



## STRATEGIC AND NATURAL RISK IN ENTREPRENEURSHIP: AN EXPERIMENTAL STUDY

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*We report on the results of experiments where participants choose between entrepreneurship and an outside option. Entrepreneurs enter a market and then make investment decisions to capture value. Payoffs depend on both strategic risk (i.e., the investments of other entrepreneurs) and natural risk (i.e., luck). Absent natural risk, participants endogenously sort themselves into entrepreneurial and safe types, and returns from the two paths converge. Adding natural risk fundamentally changes these conclusions: Here we observe excessive entry and excessive investment so that entrepreneurs earn systematically less than the outside option. These payoff differences persist even after many repetitions of the task. With a risky outside option, entry further increases and about one-third of entrepreneurs adopt a passive strategy, investing little or nothing. Finally, we examine an environment where an individual must become an entrepreneur but chooses the stakes over which she will compete. Due to under-entry and under-investment in the high stakes setting, the returns gap grows to over 15 percentage points. A two-factor model incorporating loss aversion and love of winning can rationalize these returns patterns.*

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## 1. INTRODUCTION

Many view entrepreneurship as a fundamental driver of economic growth. As a result, countries routinely subsidize entrepreneurship, especially small-scale ventures. An important determinant of entrepreneurial activity and performance are the risks entrepreneurs face. Thus, much of the entrepreneurship literature seeks to identify characteristics, such as risk preferences, as well as personality traits of would-be entrepreneurs.<sup>1</sup> Wu and Knott (2006) point out that, although entrepreneurs are conventionally risk-averse in responding to demand uncertainty, they are risk-seeking (overconfident) about risks related to their own ability. In this paper, we distinguish between two aspects of risk: Strategic risk is the risk associated with the fact that payoffs are affected by the actions of other entrepreneurs and success or failure depends not only on one's own entrepreneurial decisions, but also on the entrepreneurial decisions of others. It is more difficult to succeed, and entrepreneurial returns are likely to be lower, in crowded markets where competitors invest heavily. Natural risk recognizes that entrepreneurial decisions alone do not determine financial outcomes. Luck also plays a crucial role. Certainly, any aspiring entrepreneur opening up a new restaurant or coffee shop realizes the role that fads, fashions, and other vicissitudes of fortune have on outcomes. We study the impact of these different types of risk on entry into entrepreneurship and subsequent performance.

Controlling for differences in strategic versus natural risk as well as the levels and riskiness of a would-be entrepreneur's outside option is difficult using field data. Thus, we use laboratory experiments to examine how these factors influence entrepreneurship. This has the advantage that we can control for these aspects of the market precisely. It also lets us compare rates of return between entrepreneurship and an outside option including how these returns vary over time. Finally, we also examine the life-cycle of entrepreneurship decisions, that is, how experience affects both entry and investment in entrepreneurial activity.

As far as we are aware, our study is one of the first to investigate different types of entrepreneurial risks using the methodology of laboratory experiments. We do this by examining choices to enter a competitive environment, where we manipulate the risks associated with entering or not.<sup>2</sup> Although we refer to entrants as "entrepreneurs" throughout the paper, this is merely a metaphor for the situations that we sought to approximate via experiments. We labeled choices neutrally when presenting them to subjects, and we cannot know if a subject had in mind the role of entrepreneur. We could equally well have labeled an entrant as a "contestant" because our entrepreneurship game is mathematically equivalent to a Tullock contest. Previous experiments have examined isolated aspects of the entrepreneur's choice. For example there is an extant experimental literature on the decision to enter the market in the first place. In the standard entry experiment, individuals simultaneously decide whether or not to enter and payoffs are determined according to a schedule such that entry payoffs are decreasing in the number of entrants. Equilibrium, which is in mixed strategies, suggests that

1. See, for example, Parker (2009) who offers a survey as well as Caliendo and Kritikos (2012) for an overview of recent developments in this literature.

2. Camerer and Lovo (1999) also study entry into a tournament-like setting, but do not manipulate risks. Several experiments have used a similar competitive environment to us (Tullock contests, Tullock, 1980), and manipulate the riskiness of the contest, but do not examine entry decisions (e.g., Chowdhury et al., 2014; Masiliunas et al., 2012; Fallucchi et al., 2013; Shupp et al., 2013). We summarize these findings on p. 6. See also Bohnet et al. (2008), as well as Eckel and Wilson (2004), for comparisons of strategic and natural risk in trust settings.

entry will occur up to the point where the expected profits of each entrant are equal to the value of the outside option. The main finding in this literature is that theory models of entry perform well in characterizing behavior. Indeed, Nobel Laureate Daniel Kahneman famously quipped that theory worked like “magic” in predicting behavior in these games.<sup>3</sup> Subsequent studies have found slight tendencies toward excess entry when equilibrium predicts few entrants and under-entry when equilibrium predicts many entrants (see Camerer, 2003, for a review). Even so, the fundamental prediction of competitive equilibrium—payoff equalization of entrants relative to the second best alternative—continues to acquit itself nicely.

The central contribution of our paper is to study entry decisions in contexts that more closely mimic those faced by entrepreneurs. Specifically, we modify the standard entry game as follows: Subjects make real-time entry decisions where they observe the number of entrants currently in the market. In our view, this is a closer match to the reality of entry than the usual model where entry decisions are made simultaneously and where the key difficulty is to overcome the coordination problem. Following the entry decision, entrants participate in a Tullock (lottery) contest in which they simultaneously make investments in their businesses. Larger relative investments produce a greater expected share of the profits in the industry; however success is by no means guaranteed. In some treatments, luck plays a key role—here a single winner is determined where the probability of winning is proportional to the relative investments made. In contrast, in our Shares treatment, the link between payoffs and investment is more direct. Each entrant enjoys a fraction of industry profits in proportion to their investments.

We also vary the nature of the outside option. We conduct treatments where the outside option is deterministic. But in practice the alternative to not entering a market may be inherently risky. Indeed, often the second best use of an entrepreneur’s time and talent is undertaking another, different startup. To capture these differences, we also report the results of treatments where the payoff from the outside option is stochastic (Coin Flip treatment) and where the outside option represents an alternative entrepreneurial opportunity with different stakes (Dual treatment).

Together, our treatments shed light on the role of strategic versus natural risk on entry decisions and post-entry performance. They also allow for a more nuanced view of the fundamental prediction of competitive equilibrium—the equalization of the value of inside and outside options—when outside options have both environmental and strategic risk as well. Our experiments are designed to come closer in bridging the gap between the simple and elegant theory of equilibrium entry with the messy reality of real world entry decisions.

We begin by reproducing the results from standard entry experiments (Baseline treatment). Consistent with earlier studies, we observe payoff equalization between entrepreneurship and the fixed outside option in a setting where “entrepreneurship” merely amounts to entering a market and where each entrepreneur earns a fixed payoff which is declining in the number of entrants. Moreover, specialization naturally arises: some individuals repeatedly choose the entrepreneurship path whereas others follow a different path and select the outside option.

Our main findings are:

In the Baseline experiment, entrepreneurs’ return on investment converges to the outside option from below. This conclusion is unaltered with the addition of *strategic* risk. When entrepreneurship involves *natural* risk as well, its return

3. Kahneman (1988).

persistently lags the outside option, even after 50 periods. The returns gap is widest in the Dual treatment, where the high stakes market produces returns exceeding low stakes by more than 15 percentage points.

Entrepreneurial entry increases with the addition of natural risk, and increases still more when the outside option exhibits natural risk as well. Natural risk also increases investment although when this risk is added to the outside option, about one third of entrepreneurs adopt a passive strategy, investing little or nothing in their ventures.

Entry occurs rapidly absent natural risk, but slows when this risk is added, exhibiting a bimodal structure where the first entry occurs either extremely early or much later in the entry stage.

