (135.5 in last 10 pds)
	less loss averse	3	30	Fixed	30	300	200	156.2 (151.6 in last 10 pds)
Schmitt, Shupp, Swope and Cadigan (2004)	static	2	5	Random	98	15	12	175.7
Shupp (2004)	single-prize; low information	4	15	Random	12	40	144	67.9
	single-prize; high information	4	15	Random	24	40	144	70.6
Schmidt, Shupp and Walker (2006)	single prize	4	1	-	44	80	288	69.6
Fonseca (2006)	simultaneous; symmetric	2	30	Random	30	300	200	200.2 (170.8 in last 10 pds)
Abbink, Brandts, Herrmann and Orzen (2007)	1:1	2	20	Fixed	28	1000	1000	205.2
Herrmann and Orzen (2008)	Symmetric Direct, one-shot	2	1	-	46	16	16	238.9
	Symmetric Direct, repeated	2	15	Random	46	16	16	216.2

How might introducing an outside option affect these results? Some experiments have found that the introduction of market forces can play an important disciplining role in reducing or even eliminating discrepancies between observed behavior and theory. Braga, Humphrey and Starmer (2006) provide a useful overview of experiments studying willingness to pay/willingness to accept disparities and preference reversal phenomena. They also provide important results on how competitive dynamics influence behavior, noting that while some market mechanisms eliminate preference reversal anomalies, others do not (see also Cox and Grether, 1996). Thus they conclude that it is not market experience per se that drives out anomalies, but rather more nuanced features of the competitive forces. As far as we are aware, the only previous study of a Tullock contest preceded by an entry decision is one of Anderson and Stafford's treatments. They find that entry is reduced by introducing an entry fee, but even with the fee rent-seeking expenditures exceed predicted levels. The one-shot nature of their experiment may, however, limit the effectiveness of entry fees as a disciplining device.

3. Contests with endogenous participation

Consider the following simple contest with endogenous participation. N risk-neutral individuals can enter a rent-seeking contest or choose an outside option worth F . Each individual has a fixed endowment worth w . Individuals endogenously choose the time, t , at which to make the decision to opt in or out. Time is continuous in the model starting at time $t = 0$ and ending at time $t = 1$, at which point the contest takes place. All decisions are publicly observable at the instant they are made. If an individual has not made a decision at time $t = 1$, a decision is selected for him or her—equally likely to be an opt-in or opt-out. The number of contest participants at time $t = 1$ is common knowledge. Individuals opting into the contest simultaneously make investment decisions $x_i \in [0, w]$. Aggregate investment is denoted by $X = \sum_j x_j$ where the summation is taken over all contestants. The probability that player i wins the contest is given by the contest success function x_i/X .

Earnings are determined as follows: If a player opted out of the contest, then she earns $w + F$. If she opted in and won the contest, she earns $w + P - x_i$ where P is the value of the prize for winning the contest. If she opted in and lost the contest, she earns $w - x_i$. The contest has

only a single winner; thus, the expected earnings of a contestant who invests x_i when total investment by all contestants is X is given by $\pi_i = w + x_i P / X - x_i$.

3.1 Equilibrium

Suppose that n agents have entered the contest at time $t = 1$. The unique symmetric Nash equilibrium entails investments equal to $x^* = (n-1)P/n^2$ yielding an equilibrium expected payoff of $\pi^* = w + P/n^2$ to everyone who opted into the contest. Clearly, payoffs decrease with the number of individuals entering the contest.

It remains to identify the number of individuals participating in the contest. We assume that $P > F > P/N^2$, so that there is an incentive for at least one player to enter the contest, but the outside option is more attractive than a contest involving all players. Clearly, in any pure strategy equilibrium, the equilibrium number of participants, n , occurs when one additional entrant would reduce the expected payoff from the contest below that of the outside option. That is, in equilibrium, n is the smallest integer such that

$$\frac{P}{(n+1)^2} \leq F.$$

For generic parameter values (i.e., when $\sqrt{P/F}$ is not integer valued) opting into the contest, in equilibrium, yields strictly higher expected payoffs than opting out. This suggests that the first n participants opt into the contest at time close to $t = 0$ with the remainder opting out at any point prior to time $t = 1$.¹ Formally, if players are randomly called upon to make an entry decision the first

$$n^* = \left\lfloor \sqrt{P/F} \right\rfloor$$

players should enter, and the remaining players should opt out, where $\lfloor \cdot \rfloor$ denotes the integer floor function. Entrants should subsequently play the unique symmetric equilibrium of the rent-seeking game. Of course, since all of the players are identical in the model, the identity of the players choosing to opt into the contest is not uniquely determined.

This simple model of contests with endogenous entry is a straightforward extension of the classic Tullock rent-seeking model with the addition of what is, in effect, a zero profit condition.

¹ To avoid having to consider events where individuals make choices at exactly the same time, assume that individuals suffer infinitesimal trembles in the timing of their decisions.

Essentially, the model is a slightly modified version of that analyzed in Corcoran (1984) as well as Corcoran and Karels (1985). Somewhat related is Fullerton and McAfee (1999), who study contests where agents are heterogeneous and entry is determined by an auction. Mathews and Nomoro (2008) consider entry decisions when each agent faces multiple possible contests. See Nitzan (1994) and Konrad (2007) for excellent surveys of the theoretical rent-seeking literature.

3.2 Further considerations

The preceding analysis assumes that all contestants are simultaneously maximizing their own expected earnings. Of course, if contestants have different motivations or are boundedly rational then contest expenditures might exceed or fall short of equilibrium levels.

For example, suppose agents are not attempting to earn as much as possible for themselves, but rather are attempting to beat other contestants. More specifically suppose a contestant maximizes the difference between her earnings and the average earnings of other contestants, i.e. her objective is $u_i = \pi_i - \sum_{j \neq i} \pi_j / (n-1)$. Then it can be shown that equilibrium of the n -player game with payoffs (u_1, \dots, u_n) involves full dissipation. This is closely related to the prediction of over-dissipation relative to Nash equilibrium made by evolutionary models. Noting that a contestant's expected earnings can be written as $\pi_i = w + x_i (P - X) / X$, it should be clear that for any profile of expenditures, as long as there is less than full rent dissipation, $P > X$, the most successful contestant will be the one who spends the most. Thus, evolutionary or imitative processes, whereby better performing strategies receive more reinforcement, lead to over-dissipation relative to equilibrium. Hehenkamp, Leininger and Possajennikov (2004) show that for a contest with n players the Nash equilibrium strategy is not evolutionary stable, and the unique evolutionary stable strategy involves full dissipation: $x = P/n$. Thus, relative earnings considerations may make contestants even more competitive than is predicted by equilibrium analysis applied to absolute earnings.²

Adding an outside option and endogenizing participation in the contest alters this conclusion. If we apply maximization of earnings differences or evolutionary stability to the N -player game, taking into consideration payoffs of n contestants and $N - n$ outsiders, then in the contest stage each contestant spends

² Morgan, Steiglitz and Reis (2003) show that maximization of relative payoffs generates similar excessive competitiveness in auctions.

$$x = \frac{N}{N-1} \frac{n-1}{n^2} P$$

leading to expected contest earnings of

$$\pi = w + \frac{N-n}{N-1} \frac{P}{n^2}$$

(see Hehenkamp et al., 2004), while outsiders earn $w + F$. Already, because contestants compare their earnings with outsiders as well as other contestants, expenditures fall short of full dissipation. Moreover, earnings differences are given by

$$u_i = \frac{N-n}{N-1} \left(\frac{N-n}{N-1} \frac{P}{n^2} - F \right)$$

for a contestant and

$$u_i = \frac{n}{N-1} \left(F - \frac{N-n}{N-1} \frac{P}{n^2} \right)$$

for an outsider. Thus, the subgame perfect equilibrium of the game where players maximize earnings differences has n players enter where n is the smallest integer such that

$$\frac{N-n-1}{N-1} \frac{P}{(n+1)^2} \leq F.$$

Although for any n , contestants still spend more than x^* , the entry decisions result in fewer entrants and this brings expected earnings from the contest approximately into line with the value of the outside option.

4. Experimental design and procedures

The experiment consisted of six sessions conducted at the University of Nottingham in Spring 2008. A total of 102 subjects, recruited from a campus-wide distribution list of undergraduates, participated in the experiment, and no subject appeared in more than one session.

A session consisted of either 12 or 18 subjects, and the following procedures were common to all sessions. At the beginning of a session, the subjects were seated at computer terminals and given a set of instructions which were read aloud. Any questions were dealt with in private by a monitor. No communication between subjects was permitted, and all choices and information were transmitted via computer terminals. Before the decision-making part of the experiment began, groups of six subjects were randomly formed and these remained fixed for the

entire session. Subjects did not know which of the other people in the room were in their group. The decision-making part of the session then consisted of fifty rounds. In each round, a subject was given 100 points and had to choose between two options, labeled “A” and “B”. A timer was displayed on the subjects’ screens, counting down 15 seconds. Subjects were informed that if they did not make a choice within the time limit the computer would make a choice for them at random.³ During this time they could see how many members of their group had chosen A, how many had chosen B, and how had not yet chosen.

Those choosing option A received an additional 10 points for the round, while those choosing option B competed for a prize. The prize varied across sessions according to treatment: in the small prize treatment the prize was worth an additional 50 points, while in the large prize treatment it was worth an additional 200 points.

In both treatments, if only one person entered a contest that person received the prize and no lottery was conducted. Otherwise, subjects choosing to compete for a prize could buy up to 100 ‘contest tokens’ at a cost of 1 point per token. These choices were made independently and simultaneously. Each contestant then received the prize with a probability equal to the number of tokens he or she bought divided by the total number of tokens bought by all contestants in his or her group. The winner was determined using a computerized lottery wheel. All subjects in the group, whether they had entered or not, observed the purchase decisions and the lottery for the contest option. All subjects were also reminded of the fixed payment from the outside option. Table 2 summarizes the experimental treatments and provides the relevant equilibrium predictions for our parameters.

Table 2. Experimental design and equilibrium benchmarks

<i>Treatment</i>	<i>Parameters</i>				<i>Equilibrium predictions</i>							
	Endowment (w)	Players (N)	Outside pay (F)	Prize (P)	Invs. conditional on entrants (x^*)						Entrants (n^*)	
					1	2	3	4	5	6		
Small Prize	100	6	10	50	0.0	12.5	11.1	9.4	8.0	6.9	2	
Large Prize	100	6	10	200	0.0	50.0	44.4	37.5	32.0	27.8	4	

³ Once the timer on the display had counted down from 15, the computer made the decision only after ‘0’ had been displayed for one second. Thus, the effective time limit for subjects was, in fact, 16 seconds. About 3% of decisions were made randomly. Our results are unaffected by the inclusion or exclusion of this data.

At the end of the session, one round was chosen at random and subjects were paid in cash according to their point earnings from this selected round. An exchange rate of £0.10 per point was applied. Sessions took around 75 minutes and earnings ranged between zero and £29.60, averaging £11.11 (approximately US\$22 at the time of the experiment).

5. Results

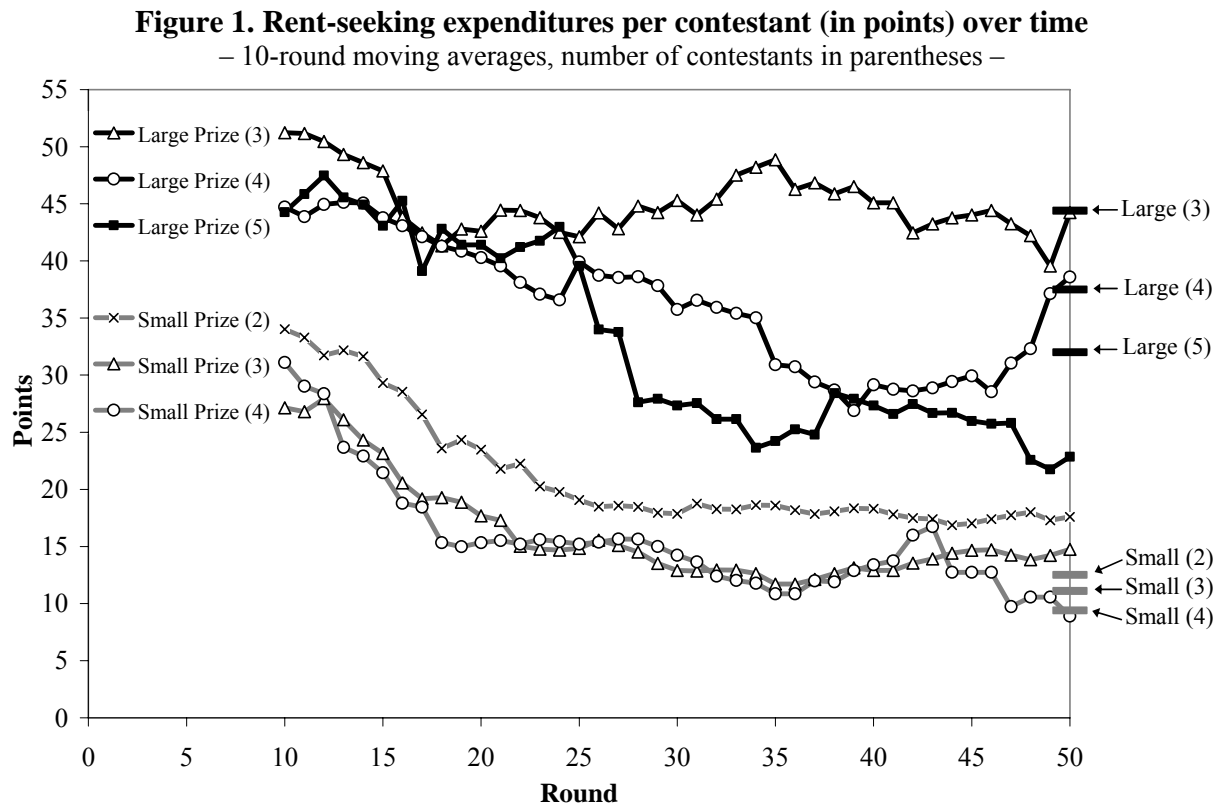
In Section 5.1, we focus on rent-seeking expenditures in the contest. Section 5.2 takes up the question of entry into the contest in terms of the number of entrants, the timing of entry, and the expected payoffs from entering versus not entering. Finally, Section 5.3 examines how gender correlates with subject choices. In particular, our experiment shares many of the same features as recent influential studies on the relationship between gender and competition enabling meaningful comparisons.