Despite natural risk, the high stakes setting exhibits less entry and investing than the risk-neutral prediction. Simultaneously, the low stakes setting exhibits excess entry and investment; thus accounting for the extreme difference in returns. This pattern persists even with considerable subject experience.

No single factor such as mistakes or risk aversion, can explain the data patterns; however, the combination of love of winning and loss aversion can rationalize key features of the data including the persisting gap in returns.

Our most important finding is the failure of competitive equilibrium to equalize returns. Our data resemble many real-world patterns where entrepreneurial returns systematically lag employment alternatives albeit with spectacular individual successes.<sup>4</sup> Importantly, the experiments isolate a key driver—natural risk—leading to this behavior. These patterns are not explained by risk-seeking, but can be explained by an intrinsic love of winning together with usual levels of loss aversion.

Our findings also shed light on the experimental literature on contests.<sup>5</sup> The main finding in this literature is that there is excess investment in these contests when competitors are exogenously chosen. We allow for endogenous selection as well as varying the payoff structure on the contest. A key finding is that, by eliminating natural risk from the contest, overinvestment moderates significantly and indeed, payoffs are close to equilibrium predictions. This result is consistent with those from other recent contest experiments using an exogenous number of contestants that look at the effect of removing natural risk from the contest (Chowdhury et al., 2014; Fallucchi et al., 2013; Shupp et al., 2013). However, the result is at odds with Cason et al. (2010), who performed a real effort experiment where the outside option consists of piece rate payments and the inside option is either a shares or winner-take-all contest. They find that the shares (proportional prize) contest leads to greater entry but no difference in individual performance (the analog to investments in our setting) relative to a winner-take-all scheme. They suggest that differential entry is the result of skill differences among individuals. Perceived skill differences appear less pronounced in our setting, perhaps explaining the reversal in entry propensity.

The results from our Dual treatment relate to Mazzeo (2004) and Nguyen-Chyung (2011), who highlight how changes in natural risk affect decisions about the type of

4. See, for example, Bloomberg Business Week (2003).

5. See, for example, Millner and Pratt (1989, 1991), Shogren and Baik (1991), Davis and Reilly (1998), Anderson and Stafford (2003), Potters et al. (1998), Fonseca (2009), Herrmann and Orzen (2008), or Morgan et al. (2011). Dechenaux et al. (2013) provide a recent survey of this literature.

entrepreneurship to pursue. In particular, we find that when the stakes from winning the market increase (i.e., entrepreneurship becomes riskier), individuals scale back their entry and investment choices compared to equilibrium.

The persisting gap in returns to entrepreneurship compared to the outside option, and our explanation, are consistent with the seminal paper of Hamilton (2000). He also observes negative returns to entrepreneurship and traces this to non-pecuniary benefits.

The remainder of the paper proceeds as follows. Section 2 describes the experiment as well as the rationale for each of the treatments and provides theoretical benchmarks. In Section 3, we present the results of the experiments in terms of entry and investment decisions. We pay particular attention to the dynamics of these choices—as we will see, experience plays a key role. In Section 4, we explore various possible explanations for the patterns in the data, and reject all single factor explanations. We show that a two factor model containing loss aversion and love of winning can explain the main patterns in the data both qualitatively and quantitatively. Section 5 concludes.

## 2. EXPERIMENTAL DESIGN, PROCEDURES, AND PREDICTIONS

We conducted multiple sessions of the experiment at the University of Nottingham using subjects recruited from a campus-wide distribution list of undergraduates. No subject appeared in more than one session.

At the beginning of each session, we seated subjects at computer terminals and gave them a set of instructions, which were read aloud.<sup>6</sup> A monitor privately dealt with any questions, and we permitted no communication between subjects. Choices and information were transmitted via the computer network. Before the decision-making part of the experiment began, we randomly divided subjects into groups of six, and these remained fixed for the entire session. Subjects knew this but did not know with whom they were grouped. Subjects earned points during the decision-making part of the session, consisting of 50 rounds. We randomly chose one of these rounds and paid subjects in cash according to their point earnings from it using an exchange rate of £0.10 per point. Sessions were 50 to 75 minutes long, and subjects earned between zero and £28.50, averaging £10.81 (approximately US\$20 at the time of the experiment).

Subjects began each round with 100 points and chose between two options labeled “A” and “B,” where “A” corresponds to the outside option and “B” corresponds to the decision to become an entrepreneur. Subjects saw a timer, counting down 15 seconds, during which they were to make this choice. Subjects knew that if they did not choose within the allotted time, the computer chose for them at random.<sup>7</sup> During this time a subject saw how many members of her group chose each option and how many had yet to choose. Once a subject had chosen, she could not reverse that decision. Choice information was anonymous—a subject could only see how many members there were in each category, but not their identity. We did this to minimize the ability of subjects to build reputations.

We varied the consequences from choosing A or B across experimental treatments to study the effects of different types of risk and different outside options. Each session featured only a single treatment, so our identification is between subjects. In each

6. See Appendix A for the instructions used in the experiment.

7. Once the timer had counted down from 15, the computer displayed “0” for one second before it made the random choice. Thus, the effective time limit for subjects was in fact 16 seconds. About 2.5% of decisions were made by the computer. Our results are unaffected by the inclusion or exclusion of these data.

case, the instructions explained the relevant consequences of each choice using neutral language.

Our Baseline treatment replicates earlier laboratory experiments on entry. Earnings depended only on the number of entrants, and there were no post-entry decisions. In this treatment, the outside option yielded 10 points whereas each of  $n$  entrepreneurs earned  $50/n^2$  points (rounded to integers). Subjects learned the payoffs of all group members after each round.

The Shares treatment examines whether introducing post-entry choices, but not natural risk, alters entry behavior. The outside option is unchanged in this treatment, but we paid entrepreneurs based on their investments, which were made simultaneously, after the entry phase and knowing the number of entrepreneurs in the market. Specifically, entrepreneur  $i$  investing  $x_i$  (taken from her initial endowment) earned a share  $x_i / \sum x_j$  of a 50 point prize (rounded to integers). At the end of each round, all subjects in the group, entrepreneurs or not, were informed about all payoffs, the investments of each entrepreneur, and also reminded of the fixed outside option.

The entrepreneurship subgame with  $n$  entrepreneurs has a unique symmetric equilibrium characterized by an investment of <sup>8</sup>

$$x^*(n) = \frac{50(n-1)}{n^2}.$$

Given this equilibrium investment behavior, the expected profit from entrepreneurship when there are  $n$  entrants is  $\pi^*(n) = 50/n^2$ —the same as in the Baseline treatment. Consequently, there is no predicted difference in the entry phases of the Shares and Baseline treatments. Two entrepreneurs should enter and then earn 13 points each.

The Winner-Take-All treatment adds natural risk to the entrepreneurship environment. This treatment reflects the idea that real-world success depends on a combination of investment and luck. This treatment is identical to Shares save for the fact that a single entrepreneur received the entire 50 points and the others nothing. The probability of winning depended on the relative investments, that is,  $x_i / \sum x_j$ . To determine the winner a computerized animated lottery wheel was used. If exactly one entrepreneur chose to enter, that person received the prize automatically without having to invest.

Under risk neutrality, this treatment is isomorphic to Shares. If agents are risk averse, then they will require compensation for entrepreneurship risk with the resulting prediction that entrepreneurial returns should exceed the outside option.

The Coin Flip treatment reflects the fact that, in reality, non-entrepreneurship employment also contains risks. Of interest are the effects of varying the risk of the outside option, without changing its average return, on entry into entrepreneurship. In this treatment, the outside option involved a lottery in which the subject, with a 50–50 chance, either won 35 points in addition to the initial endowment or lost 15 points. The outcome of this lottery was determined and visualized with a computerized coin toss. In all other respects the Coin Flip and the Winner-Take-All treatments were identical. Also as in the other treatments, all subjects observed both the payoffs of the entrepreneurs and non-entrepreneurs (in this case: either +35 or –15).