5.1 Investment

Figure 1 illustrates investment behavior over time, conditional on the treatment (Small Prize versus Large Prize) and conditional on the number of entrants. The figure only presents the time series for subgames with sufficient number of observations: in Small Prize, contests with five or six contestants were rarely observed and are not shown here; in Large Prize, contests with two or six contestants were rarely observed and are not shown here. Overall, the figure accounts for 96% of all investment decisions recorded. The relevant theoretical benchmarks from Table 2 are displayed on the right hand side as horizontal blocks.

Several broad features are worth noting. First, subjects appear to adjust their investing behavior over time. In the early rounds of the small prize treatment we observe very substantial excess expenditures relative to the theoretical predictions. Average expenditures in the first 10 rounds in Small Prize (2), (3) and (4) exceed the corresponding equilibrium benchmarks by 172%, 145% and 231%, respectively. Overly aggressive expenditures are also present in the early rounds of Large Prize, but less pronounced: the analogous figures for Large Prize (3), (4) and (5) are 15%, 19% and 38%, respectively. A different picture emerges towards the end of the sessions. Although over-investment is still present—investments in the last 10 rounds of Small Prize (2) and (3) exceed the equilibrium benchmark by 41% and 33%—it is less extreme than in the early rounds. Moreover, in Small Prize (4), Large Prize (3) and Large Prize (4), investments

are close to predictions—the averages over the last 10 rounds deviate by -5% , $\pm 0\%$ and $+3\%$, respectively—and in Large Prize (5) we even observe under-investment with an average (over the last 10 rounds) that is 29% *below* the equilibrium level.



Second, despite the relatively large number of rounds and extensive feedback in our experiment, behavior continues to evolve even up to the final rounds. For instance, in Large Prize (4) and Small Prize (3) expenditures increase substantially towards the end of the experiment, after declining in the earlier part.

How do expenditures compare with equilibrium predictions? In terms of directional comparative statics, equilibrium predicts well. Specifically, the Nash prediction suggests that, for a given number of entrants, expenditures should increase with the size of the prize. This holds in our data: average rent-seeking expenditures are considerably higher in the large prize contest than in the small prize contest for a given number of entrants.

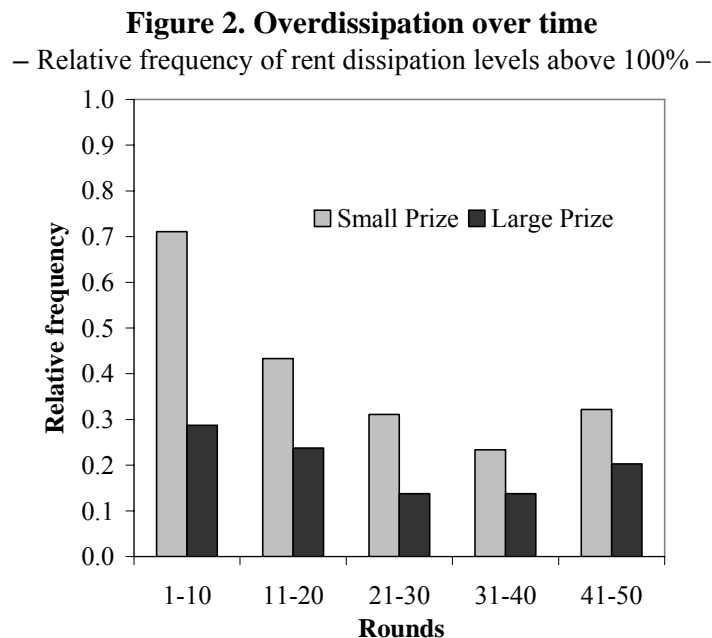
Equilibrium also predicts that, for a given prize, individual expenditures decrease with the number of entrants. This prediction also holds in our data: Average investments in the second

half of the experiment (rounds 26-50) in Small Prize (2), (3) and (4) are 17.7, 13.8 and 11.9, respectively. In Large Prize (3), (4) and (5) they are 44.5, 33.9 and 23.4.

In terms of level predictions, however, equilibrium predictions do less well. In the first 10 rounds of the experiment, subjects tend to overinvest relative to equilibrium predictions. In the small prize contest, average overinvestment amounts to 17.8 points while in the large prize contest, average overinvestment is 8.1 points. Both differences are significant at the 10% level.⁴ With experience, subjects learn to moderate their investment choices. In the last 10 periods of the experiment, overinvestment in the small prize treatment falls to 4.4 points (significant at the 10% level) while, on average, there is underinvestment of 3.5 points in the large prize contest (not significant at conventional levels).

Overdissipation

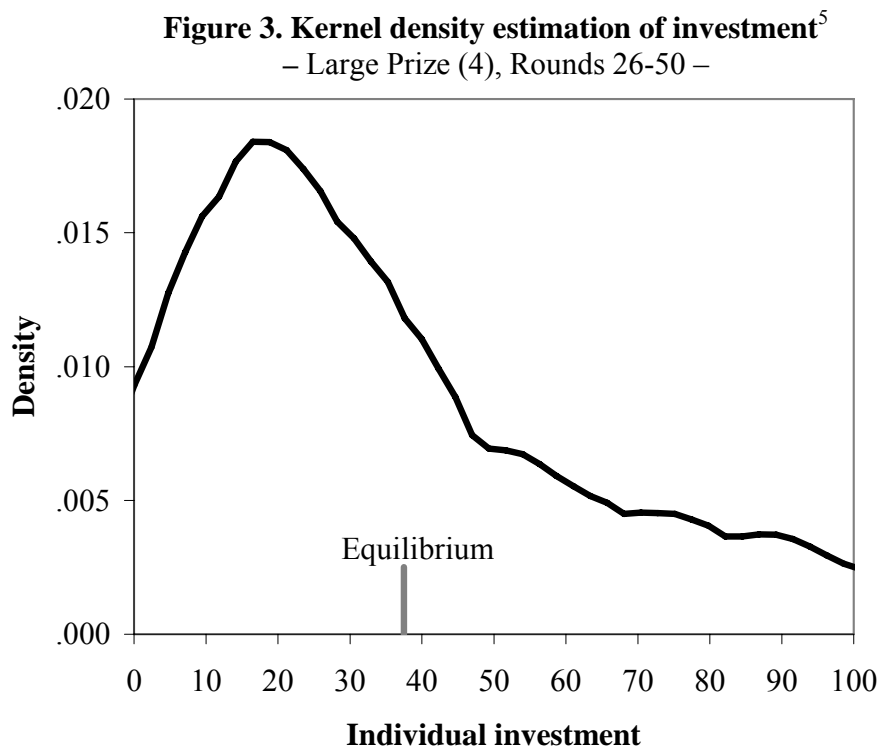
The contest literature has long been concerned with the idea of overdissipation of rents—the possibility that the total investment in securing the prize ends up exceeding the value of the prize. While according to standard equilibrium analysis overdissipation should never occur, the overinvestment we observe, particularly in the small prize treatment, suggests it as a possibility. Figure 2 shows how often overdissipation occurs in our treatments.



⁴ Statistical results reported in sections 5.1 and 5.2 are based on Fisher exact two-sided tests of average behavior treating the group as the unit of observation. We had nine such groups in the small prize contest and eight such groups in the large prize contest.

As the figure indicates, the phenomenon of overdissipation is not a rare occurrence. Indeed, in the early rounds of the small prize treatment overdissipation appears to be the norm rather than the exception. Later, as subjects reduce their expenditures, the frequency of overdissipation diminishes but remains stubbornly high. Even in the large prize treatment, where average investments are often *below* the Nash prediction, overdissipation occurs almost 20% of the time over the last 10 rounds of the experiment.

Comparing Figures 1 and 2 offers an apparent puzzle—how can investment in the large prize treatment fall mostly below the Nash prediction yet produce overdissipation almost 20% of the time? A key difference between the theory model and actual behavior is the *variability* of investment decisions. To illustrate this, Figure 3 presents a kernel density for investment in the large prize contest when $n = 4$ based on the second-half data.

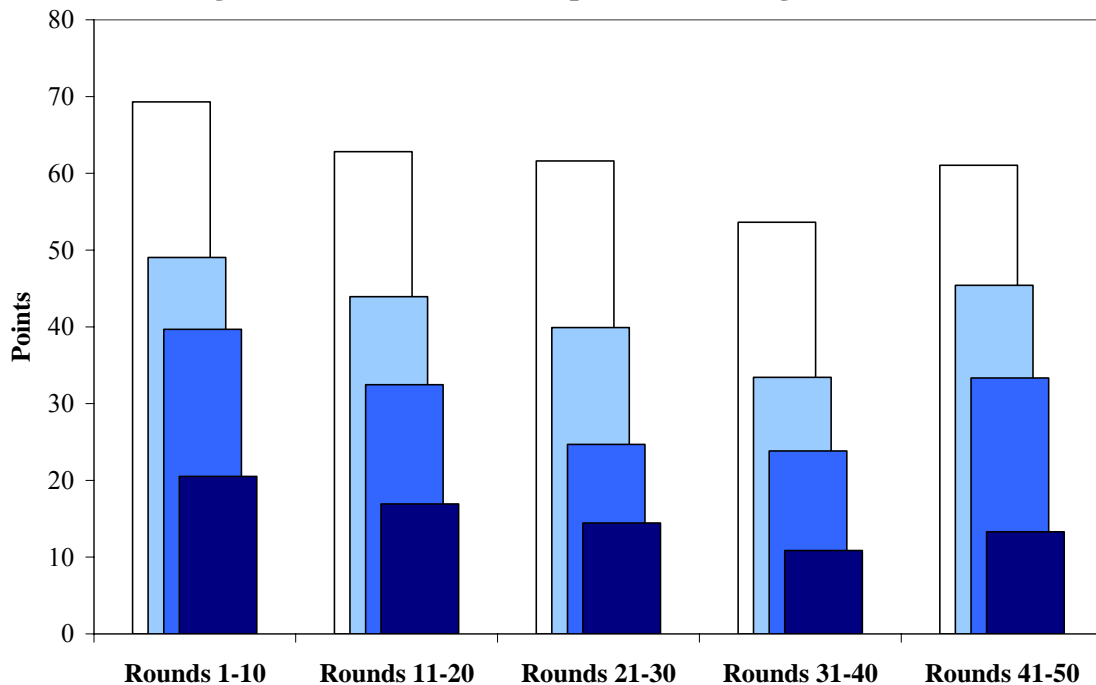


As the figure reveals, while the peak of the density occurs substantially below the Nash prediction, there is a long right tail which offers the possibility of severe overdissipation. Similar dispersion patterns occur for other contest sizes, leading to the possibility of overdissipation.

⁵ Stata default Epachnikov kernel density estimator used.

The dispersion seen in Figure 3 suggests that subjects are heterogeneous in their expenditure patterns. One might have thought that selection into the contest would reduce this heterogeneity by screening out certain “types” of investors. This seems not to be the case. Figure 4 rank orders investment amounts from highest to lowest in the large prize treatment when $n = 4$. If there were only a few types of investors, one would expect clustering between ranks. Instead, the figure shows large and persistent gaps in expenditures between ranks. In other words, subjects exhibit a wide array of investment “styles” and the power of selecting endogenously into the contest does not drive out style variation.

Figure 4. Ranked Contest Expenditures, Large Prize (4)



5.2 Entry

Endogenous participation offers an important channel by which the market might adjust the expected payoffs in contests as players enter or exit the contest depending on its returns relative to the fixed outside option. Table 3 shows the average contest returns (relative to the outside option) as a function of the number of entrants in the contest.

Table 3. Average payoff differences (in points) compared to the outside option*

Entrants	Small Prize		Large Prize	
	1 st half	2 nd half	1 st half	2 nd half
1	+40.0	+40.0	--	+190.0
2	-9.5	-2.7	+12.5	+16.8
3	-14.8	-7.1	+12.2	+12.2
4	-19.4	-9.4	-1.0	+6.1
5	-29.2	-16.0	-8.8	+6.6
6	--	-16.7	-9.8	--

* Empty cells ('--') indicate cases that were not observed in the experiment.