We picked the two coin-flip outcomes so that the expected return was 10 points and the variance of the coin-flip payoffs was identical to the variance of payoffs under entrepreneurship in the risk-neutral equilibrium.

8. See Szidarovszky and Okuguchi (1997) for proof of uniqueness.

Rarely is it the case that there is only one opportunity available to a would-be entrepreneur. Evaluating from a set of opportunities is critical to entrepreneurship. The profitability of these opportunities will, of course, vary depending on how many others pursue them as well. To capture this, we conducted a Dual Market treatment, where the outside option was *another entrepreneurship game*. Here, option A is a winner-take-all game with a prize worth 200 points whereas option B is a winner-take-all game with a prize worth 50 points. Options A and B represent high and low stakes entrepreneurship opportunities, respectively. Under a risk-neutral equilibrium, if  $n$  entrepreneurs choose the 50-point contest their expected payoff is  $50/n^2$  points each, whereas the expected payoff for the remaining entrepreneurs in the 200-point contest is  $200/(6-n)^2$  points. The expected payoffs are equalized, and equal to 12.5, when  $n = 2$ . With two entrepreneurs in the 50-point contest and four in the 200-point contest switching to the other contest would leave any entrepreneur worse off. Under any other distribution of entrepreneurs between the two contests, however, switching is always payoff-improving for individuals in one of the two groups.

So far we discussed the predictions for risk-neutral entrepreneurs only. In Appendix B, we offer a theory of continuous time entry under general risk- or loss-averse preferences. The theory predicts both the amount and timing of entry. Our main results are:

- (1) Regardless of preferences, exactly two individuals enter in the Baseline and Shares treatments. Entry occurs at the earliest possible moment.
- (2) In the Winner-Take-All treatment, exactly two individuals enter. If entrepreneurship is *contested* (i.e., more than two people would like to enter following the first entrant), then entry occurs immediately. If not, then entry can occur at any point in equilibrium.
- (3) Under the Coin Flip and Dual treatments, there are at least two entrants in the small-prize contest. If this market is contested, entry occurs immediately.

Altogether 270 subjects participated in the experiment, 54 in each of the five treatments. We ran a total of 15 sessions, three in each treatment, 18 subjects per session. Each session was comprised of three groups of six subjects, yielding a total of 9 statistically independent observations per treatment.<sup>9</sup> Table I summarizes experimental design.

### 3. RESULTS

#### 3.1. OVERVIEW

We describe aggregate results using the metrics of the number of entrants and normalized investment. Normalized investment is simply the difference between a subject's investment and their expected value/share of the prize under symmetric investment behavior. Because entrepreneurs had an endowment of 100 tokens, the negative of this statistic is the return on investment (hereafter ROI, and expressed as a percentage) from entrepreneurship. The outside option yields a 10% return in all treatments except Dual where also under the outside option investments needed to be undertaken. Competitive equilibrium implies that returns on investment under the two paths should be equal;

9. In one of our Dual Market sessions a technical problem resulted in our losing the last three rounds of data from one group and the last two rounds of data from the other two groups.

**TABLE I.**  
**EXPERIMENTAL TREATMENTS**

Treatment	Outside Option ("Option A")	Entrepreneurship ("Option B")	Equilibrium # Entrepreneurs	Experimental Groups	Inside Option Risk		Outside Option Risk	
					Strategic	Natural	Strategic	Natural
Baseline	10 points	Fixed payments declining in number of entrepreneurs	2	9	No	No	No	No
Shares	10 points	50-point proportional-shares contest	2	9	Yes	No	No	No
Winner-Take-All	10 points	50-point winner-take-all contest	2	9	Yes	Yes	No	No
Coin Flip	50-50 chance of +35 or -15 points	50-point winner-take-all contest	2	9	Yes	Yes	No	Yes
Dual Market	200-point winner-take-all contest	50-point winner-take-all contest	2	9	Yes	Yes	Yes	Yes

**TABLE II.**  
**ENTRY AND INVESTMENT BEHAVIOR—ALL ROUNDS<sup>10</sup>**

Treatment	Entry		Normalized Investment Investment – (Prize/Entrants)	
	Predicted	Actual	Break-Even	Actual
Baseline	2	2.5***	–	–
Shares	2	2.4***	–10	–4.1***
WTA	2	2.6***	–10	–0.4***
Coin Flip	2	3.6***	–10	–2.4***
Dual (Small)	2	2.4***	–10	–3.1***
Dual (Large)	4	3.6***	–10	–17.3*

hence the theory prediction of –10 (i.e., a 10% ROI from entrepreneurship), independent of the number of entrants.

Table II presents the results of these two metrics, averaged over all rounds of the experiment and delineated by treatment. For comparison, we also report the equilibrium predictions. The stars after each metric denote the results of Fisher-Pitman permutation tests comparing the empirical outcome to the theory prediction. Stars denote significance at the 1, 5, and 10% levels for three, two, and one star, respectively.

Table II shows considerable excess entry, which is most striking under the Coin Flip treatment. The exception to this pattern occurs in the Dual treatment with a large prize. Excess entry is not, *per se*, disastrous to the returns from entrepreneurship provided that subjects scale back investments sufficiently. However, Table II shows that this is not the case. Returns from entrepreneurship fall well below the 10% threshold. The Winner-Take-All treatment leads the way providing a measly 0.4% return. On the other hand, excess returns can be found in the Dual (Large) treatment where entrepreneurship

10. To obtain *p*-values we use a two-sided Fisher-Pitman permutation test for paired replicates at the level of statistically independent groups for both entry as well as normalized investment. We test entry against the Nash equilibrium prediction of two entrants in the small prize contest and four in the large prize contest and normalized investment against break-even normalized investment of -10. Note that we will use the same test procedure throughout this section when we statistically compare observed behavior and theoretical benchmarks.



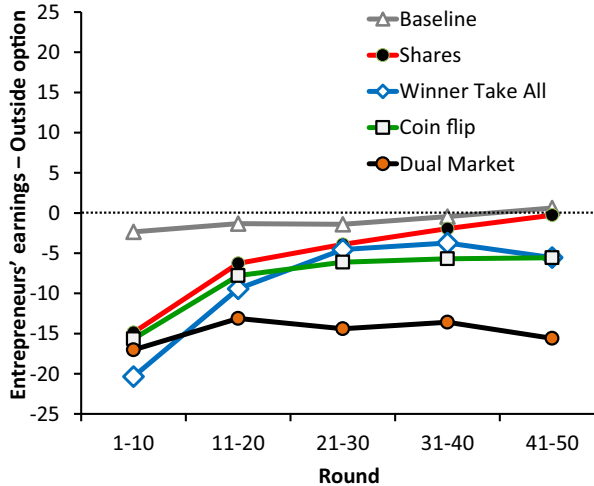


FIGURE 1. PAYOFF DIFFERENTIALS—ALL TREATMENTS

yields a whopping 17.3% ROI. As the stars on the table show, these discrepancies from the theory predictions are all statistically significant at conventional levels.

### 3.1.1. CONVERGENCE TO COMPETITIVE EQUILIBRIUM

The fundamental prediction of competitive equilibrium is that returns from entrepreneurship should equal those under the outside option. Although Table II showed this was not the case, this could reflect a transition to competitive equilibrium as subjects learned how to play the game. That is, a weaker requirement is simply that payoffs *converge* to the competitive equilibrium prediction. For each treatment, Figure 1 plots the returns differential, the difference between the ROI under entrepreneurship and that under the outside option. A negative number indicates superior returns from the outside option whereas a positive number indicates superior returns from entrepreneurship. The dotted line at zero represents the competitive equilibrium prediction. Each data point represents the average payoff difference over a ten round period.