For the small prize contest, overinvestment drives the expected payoff below the outside option even when there are only two entrants. As more players enter, expected earnings further deteriorate. For the large prize contest, returns turn negative only after there are four entrants in the first half of the experiment. In the second half, thanks to *underinvestment* in the contest, even five entrants can profitably compete.

Table 4 presents aggregate entry decisions. While the Nash prediction is that two players enter the small prize contest, one might expect that, on average, fewer than this number will choose to enter owing to the negative returns to two person competition shown in Table 3. In fact, however, we observe precisely the opposite—on average there are 2.7 entrants in the first half of the experiment (rounds 1-25) and 2.5 in the second half (rounds 26-50). While market forces lead to significant exit in the small prize contest over time (p-value = 0.008), there is significant excess entry compared to the Nash prediction (p-value = 0.004 for rounds 1-25 and 0.012 for rounds 26-50).

For the large prize contest, the Nash prediction is four entrants. Owing to underinvestment in the contest, one might expect more entry than the Nash prediction. Again, we observe precisely the opposite—on average there are 3.6 entrants in the first half and 3.7 in the second half. Both figures differ from the Nash prediction at the 6% (first half) and 12.5% (second half) significance level. Despite profit opportunities from entry, there is *no* significant change in the number of entrants in the first versus second half of the experiment (p-value = 0.708).

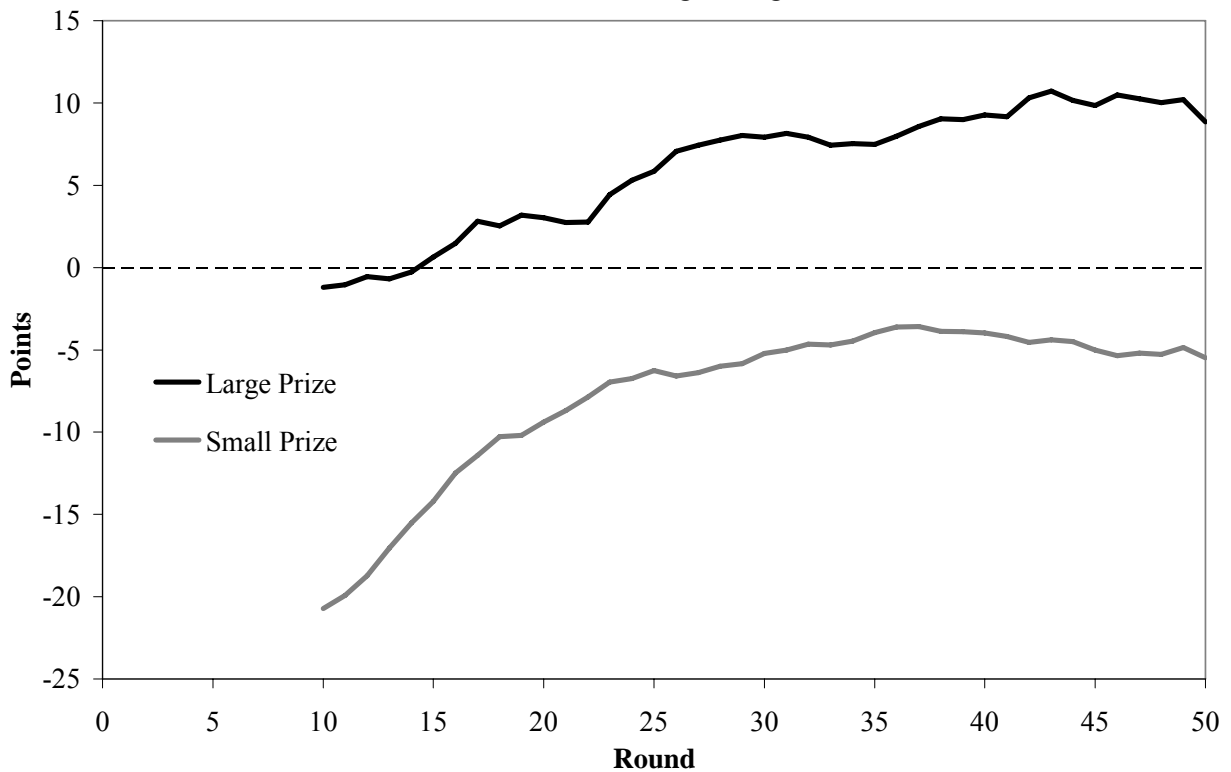
Table 4. Distribution of number of entrants*

Entrants	Small Prize		Large Prize	
	1 st half	2 nd half	1 st half	2 nd half
0	0.4%	0.0%	0.0%	0.0%
1	6.7%	4.9%	0.0%	0.4%
2	34.2%	52.4%	8.4%	2.7%
3	39.1%	35.6%	32.4%	39.1%
4	17.3%	5.8%	35.6%	29.3%
5	2.2%	0.9%	11.6%	16.0%
6	0.0%	0.4%	0.9%	0.0%

* The highlighted rows correspond to the relevant equilibrium prediction.

Because investment levels and entry rates vary across rounds we might expect variations in contest earnings also. Figure 5 presents the difference between average contest earnings and the outside option across rounds.

Figure 5. Difference between contest earnings and outside option
– 10-round moving averages –



By allowing free entry and exit from the contest, it should be the case that the payoff from entry is approximately equal to the outside option. In the small prize contest, contest earnings began substantially below this, improving over rounds, converging to a level somewhat below the earnings from the outside option. Entrants earned 96 points on average during the first half of the experiment and 105 points during the second half. While this increase in earnings is significant (p -value = 0.012), contest payoffs remain significantly below the fixed outside option in both the first half (p -value = 0.004) as well as the second half of the experiment (p -value = 0.066).

In the large prize contest, there is initially little difference between contest earnings and the outside option. However, by the middle rounds of the game the contest is producing about a 10% higher return than the outside option. This persists until the end. Large prize contestants average 112 points during the first half and 119 points during the second half of the experiment. Contest payoffs are not significantly different from the fixed outside option during the first half (p -value = 0.492) and only marginally significant during the second half of the experiment (p -value = 0.148).

To summarize, while the dynamics of entry are consistent with market forces in the small prize contest, even at the end of the experiment subjects were earning less than their fixed outside option by participating in the contest. This difference seems especially surprising given that, by opting out of the contest, subjects could secure 110 points while avoiding the risk of the contest. For the large prize contest, there was surprisingly little entry given the profit opportunities available. While initially payoffs were approximately equal across the two options, by the end of the experiment, payoffs had drifted apart with the contest producing about 10% higher returns than the outside option.