As the figure shows, payoffs from entrepreneurship lag those from the outside option in early rounds regardless of the treatment. This stems from both excess entry and investment. In the Baseline treatment, the returns differences start small and soon converge to equilibrium. The Shares treatment also converges by round 40 despite a 15% returns differential at the start of the experiment. However, these are the only treatments to converge. For all other treatments, we can reject the null hypothesis of no payoff difference over the last ten rounds of the experiment at conventional levels, again using a Fisher–Pitman permutation test.

Treatments also display differing trends. For instance, the Coin Flip and Winner-Take-All treatments approximately track the Shares treatment through round 30 and then stall out at a negative returns differential. Indeed, payoff differentials worsen in the last ten rounds under Winner-Take-All. The Dual treatment shows no trend whatsoever. Initially, the returns under the large prize (the equivalent of the outside option under the other treatments) vastly exceed those under the small prize, offering about a 17% higher return, and remain at approximately this level throughout the experiment. Thus, we see no evidence of convergence to equilibrium when entrepreneurship contains natural risk.

**TABLE III.**  
**ENTRY AND INVESTMENT BEHAVIOR—LAST 10 ROUNDS**

Treatment	Entry Predicted	Normalized Investment Investment-Prize/Entrants		
		Actual	Break-Even	Actual
Baseline	2	2.3***	–	–
Shares	2	2.1	–10	–9.5
WTA	2	2.5***	–10	–4.4*
Coin Flip	2	3.9***	–10	–4.6***
Dual (Small)	2	2.6***	–10	–5.8***
Dual (Large)	4	3.4***	–10	–20.8**

Table III provides additional detail for how choices change as subjects gain experience. It reports the same statistics as Table II but restricts attention to the last ten rounds of the experiment.

As with Table II, we overwhelmingly reject the theory predictions for entry save for the Shares treatment. Moreover, entry does not move in a consistent direction either—relative to entry over all rounds, late round entry falls modestly in Shares and Winner-Take-All but increases in Coin Flip and Dual (Small). Strikingly, Dual (Large), which offers exceptionally good returns, sees a reduction in entry in late rounds compared to all rounds.

Normalized investments, however, display more consistent patterns. In Shares, they converge to something close to equilibrium. In all other treatments normalized investments differ from equilibrium, but are now somewhat closer to the returns from the outside option. Subjects seem to learn to moderate their investments in the face of excess entry into entrepreneurship.

### 3.1.2. TIMING OF ENTRY

In addition to the number of entrants, our continuous time environment allows us to examine the timing of entry decisions. In Figure 2, we plot kernel densities of the time at which the first and second person entered into entrepreneurship. The first entrant's timing is shown as a dashed line whereas the timing of the second entrant is depicted as a solid line.

The theory predicts that, under contestability condition, all entry occurs near the start of each round. Early entry stems from the fact that the pecuniary expected payoffs from entrepreneurship slightly exceed the outside option owing to integer constraints. When this difference is precisely observed by players, as in the Baseline treatment, the predicted entry forces occur. As the figure shows, the first entry occurs very close to the start of the game as does subsequent entry. The median time of the first and last entry is a mere 0.31 and 0.56 seconds, respectively, under Baseline.

Adding the investment phase breaks the clear link between entrepreneurship payoffs and entry, which attenuates the force of early entry incentives. If subjects do not anticipate systematic payoff improvements from entrepreneurship over the outside option, the rationale for early entry disappears. Because the rate of return from entrepreneurship lags the outside option, there is no empirical rationale for early entry.

11. Kernel Density estimates of the timing of the first (dashed) and second (solid) entry decision. Kernel = Epanechnikov, Bandwidth = 1.

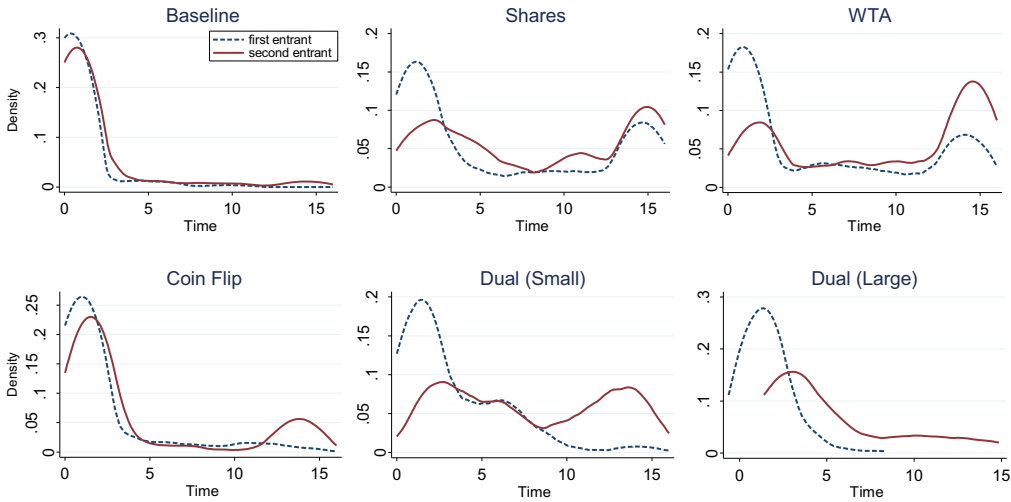


FIGURE 2. TIMING OF FIRST AND SECOND ENTRY (ROUNDS 41–50)<sup>11</sup>

This explains why one does not see early entry, but does not explain the U-shaped pattern.

One possible explanation takes its inspiration from clock games (Brunnermeier and Morgan, 2010)<sup>12</sup>. Entry in these games accounts for both pre-emption and waiting motives. Because only a limited number of individuals can enter, early entry is advantageous; however the payoffs from successful entry are higher the later the entry, which encourages waiting. The analogy is inexact. There are no exogenous limits on entry in our game, nor does the timing directly affect payoffs. As a result, theory predictions turn entirely on the number of individuals who perceive the equilibrium payoffs from entry as exceeding the outside option. When sufficiently many individuals see the situation this way, theory predicts early entry. When few individuals see the situation this way, any pattern of entry, including late entry, is consistent with equilibrium.

Clock games also predict that, when entry is transparent, that is, observed by all the players, herding will occur immediately following the first entry. The reason is that, in clock games, all players see entry as superior to the outside option. This is not the case in our setting, nor do we see herding. Following the first entry, the median second entrant waits roughly 1.8 seconds in all treatments exhibiting natural risk. Although this time appears short, it represents a conscious delay on the part of the second mover in light of psychometric estimates that place human reaction time for tasks of this nature at roughly 0.5 seconds.<sup>13</sup> Similarly, the median last entrant delays for around 5 seconds before entering.

The selection of late entry, we suspect, arises from risk considerations. As usual, equilibrium in our model presumes that players perfectly anticipate the final number of entrants and resulting payoffs. This is, of course, not true in reality. By moving late,

12. Formally, clock games are continuous time exit games with increasing payoffs over some interval, whose termination point is unknown by all players. Once  $k < n$  individuals exit, payoffs collapse to  $\pi_0$ . Those who have not exited receive this payoff. If fewer than  $k$  players have existed by some uncertain end time  $T$ , payoffs collapse exogenously and again those remaining receive this payoff. Each player receives a private signal about  $T$  at a random time  $t_i$ . In equilibrium, individuals wait for some fixed time,  $\tau$ , after receiving the signal, and then exit. The waiting time balances the marginal gains from waiting with the risk of payoff collapse.

13. See Welford (1980).

**TABLE IV.**  
**GINI COEFFICIENTS**

Treatment	All Rounds	Rounds 1–10	Rounds 41–50
Baseline	0.61	0.51	0.83
Shares	0.61	0.54	0.81
Winner-Take-All	0.52	0.51	0.66
Coin Flip	0.42	0.44	0.49
Dual Market	0.48	0.47	0.63

subjects perhaps gain more precise estimates of the total number of entrepreneurs or have less to fear out of equilibrium events where there are “excess” entrants. This reduces the strategic risk associated with late entry and perhaps leads to its selection.