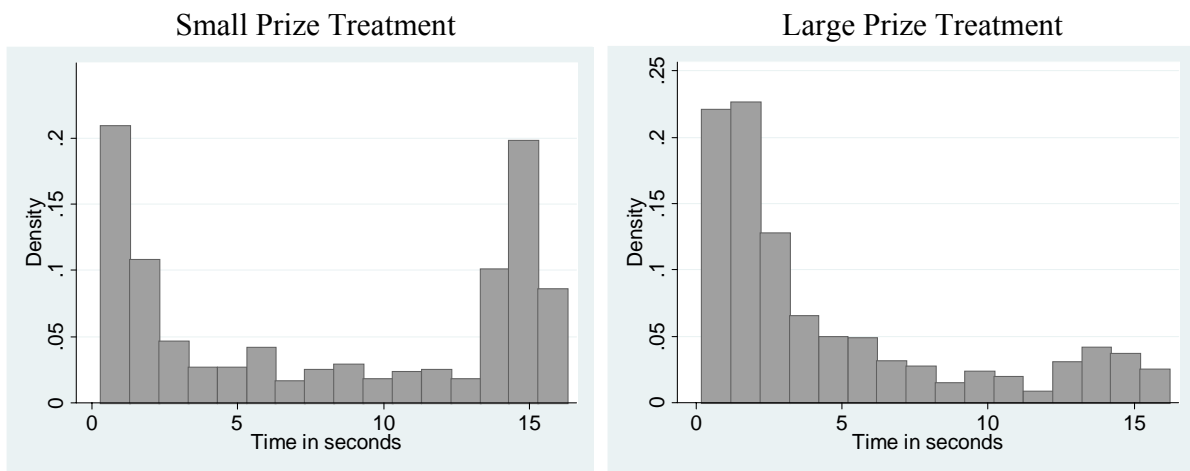
The discrepancies between our results and those from some experimental market entry games such as Kahneman's (1988) study, where equilibrium organizes the data remarkably well, seem to suggest that the forces of selection work considerably less well when the payoffs as a function of the number of entrants are *endogenously* determined as opposed to exogenously specified. However, our results are in fact consistent with a number of experimental studies that report tendencies toward excess entry when theory predicts few entrants and under-entry when theory predicts many entrants; see Camerer's (2003) review in the context of market entry games and the results of Morgan, Orzen and Sefton (forthcoming) in the context of a route choice

problem. A difference between this literature and our study here is that our contests introduce an additional element of risk. While risk aversion could be utilized to explain the patterns observed in our large prize treatment, it seems inconsistent with the results under the small prize treatment.

Timing of entry decisions

Theory predicts that entry will occur early as subjects seek to secure the superior rents from the contest relative to the outside option. Figure 6 displays the actual timing of subject decisions to enter the contest in the second half of the experiment.

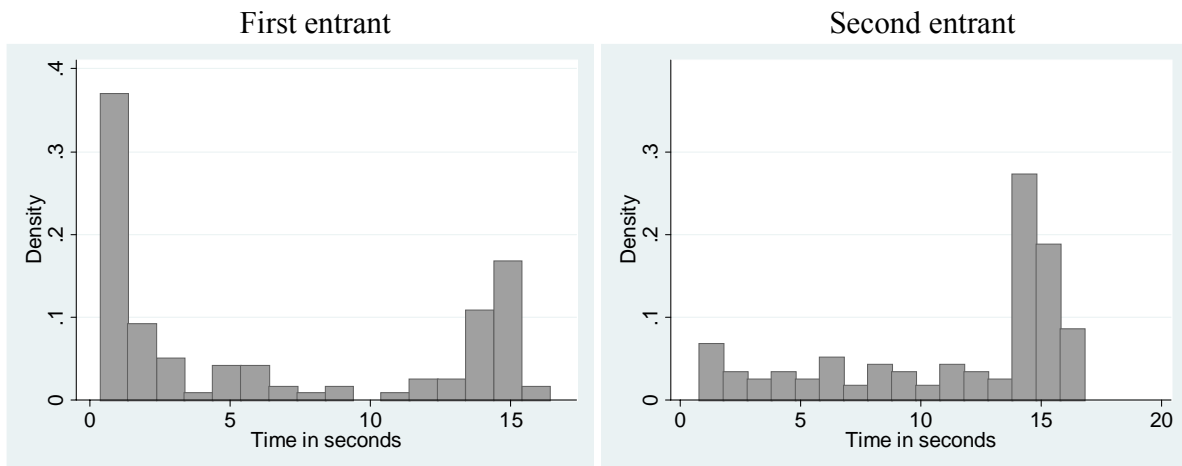
Figure 6. Timing of entry decisions, rounds 26-50



As the figure shows, timing in the large prize treatment is consistent with the theory prediction—most entry occurs early. In Small Prize—where the rents from the contest are in fact *not* superior to the outside option and particularly low when the contest becomes overcrowded—the timing pattern is very different: contestants enter either very early or very late.

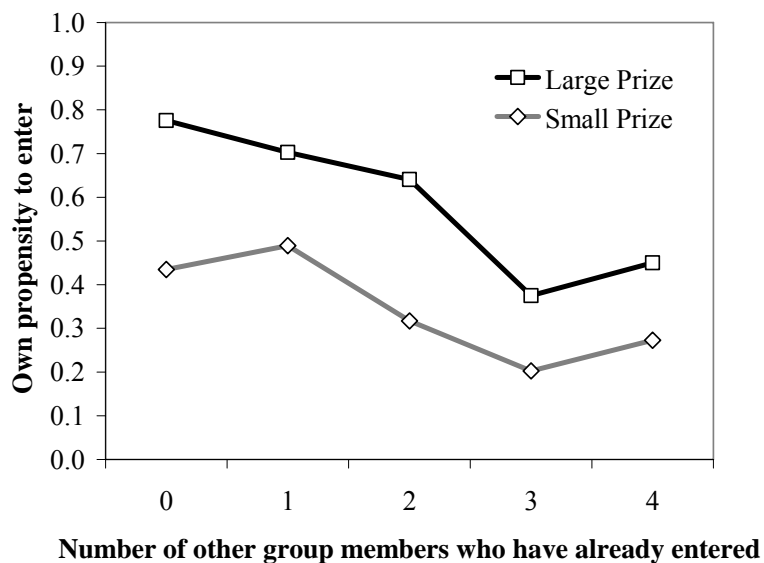
Figure 7 shows the timing decisions for small prize contests that end up with exactly two contestants. As the figure reveals, while the *first* contestant often enters early—usually in the first few seconds—the *second* contestant uses a “sniping” strategy—waiting until the last possible moment to enter.

Figure 7. Timing of entry decisions for $n = 2$, Small Prize, rounds 26-50



What drives subject entry decisions? One might expect that further entry would be less likely the more current entrants there are in a contest since, as we saw above, the returns to entering a contest decline in the number of competitors. Anticipating this, subjects might rationally be less inclined to enter contests with more crowded fields of competitors. To investigate this possibility, we examine a subject’s entry propensity—the probability that he or she will ultimately enter the contest—as a function of the number of competitors already in the contest at the time of the decision to enter or exit. Figure 8 displays the results of this analysis.

Figure 8. Individuals’ entry propensity as a function of the number of prior entrants
 – Second-half data (rounds 26-50) –



As one would expect, entry propensities are consistently higher when the prize is large. Moreover, entry propensities mainly decline with the number of rivals, yet curiously, both treatments exhibit a slight uptick in entry when there are 4 other entrants as compared to when there are only 3 entrants. This, however, seems to be mainly an artifact of the small number of observations for which there are five entrants.

5.3 Gender

Recently, there has been considerable interest in how performance under competition differs by gender and, in turn, how this affects gender distribution in competitive positions. Niederle and Vesterlund (2007) report results of laboratory experiments where subjects performed a maze-solving task. Despite observing no gender differences in terms of skill at doing the task, when a competitive payment system was implemented, women opted out of the competition at vastly greater rates than men. Gneezy, Niederle, and Rustichini (2003) report results of laboratory experiments for a similar task but where entry was not endogenous. They find that increases in the competitiveness of tournament incentives lead to gap in the performance of men and women. In particular, men outperform women at the task when compensation is based on a tournament structure.

Like these papers, our experiments allow subjects to endogenously choose between a competitive compensation structure (the contest) and a fixed outside option. While our contest does not require skill at a specific intellectual task (like maze-solving), performance in the contest does depend on the quality of their investment choice once in the contest—arguably also an intellectual task. Thus, one might expect to find fewer women entering the contest and worse performance among those who entered.

How do women perform after selecting into the contest? Table 5 displays average point earnings of men and women choosing to participate in the contest. In the first 25 rounds of the experiment, we find little evidence of gender differences. However, in the last 25 rounds, a gender difference does emerge—the point earnings of women in the contest are lower than those of males. Using a simple t-test with unequal variances (treating individuals' round earnings as the unit of observation), we find that this long-run difference in performance is significant at the 1% for the small prize treatment and at the 10% level for the large prize treatment.

Table 5. Gender difference in contest performance outcomes
 – Average point earnings by treatment and gender –

		<i>Rounds 1-25</i>	<i>Rounds 26-50</i>
Small Prize	– Female	94.5	101.6
	– Male	98.2	109.7
Large Prize	– Female	113.1	112.1
	– Male	111.5	123.2

Since selection into the contest is endogenous, two different factors may account for the performance gap. Females may enter contests having more entrants or females may make worse investment decisions for a contest of a given size. Table 6 displays the average number of entrants in contests.

Table 6. Gender difference in rivalry of contests entered
 – Average number of entrants in a contest conditional on entering –

		<i>Rounds 1-25</i>	<i>Rounds 26-50</i>
Small Prize	– Female	3.1	2.8
	– Male	3.0	2.6
Large Prize	– Female	3.9	4.0
	– Male	3.8	3.7

Overall, the contests women select into tend to have more contestants than the contests men select into. Using a standard t-test, the differences in the number of rivals in contests entered by men versus women are significant at the 10% level for both treatments in the first 25 rounds, and significant at the 5% [1%] level for the small [large] prize in the last 25 rounds.

How do women end up in contests with more rivals? One possibility is that women decide to enter the contest early and risk being in a contest with too many rivals. An alternative is that women wait to enter but are more optimistic than men about their prospects of winning a contest with a given number of rivals. Table 7 displays the timing of the average entry decision to enter sorted by gender.

Table 7. Gender difference in entry timing decisions
 – Average time of decision to enter (in seconds) –

		<i>Rounds 1-25</i>	<i>Rounds 26-50</i>
Small Prize	– Female	11.0	8.3
	– Male	10.0	8.0
Large Prize	– Female	8.3	5.3
	– Male	8.3	4.2

As the table shows, we observe either little timing differences between men and women (first half large prize, second half small prize), or a tendency for men to enter sooner than women (first half small prize, second half large prize). The differences that occur are statistically significant (at the 5% level for first half small prize and at the 1% level for second half large prize). Thus, it seems that the decision of females to enter more crowded contests is not a product of their moving first and being unpleasantly surprised at the number of rivals.

To examine performance differences by gender for a contest of a given size, we regress investment by individual i in round t on gender controlling for the number of rivals and restricting the sample to rounds 26-50. We perform this analysis separately for the small and large prize treatments. In the large prize treatment, the results reveal essentially no difference in investment behavior. However, in the small prize treatments, we obtain a regression coefficient of 5.3 which is significant at the 1% level. The coefficient indicates that women are considerably *more* aggressive in their rent-seeking expenditures than are men. Since the average rent-seeking expenditures for this treatment are above Nash equilibrium levels, the even greater aggressiveness of females only serves to lower their average payoffs in the contest.

Do women anticipate these performance differences and therefore eschew the contest at higher rates than their male counterparts? The answer is no. Table 8 displays the gender composition for the outside option and the contest. As the table shows, there is no evidence of a selection effect leading women not to participate in the contest. If anything, we observe the reverse—in the first 25 rounds of the large prize treatment, women are statistically significantly more likely to enter the contest at the 5% level.

Table 8: Gender composition in contests
– Fraction of females in a given treatment-choice –

		<i>Rounds 1-25</i>	<i>Rounds 26-50</i>
Small Prize	– Outside option	55.2%	55.7%
	– Contest	56.0%	55.3%
Large Prize	– Outside option	32.2%	36.6%
	– Contest	41.0%	38.3%

To sum up, the performance gap is attributable to women entering more rivalrous contests and then bidding more aggressively than their male counterparts. These performance differences are apparently not anticipated correctly by women in our study since they choose to enter the contest at the same rate as men. The latter result is especially surprising in light of the results of Dohmen et al. (2005) on gender differences in risk preferences.

6. Conclusions

It is often suggested that departures from equilibrium observed in laboratory experiments are likely to be “cured” in practice through the discipline of the market. A common example is someone with intransitive preferences. Even if such a person existed, it is argued, he or she would have little bearing on the market since, thanks to being vulnerable to exploitation in the market, such an individual would have either exited or gone bankrupt. In this paper, we examine how anomalous contest behavior changes when subject to market discipline in the form of endogenous entry.