To summarize, the U-shaped pattern we observe for the timing of initial entry (especially in the Shares and Winner-Take-All treatments) likely reflects an informational motive not present in any equilibrium theory. In addition, unlike clock games, there is no exogenous limit on entry in the entrepreneurship game, even though massive entry is ruinous for payoffs. This creates a cautionary motive explaining the even more diverse timing of the second entrant.

### 3.2. WHO BECOMES AN ENTREPRENEUR?

We previously saw that entry and investment varied across treatments; that is, depending on the combination of strategic and natural risk associated with the inside and outside options, subjects were more or less likely to pursue entrepreneurship and to invest aggressively. We now examine individual level factors driving entry and investment.

Of course, to study individual factors requires that, to some degree, individuals sort themselves into entrepreneurial and non-entrepreneurial types. Much of the extant entrepreneurship literature, concerned as it is with identifying an “entrepreneurship gene,” presupposes such a sorting, but cannot run the counterfactual experiment of exposing the same entrepreneur to the same set of stimuli and seeing whether he or she still pursued the same path. Our experiment, however, makes such an analysis possible. Table IV displays Gini coefficients of entrepreneurship—the fraction of entry decisions accounted for by each of the subjects—for each of the treatments. As with a standard Gini coefficient, a value equal to zero indicates equality—all subjects are equally likely to pursue each path. A coefficient equal to one denotes the opposite extreme—subjects always choose a single path to the exclusion of the other. The three columns of the table show how this measure of specialization varies over the course of the experiment.

As the table shows, experience tends to lead subjects to more defined roles. In every treatment, the Gini coefficient associated with the first 10 rounds of the experiment is lower than for the last 10 rounds.<sup>14</sup> This suggests that, at least initially, subjects experiment with different roles before determining the most suitable. Even though subjects exhibit less variability in roles over time, they continue to switch, even in the final 10 rounds of the game.

14. Formally, a permutation test reveals that the difference in Gini coefficients between the first and last 10 rounds of the experiment are all significant at the 5% level save for Coin Flip, where there is no significant difference.

Focusing on rounds 41–50, one can roughly group specialization into three tiers. Treatments where natural risk is absent (Baseline and Shares) have the highest level of specialization. As we introduce natural risk, specialization falls. The Dual and Winner-Take-All treatments represent an intermediate level of specialization whereas the Coin Flip treatment displays the lowest level of sorting.<sup>15</sup> With the introduction of natural risk, roles might well change depending on whether a subject has been lucky or not. In the individual level analysis below, we show that luck is, indeed, an important driver to the entrepreneurship decision.

The degree of specialization shown in Table IV suggests that it is fruitful to examine the key drivers of entrepreneurship. The extant literature offers guidance as to which explanatory variables to include. Obviously, skill at the entrepreneurship task is a critical factor. We examine skill in several different ways: by direct measurement, as well as by having a background more suited to the task of playing the entrepreneurship game. Our direct measure consists of calculating the *expected* payoffs from entrepreneurship over the first 25 rounds of the experiment for each individual.<sup>16</sup> This allows us to capture decision quality relatively untainted by the luck element of some of the treatments.

Our indirect skill measures reflect the quantitative nature of the investment task. We include a dummy variable “numerate” which equals one if the subject indicated a major in a field where mathematics or statistics are widely used. Likewise, business or economics training would seem to be helpful in investing, so we include a dummy for these majors labeled “business/econ.” Appendix C contains the list of major fields we included in these two measures.

As hinted above, luck might also play an important role. We measure luck as the difference between expected payoff and actual payoff from entrepreneurship in a given round. In Coin Flip, we also construct an analogous luck variable for a success in the outside option.

Our dependent variable is the decision to become an entrepreneur taken in each round. We perform a probit analysis where we explain entry by skill, luck lagged by one round, and demographic variables. Because we constructed the skill variable using rounds 1–25, our analysis covers rounds 26–50 only. We compute separate estimates for each treatment; thus, allowing for the possibility that explanatory variables like female might differ depending on the risk structure of the environment. Finally, to control for possible autocorrelation and heteroskedasticity, our hypothesis tests use robust standard errors clustered at the subject level. Table V reports the results of this analysis where we report coefficient estimates as marginal effects.<sup>17</sup>

Using our direct measure, greater skill at the task strongly predicts entrepreneurship. We can interpret the regression coefficients on skill as the percentage increase in the probability of becoming an entrepreneur given a one unit increase in skill. To put this increase in skill in perspective, the interquartile range of the skill measure is about

15. Formal statistical tests support this division. Treating each group as the unit of observation and performing a permutation test on rounds 41–50 reveals that Baseline and Shares are statistically indistinguishable although both are different from Winner-Take-All and Dual at the 10% level. Similarly, Dual and Winner-Take-All are statistically indistinguishable, but Coin Flip differs from Winner-Take-All at the 10% significance level.

16. Using a similar performance-based skill measure, Nguyen-Chyung (2011) shows that real estate agents who sold more houses are more likely to pursue entrepreneurship than those who were less successful.

17. Owing to concerns about correlation between numerate and business/econ, we also performed the analysis twice separately including only one of these variables. The results are little changed compared to Table V.

**TABLE V.**  
**SKILL, LUCK, AND SELECTION INTO ENTREPRENEURSHIP**

Treatment	Skill	Numerate	Business/Econ	Luck Inside	Luck Outside	Female
<b>Baseline</b>	0.131***	0.08	0.16	–	–	0.02
<b>Shares</b>	0.018*	0.12	0.05	–	–	0.09
<b>Winner-Take-All</b>	0.011***	–0.00	–0.27***	0.006***	–	0.13*
<b>Coin Flip</b>	0.011***	0.10	–0.07	0.002**	0.000	–0.10*
<b>Dual Market</b>	–0.010***	–0.06	–0.10	0.002**	–0.001***	0.00

10 units. Thus, a subject at the top of this range is about 131% more likely to enter in the Baseline treatment compared to a subject at the bottom of the range.

Risk, whether natural or strategic, severely attenuates this connection. Compared to Baseline, the introduction of strategic risk in Shares produces a sevenfold drop in the influence of skill. Compared to Shares, the introduction of natural risk further dilutes the influence of skill, cutting it almost in half. Nonetheless, skill still matters in a Winner-Take-All setting, producing an 11% difference in entry probability over the interquartile range.

One might question whether a skilled player in the investment game is indeed skillful overall because entry earns negative returns on average. This, however, overlooks the variability in entry payoffs, which depend, in part, on skill. Thus, a highly skilled subject choosing entrepreneurship will not necessarily receive the average payoff. To illustrate this, consider the average payoff from entrepreneurship of “highly skilled” as well as “non-highly skilled” subjects in the Winner-Take-All treatment. Define a “highly skilled” entrepreneur as a subject who on average at least broke even in the first 25 rounds of play (i.e., had a payoff greater or equal to 110 upon entry). Using this definition the average payoff from entrepreneurship of “highly skilled” subjects in the last 10 rounds equaled 113.9 whereas it equaled 103.5 for “non-highly skilled” subjects. Statistical tests confirm that “highly-skilled” entrepreneurship yields comparable payoffs to the outside option of 110.

Finally, notice that the skill coefficient changes signs in the Dual treatment, indicating that individuals who are more skilled are more likely to choose the outside option—the large prize entrepreneurship game.

Indirect measures of skill have much less predictive power and, where significant, are associated with less entry. In particular, our numerate measure is never statistically significant though the coefficient estimates indicate the more numerate are more likely to enter (save for the Winner-Take-All treatment). The business/econ measure suggests a negative association of this background with entrepreneurship. Indeed, in the Winner-Take-All treatment, a business or economics major is 27% *less* likely to pursue entrepreneurship than someone without such training. Given that the ROI on entrepreneurship is lower than the outside option in this treatment, individuals having this background, though more skilled at the investment task, might also be better able to recognize that entrepreneurship simply does not produce a return sufficient to expose oneself to natural risk.

Luck also matters although the marginal effects appear to be much smaller than the influence of skill. This, however, is deceiving. Although there is a 10-point difference across the interquartile range of skill, there is a 50-point swing between being lucky and unlucky in the market. Thus, the luck coefficient in the Winner-Take-All treatment

**TABLE VI.**  
**FRACTION OF LOW BIDS BY ENTRANTS (ROUNDS 41–50)**

Shares	WTA	Coin Flip	Dual <sup>20</sup>
0.048	0.076	0.344	0.102

shows that lucky entrepreneurs are about 30% more likely to enter in the next period compared to unlucky competitors.<sup>18</sup>

The persistent effect of luck is only present in circumstances where skill also plays a role. When luck is completely outside of a subject's control, as in the outside option of the Coin Flip treatment, it has no bearing on future choices.

Finally, we consider gender. Niederle and Vesterlund (2007) found that, in real effort games, women avoided a tournament payoff structure, as in our entrepreneurship game, even controlling for skill. Furthermore, many studies find women to be more risk averse than men. Then again there is evidence that women exert higher efforts in contests and bid more in different types of auctions than men (see Price and Sheremeta, 2015, and references therein). In our data gender seems to have no consistent predictive power across treatments. In the treatments with no natural risk (Baseline, Shares) there is no gender effect at all. In the Winner-Take-All treatment the coefficient on female indicates that women are 13% more likely to enter the contest compared to men, whereas in Coin Flip they are 10% less likely to enter. Note, however, that the coin flip option associated with staying out is, overall, the riskier alternative in this treatment (as measured by the standard deviation of payoffs and given the actual play in the coin flip contests). Thus, in both treatments, women are systematically pursuing the higher risk activity. Yet they do not follow this pattern in the Dual treatment. Here, despite higher risk and return, they do not systematically favor the high-stakes environment.

### 3.3. PASSIVE INVESTING

Having examined entry in detail, we now turn to investment strategies. A striking aspect of the data is the large fraction of subjects that select entrepreneurship and then make zero or trivial investments to secure the prize. We define a "low bid" as investing 4 or less.<sup>19</sup> Several factors might motivate such investment strategies: they could be an attempt to signal to others to coordinate on a collusive outcome; they might reflect a strategic judgment that returns are highest under modest investments; or they could represent a flight from risk. Table VI displays the fraction of low bids by treatment occurring in the final ten rounds of each session.<sup>20</sup>

Regardless of treatment, about 5% or more of choices entail low bids. Adding risk to the outside option more than doubles this amount. Because these statistics are for the last ten rounds (the fractions are similar for earlier rounds), we can discount collusive explanations. In the Winner-Take-All treatment, low bidding has some merit

18. Even though success or failure is drawn independently in each round, responding to this cue is not necessarily irrational. Because success is a combination of luck and skill, a subject experiencing success may attribute this outcome, in part, to skill, in which case increased entry is rational. An analogous argument holds for decreased entry following failure.

19. Our conclusions do not change if a somewhat lower or higher threshold for low versus high bids is used.

20. In Dual we consider the fraction of low bids of both small- and large-prize contest entrants.

as an investment strategy, earning more, on average, than the average investment made by subjects. In Coin Flip, it breaks even whereas in all other treatments, low bidding worsens payoffs—quite dramatically in the high stakes Dual treatment. Among low bids, zero bids do even worse. Thus, it seems debatable that this represents a winning investment strategy.

This leaves flight from risk as the best explanation for this pattern. This might seem problematic for treatments like Winner-Take-All where the outside option is riskless, but one needs to account for uncertainty about the number of entrants. For instance, an individual might enter a winner-take-all contest early, anticipating that there will be one or two additional entrants. If unexpectedly many individuals enter, a risk or loss averse individual might be better served by “giving up,” that is, submitting a low bid, rather than making the aggressive bet needed to be successful.

There is some evidence that this is the case. Conditional on submitting a low bid in the last 10 rounds, an entrant comes in 3.5 seconds following the start of the round, on average, and is in a group consisting of 3.1 entrepreneurs, on average. By contrast, the average entrant choosing a regular investment comes in 8.3 seconds after the start of the game and is in a group consisting of 2.7 entrepreneurs, on average.

#### 4. EXPLAINING THE FINDINGS

Compared to standard risk-neutral theory, our results present a number of puzzling findings. Although the theory works well for the Baseline and Shares treatments, it fails in various ways for the other treatments. Specifically, except when the winning prize is very large, there is excess investment and entry. When the outside option is random, additional entry occurs followed by passive investment. Finally, when the winning prize is large, there is insufficient entry and investment relative to the Nash prediction. A successful amendment to the model should explain all of these deviations from the theory. We study six likely possibilities: love of winning, risk preferences, loss aversion, over-optimism, preferences for skewness and mistakes. None of these explanations can explain the above patterns alone. Combining two explanations, love of winning and risk/loss aversion, can explain most of the patterns in the data. We illustrate this by calibrating parameters of the amended model to the data and comparing the predicted and actual entry and investments across treatments.

##### 4.1. LOVE OF WINNING

The standard theory predicts that individuals derive payoffs in proportion to the prize from winning the entrepreneurship game. There is, however, evidence that the mere act of winning a competition provides rewards sufficient to induce individuals to invest. For instance, Sheremeta (2010) reports substantial participation in a lottery contest experiment with no prize. Such activity seems to indicate that individuals have a strong intrinsic love of winning motive. Similarly, Herrmann and Orzen (2008) find evidence consistent with a substantial love of winning motive in two-player contests. Casual introspection, from observing the emotional reaction of children from winning or losing board games to the intensity of intramural athletic competition in adulthood, suggests pure love of winning is a powerful motivator.

We can easily incorporate love of winning by increasing the prize by a fixed amount in settings having a unique winner. This motive explains overbidding in small



prize winner-take-all competition, but predicts overbidding (though less so) in the large prize competition as well, which is inconsistent with our findings. It does not explain additional entry nor inactive bidding in the Coin Flip treatment.

#### **4.2. RISK PREFERENCES**

Many experimental studies find that a minority of subjects exhibit risk-seeking behavior even though, on average, subjects tend to be risk-averse. Amending the model to permit risk-seeking preferences can explain the negative returns in the winner-take-all treatment. Further amending the model to allow for heterogeneous preferences, with some subjects exhibiting extreme risk aversion can also explain entry and subsequent inaction in the Coin Flip treatment. However, this explanation cannot explain entry and investment in the Dual treatment. Risk-seeking individuals should select into the large prize setting producing overinvestment whereas risk-averse subjects should shelter in the small prize setting and invest more cautiously. This is precisely the opposite of the investment patterns observed in the data.

#### **4.3. LOSS AVERSION**

Like risk aversion, loss aversion can explain entry and subsequent inaction in the Coin Flip treatment, but cannot explain the persistent negative return on investment from entrepreneurship. Like risk averse individuals, loss averse players require compensation to subject themselves to the domain of losses. Thus, loss aversion alone does a poor job of explaining behavior.

#### **4.4. OVER-OPTIMISM**

Landier and Thesmar (2009) present evidence that entrepreneurs are over-optimistic regarding the (future) value of their venture. In our setting, such over-optimism has two interpretations: subjects might overestimate their utility from winning, or they might overestimate their chances of winning. Individuals displaying excesses on either margin should differentially sort into entrepreneurship and, misperceiving the return on investment, overinvest. This could explain the persistent inferior returns from entrepreneurship. But the hypothesis runs into difficulties elsewhere. First, we do not observe consistent sorting when natural risk is present, yet sorting is the main prediction of this explanation. Second, assuming that the simple coin flip probabilities are correctly perceived, this hypothesis predicts no difference between Coin Flip and Winner-Take-All because a mean preserving spread of the outside option should have no effect on sorting or subsequent investment behavior. Instead, we observe additional entry and decreased investment in Coin Flip compared to Winner-Take-All. Perhaps the strongest evidence against this theory occurs in the Dual treatment. Here, overly optimistic individuals should sort into the large stakes contest, because a given degree of misperceived winning is magnified with the stakes. Under this hypothesis, one might expect excess entry and investment in the large stakes setting and the reverse in the small stakes setting, but we observe precisely the opposite pattern. Thus, although this prediction fits the large-scale finding of negative returns from entrepreneurship, it founders in its detailed predictions.