The authors had differing opinions on the applicability of this conventional wisdom to our setting. Some of us thought that by allowing subjects to endogenously choose whether or not to enter the contest, the “right” people would enter and equilibrium would be restored. Others thought that even if this might not be the case, our frictionless environment, the large number of iterations, and the clarity of the outside option would at least result in a situation where the expected payoffs from the inside option were approximately equal to those of the outside option. We all thought arbitrage opportunities would diminish with experience.

Our results, however, diverged greatly from our priors. Payoff differences between the inside and outside options persisted throughout the experiment and, for the case of the large prize treatment, grew *worse* over time. While the simple comparative statics of the equilibrium

predictions were borne out in the data, the level predictions were not. In the small prize contest, there was persistently too much entry and investment relative to equilibrium predictions. In the large prize contest, these results were reversed.

Is there a way to restore the “market model” and rationalize these findings? If subjects have heterogeneous risk preferences, then such a “rescue” is indeed possible. Suppose that some subjects are risk loving while others are risk averse. In the Small Prize contest, risk loving players enter the contest and, if there are enough of these, there will be excess entry and investment. Since the Large Prize contest admits a greater number of entrants at a profit, the marginal entrant becomes increasingly more risk averse. If the marginal subject is risk averse enough, then one would expect to see too little entry and investment. So far, so good.

Where this rationale runs into problems is in its ancillary predictions. For instance, a number of studies including Dohmen et al. suggest that women are, on average, more risk averse than men. Under our rationale, this would imply that female participation rates in the contest will vary with the size of the prize. However, we showed that participation rates do not vary in this way.

A more direct implication of this rationale is the following: If subjects were presented with the choice of either entering the contest with a small prize or the contest with a large prize (i.e. the outside option was replaced with a contest), then the above results should be *reversed*: risk-loving subjects should be attracted to the large contest and, as a consequence, the marginal agent in the small contest should be *less* risk-averse than that in the large contest. This in turn, would imply too little investment and entry for the small contest and too much for the large prize contest. In a successor to this paper, Morgan, et al. (2008) ran precisely this experiment and found results totally at odds with this prediction.

So what conclusions can we draw? First, the main power of the market is to affect the identity of the marginal individual opting in. In many markets, the marginal individual effectively sets the price in the market. In contest settings, however, the power of the marginal individual is more limited. Rent-seeking expenditures by inframarginal players can strongly affect the cost-benefit calculus of the marginal player thus blunting the force of the market at restoring equilibrium predictions.

The failure of the market to impose the “no arbitrage principle” is, in our view, more troubling. It suggests that, even in a simple setting like a contest, investment opportunities can

persist unnoticed for a very long time. Presumably this is due to the complexity of determining the expected returns to entering the contest. Still, compared to most real world investment opportunities, the determination of contest returns given repeated exposure to the environment seems remarkably simple. Perhaps subjects take a satisficing approach to the entry decision: Once the payoffs from the inside and outside options were “close enough,” there seemed little pressure to erase the remaining gains. It remains for future work to examine more systematically when being subjected to market pressures drives behavior toward equilibrium predictions and when it does not.

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Appendix: Instructions

Welcome! You are about to take part in an experiment in the economics of decision making. You will be paid in private and in cash at the end of the experiment. The amount you earn will depend on your decisions, so please follow the instructions carefully.

It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time, raise your hand and someone will come to your desk to answer it.

The experiment will consist of fifty rounds. In each round you will be matched with the same five other participants, randomly selected from the people in this room. Together, the six of you form a group. Note that you will not learn who the other members of your group are, neither during nor after today's session.

Each round is identical. At the beginning of the round you will be given an initial point balance of 100 points. You will then have up to 15 seconds to decide between option A and option B. If, at the end of that time, you have not made a choice, then the computer will make a choice for you by selecting randomly between the two options. During the 15 seconds, your computer screen will keep you informed of how many group members have chosen each of the options so far, as well as the time remaining for you to make a choice. At the end of the 15 seconds the computer will display your choice and the number of group members choosing each option. Your final point earnings for the round will depend on your choice and the choices of other group members as described below.

At the end of the experiment one of the fifty rounds will be selected at random. Your earnings from the experiment will depend on your final point earnings in this randomly selected round. The final point earnings will be converted into cash at a rate of 10p per point.

Option A

If you select option A, 10 points will be added to your point balance. Your final point earnings for the round will be 110 points.

Option B

[*Small Prize:* If you select option B you will have a chance to win a prize of 50 points.

First, if you are the only group member to select option B, you will automatically win the prize, and 50 points will be added to your initial point balance. Your final point earnings for the round will be 150 points.]

[*Large Prize:* If you select option B you will have a chance to win a prize of 200 points.

First, if you are the only group member to select option B, you will automatically win the prize, and 200 points will be added to your initial point balance. Your final point earnings for the round will be 300 points.]

Second, if more than one group member selects option B there will be a contest among these group members to determine who wins the prize. In this contest the players first decide how many "contest tokens" to buy. Each contest token you buy reduces your point balance by 1 point. You can purchase up to 100 of these tokens. Everybody will be making this decision at the same time, so you will not know how many contest tokens the other players have bought when you make your choice. You will have 30

seconds to make a decision about how many contest tokens to buy. If you do not make a decision within this time limit the computer will make a choice for you by selecting zero tokens.

If nobody buys any tokens, nobody wins the prize. Otherwise, your chances of winning the prize will depend on how many contest tokens you buy and how many contest tokens the other players buy. This works as follows:

A computerized lottery wheel will be divided into shares with different colors. One share belongs to you and the other shares belong to each of the other players (a different color for each player). The size of your share on the lottery wheel is an exact representation of the number of contest tokens you bought relative to all contest tokens purchased. For instance, if you own just as many contest tokens as all the other players put together, your share will make up 50% of the lottery wheel. In another example, suppose that there are four players (including you) and that each of you owns the same number of contest tokens: in that case your share will make up 25% of the lottery wheel.

Once the shares of the lottery wheel have been determined, the wheel will start to rotate and after a short while it will stop at random. Just above the lottery wheel there is an indicator at the 12 o'clock position. The indicator will point at one of the shares, and the player owning that share will win the prize. Thus, your chances of winning the prize increase with the number of contest tokens you buy. Conversely, the more contest tokens the other players buy, the lower your chances of receiving the prize.

[*Small Prize:* If you win the prize 50 points will be added to your point balance. Your final point earnings for the round will be $(100 - \text{the number of contest tokens you bought} + 50)$ points.]

[*Large Prize:* If you win the prize 200 points will be added to your point balance. Your final point earnings for the round will be $(100 - \text{the number of contest tokens you bought} + 200)$ points.]

If another player wins the prize zero points will be added to your point balance. Your final point earnings for the round will be $(100 - \text{the number of contest tokens you bought})$ points.

Now, please look at your computer screen and begin making your decisions. If you have a question at any time please raise your hand and a monitor will come to your desk to answer it.