#### 4.5. PREFERENCES FOR SKEWNESS

It is known that, adding probability weighting to loss aversion induces individuals to pay a premium for lotteries exhibiting skewness.<sup>21</sup> Astebro et al. (2009) find evidence that about 50% of subjects in their experiment exhibit these preferences. Entrepreneurs often face positively skewed outcome lotteries relative to employment, which is also a main feature of our experiment. Although this explanation can rationalize the persistent low returns from entrepreneurship, it is at odds with the Dual treatment. Payoffs in Dual (Large) are more skewed than in Dual (Small), yet there is under-entry and under-investment in the former and the opposite behavior in the latter, suggesting that this is not the primary driver for our findings.

#### 4.6. SYSTEMATIC MISTAKES (QUANTAL RESPONSE EQUILIBRIUM)

Given the complexity of investing as an entrepreneur, systematic mistakes might explain the findings. Quantal Response Equilibrium (QRE) offers a useful formalization of incorporating mistakes into choice models (McKelvey and Palfrey, 1995). Standard formulations of these models have the property that average outcomes lie between uniform choices and Nash choices, with the exact location between the two determined by the degree of bounded rationality of subjects. The reason is that, individuals with zero rationality choose at random. As rationality increases, QRE demands that individuals be more likely to choose more profitable than less profitable options. Because Nash behavior constitutes the most profitable choice, it then follows that, as rationality increases choices increasingly favor the better (Nash) option; hence all QRE must lie between random choices and Nash in any game with a pure strategy Nash equilibrium. For example, in Tullock contests the QRE model predicts average investments in between the Nash equilibrium and half the endowment (Sheremeta, 2011; Lim et al., 2013). In this setting, the expectation of random choice is to “bid” half the endowment. Because Nash behavior is in pure strategies, any QRE must lie between the two. This model of mistakes can, in principle, explain overinvestment and excess entry in small prize settings.

By itself, this explanation runs into several problems. It cannot explain excess entry in Coin Flip because entry exceeds three whereas the Nash prediction remains at two entrants. It cannot readily accommodate the mass of inactive investors under that treatment either. Because for our parameters the risk-neutral Nash equilibrium never exceeds half the endowment for any number of entrants in any treatment, mistakes that explain overinvestment when the prize is small also predict overinvestment when the prize is large, which is at odds with the data.

These conceptual failings may be excusable were the model to fit the data reasonably well. We investigate this formally by computing a maximum likelihood estimate of the bounded rationality parameter,  $\lambda$ . Previous research has shown that the  $\lambda$  parameter varies significantly across games of differing complexity (e.g., Lim et al. (2014) estimate different  $\lambda$ s for different Tullock contests that vary in the numbers of contestants, and find that  $\lambda$  is significantly lower with more contestants). Thus we allow  $\lambda$  to differ across various stages of the game (entry versus investment), various treatments, and various numbers of entrants.

No standard implementation of QRE exists for continuous time games such as our entry stage. Therefore, we assume an exogenous sequential order of entry where each

21. See, e.g., Barberis and Thaler (2003).

subject determines whether to enter based on the current “state” of the game (i.e., the order of entry and the number of previous entrants) as well as expectations about the profitability and final number of entrants. We assume that these payoff beliefs are equal to the empirical average payoff conditional on reaching an investment game consisting of precisely  $k + 1$  entrants under a given treatment.<sup>22</sup> Beliefs about the final number of entrants depend on the state as well as equilibrium entry propensities under QRE.

To illustrate this approach, consider a simplified version of the game where there are only two possible entrants. When the second player chooses to enter, there is either zero or one previous entrant, that is,  $k = 0$  or  $k = 1$ . Conditional on this, the entrant calculates the payoff from entry compared with that from non-entry and chooses the more profitable of the two probabilistically according to the standard logistic QRE specification:

$$\Pr[\text{enter}] = p(k, 2) = \frac{e^{\lambda\pi(k+1)}}{e^{\lambda\pi(k+1)} + e^{\lambda\pi_0}},$$

where  $\pi(k + 1)$  is the average profit when  $k + 1$  entrants compete,  $\pi_0$  indicates the payoffs from not pursuing entrepreneurship, and  $p(k, 2)$  denotes the probability of entry for the second player when there are  $k$  previous entrants. In the first period of the game,  $k = 0$  because no one has yet entered, and the entry propensity calculation is

$$\Pr[\text{enter}] = p(0, 1) = \frac{p(1, 2)e^{\lambda\pi(2)} + (1 - p(1, 2))e^{\lambda\pi(1)}}{p(1, 2)e^{\lambda\pi(2)} + (1 - p(1, 2))e^{\lambda\pi(1)} + e^{\lambda\pi_0}}.$$

Notice that the payoffs from entry in this stage account for the fact that, if player 1 enters, then the second player enters with probability  $p(1, 2)$ . For a given value of  $\lambda$ , a QRE is a fixed point in state contingent entry probabilities. It may be readily shown that such a fixed point exists though it is not necessarily unique.

The experimental data consist of groups of six potential entrants, making this branching process considerably more involved but not conceptually different from the two-player setting. To estimate  $\lambda$  associated with entry decisions, we compare the predicted distribution of the realized number of entrants with the empirical distribution using a log likelihood statistic whose value we maximize. We perform this estimation procedure separately for each treatment.

Because investment choices are simultaneous, the process of estimating the QRE model is more straightforward. For computational efficiency reasons, we divide investments into 21 bins consisting of investment levels 0–5, 6–10, etc. and treat these bins as the relevant strategy space.<sup>23</sup> A QRE is a fixed point in probabilities of investing in each of these bins, again using the logistic function to determine investment probabilities.

For a given treatment and number of entrants, we choose  $\lambda$  to maximize a log likelihood statistic comparing the predicted distribution of investments with the empirical distribution. This procedure yields estimates of the bounded rationality parameter for each treatment and each number of entrants.

22. The cases of a single entrant and six entrants do not occur in the data. Because subjects were informed that a single entrant would simply receive the prize without having to make post-entry investments, we use this outcome as the relevant expected payoff. For the case of six entrants we use Nash equilibrium to determine expected payoffs. Although this may not correspond to actual beliefs, our estimates are robust to a variety of other approaches including assuming that the expected payoff equals zero, the amount any player can guarantee him- or herself in this situation.

23. The bin structure addresses a common feature of choice data, the over-representation of choices that are multiples of five. Were we instead to treat each choice separately, the resulting log-likelihood estimates would be problematic owing to lack of data in many cells.

**TABLE VII.**  
**ENTRY AND INVESTMENT BEHAVIOR—LAST 10 ROUNDS: QRE VS.**  
**ACTUAL**

Treatment	$\lambda$	Entry		Normalized Investment Investment – Prize/Entrants		
		Predicted	Actual	$\lambda^{24}$	Predicted	Actual
Shares	0.53	1.9	2.1	0.3	-10.4	-9.5
WTA	0.06	2.4	2.5	0.2	-5.7	-4.4
Coin Flip	0.00	3	3.9	0.25	-0.8	-4.6
Dual (Small)	0.02	2.4	2.6	0.2	-5.1	-5.8
Dual (Large)	0.02	3.6	3.4	0.01	-10.3	-20.8

By estimating rationality parameters for investment separate from entry, we allow the degree of bounded rationality to vary between stages of the same treatment. We compute the estimates for investment independently of the entry estimates and, in determining the predicted ROI from entrepreneurship, use the empirical rather than predicted distribution of entry. Both of these strategies bias the analysis in favor of fitting the QRE model.

Table VII reports the resulting QRE estimates and compares the predicted versus actual number of entrants and normalized investment levels for each treatment. Because Baseline mainly conforms to Nash equilibrium and entails no investments, we do not apply the QRE model to this treatment.

The most striking aspect of the analysis is the low value of the  $\lambda$  estimates for entry. They imply that approximately random choice, rather than intent, drives most of the observed variation. The reason is that, when the prize is small, we observe excess entry compared to equilibrium. Because the QRE predictions lie between Nash levels and three entrants (under purely random choice), fitting this pattern requires lowering the rationality parameter. The situation is worsened by the significantly lower ROI from entrepreneurship than the outside option. Thus, to obtain even modest amounts of excess entry requires extremely low values of  $\lambda$  because mistakes in the direction of entry are quite costly. Thus, the model ascribes excess entry mainly to large decision errors, that is, random choice. It may be the case that the low rationality parameters of the fitted QRE model reflects the particular simplification of the entry game with exogenously ordered sequential entry. However, it should be noted that other entry specifications would also have to capture the same pattern of costly excess entry decisions. In particular, data from the Coin Flip treatment, where more than 50% of subjects enter, will be difficult to reconcile with QRE predictions, which predict less than 50% entry for any rationality parameter.

Turning to investments, because the QRE is a symmetric model, it struggles to fit the passive investing behavior in the Coin Flip and Dual (Large) treatments. This partially explains the large discrepancy between the predicted and actual normalized investment amounts for these treatments. In the Dual (Large) treatment, the model also struggles to explain under-investment by entrants. As with entry, accounting for “mistakes” of this magnitude forces the model to ascribe these investment choices to approximately random behavior. Even here, it misses the ROI from this path by about 50%. In short,

24.  $\lambda$  estimates were derived conditional on treatment and number of entrants. Here we report average  $\lambda$  s weighted by the empirical distribution of entry rather than the entry patterns predicted by the entry estimates.

there is simply no value of  $\lambda$  capable of producing investment behavior with the ROI we observe in the Dual (Large) treatment.

One view of  $\lambda$  is that it captures the cognitive complexity of the treatment. Taking the ratio of the  $\lambda$  estimates for Dual (Small) and Dual (Large), the estimates imply that the large prize game is 20 times as complex as the small prize game!

One objection to the above analysis is that we have biased the model against obtaining a good fit by assuming symmetric behavior despite the presence of passive investors. To address this objection, we also estimated an amended form of the QRE model that excludes these individuals. There are two types, active and inactive, in the amended model. Inactive players simply choose low investment levels, and we exclude them from the equilibrium analysis. We then apply the QRE solutions only to active players, re-estimating the  $\lambda$  parameter for investments on this subset of the data. The resulting estimates display only small differences compared to those in Table VII. The amended model continues to struggle to explain underinvestment in the Dual (Large) treatment, still attributing choice behavior to randomness.

Although the QRE model can explain certain patterns in the data, such as excess entry, it struggles with other aspects, such as underinvestment in the large prize market. Moreover, to explain excess entry requires extremely low values of  $\lambda$ . Indeed, the resulting estimates imply something very close to random choices. This is hardly a satisfying resolution of the discrepancies between the empirical findings and equilibrium predictions, nor consistent with the systematic *changes* in behavior one observes as the treatments vary.

#### 4.7. SUMMARY

To conclude, adding a single additional factor to the model is insufficient to explain the range of anomalous patterns we observe. In particular, entry and investment in the Dual contest remain a vexing problem, as does inactivity in the Coin Flip treatment. Most amendments can explain one or the other of these features in the data, but none can explain both.

#### 4.8. TWO-FACTOR EXPLANATIONS

With these limitations in mind, we turn to two-factor explanations. Some combinations of the above set of alternatives add little incremental explanatory power despite their apparent promise. For instance, we re-estimated the QRE model as above but with the addition of loss aversion. Following the model of Morgan and Sisak (2015), we postulate a gain/loss payoff structure where gains and losses relative to the reference point  $r$  were linear with a coefficient equal to 1 for gains and  $\alpha > 1$  for losses. This reflects the key feature that a monetary loss is more painful than an equivalent gain is pleasurable. We chose  $\alpha = 2$  as values close to two have been consistently found in different laboratory experiments measuring loss aversion (e.g., Kahneman and Tversky, 1992, or Abdellaoui et al., 2007). The results, available upon request from the authors, show slightly improved predictions, but overall leave Table VII largely unchanged. QRE continues to attribute the underinvestment and under entry in the large prize competition to random behavior rather than intent.

Our preferred two-factor explanation combines love of winning with heterogeneous loss/risk aversion. We postulate that individuals receive a payoff  $B$  from winning the investment game, irrespective of the size of the prize. In addition, individuals

differ in their loss/risk aversion parameter  $\alpha_i$ . Formally, individual  $i$ 's gain/loss utility function in becoming an entrepreneur with one or more rivals is:

$$U_i = \begin{cases} W + R_s + B - x_i - r & \text{if } i \text{ wins} \\ \alpha_i (W - x_i - r) & \text{if } i \text{ loses,} \end{cases}$$

where  $W$  is the initial endowment,  $R_s$  is the size of the prize, which depends on the entrepreneurship setting (i.e., small prize or large prize),  $B$  is the love of winning payoff accruing to the winner,  $x_i$  is  $i$ 's investment, and  $r$  is the reference point, which we assume is equal to the secure payoff, so  $r = W$  when the outside option exhibits natural risk and  $r = W + w$  otherwise. The parameter  $w$  represents the value of the outside option, in our experiment  $w = 10$ .<sup>25</sup> The loss aversion parameter  $\alpha_i \in \{\alpha_L, \alpha_H\}$ , where  $\alpha_H > \alpha_L > 1$ , differs by individual. For reasons that will become clear, we assume that  $n_H = 1$  individuals are highly loss averse whereas the remainder have low(er) loss aversion. Other than the addition of love of winning, the model is identical to Morgan and Sisak (2015).<sup>26</sup>

Under the assumption that the love-of-winning motive does not operate in our Baseline treatment (where there is no contest) or Shares treatment (where there is no simple winner/loser), and given that there is no natural risk in the Baseline or Shares treatments, the predictions of our two-factor model for these treatments are identical to the risk-neutral Nash equilibrium.

Predictions for the other treatments are affected, however, and as we shall see these two factors are sufficient to explain the qualitative features of the data. Love of winning motives predominates in the small prize contest, producing overinvestment and excess entry. Loss aversion motives predominate in the large prize contest producing underinvestment and too little entry. Highly loss-averse individuals opt out of the coin flip in favor of the safe harbor of inactivity in the contest.

The two-factor model can also explain quantitative features of the data. To show this, we calibrated the parameters of the model to the data. Unlike the QRE estimates, here we do not allow the model parameters to vary across the entry and investment stages of the game. In addition, we do not allow the love of winning motive to vary with the number of competitors. For instance, it might be the case that subjects derive greater pleasure from having defeated a larger group of entrepreneurs rather than a smaller group. Both of these conservative strategies make it harder for the model to fit the data.

The two-factor model has three parameters,  $B$ ,  $\alpha_L$ , and  $\alpha_H$ . Because, on average, about one subject per group is an inactive entrant in the Coin Flip treatment, we assume that exactly one individual has high loss aversion whereas the remaining five have low loss aversion. Obtaining a precise value for  $\alpha_H$  is not needed for the analysis. It suffices merely to ensure that  $\alpha_H$  is sufficiently high that entry followed by inactivity is such an individual's best response in the Coin Flip treatment. It may be readily shown that,

25. If the reference point were constant across treatments, our loss averse specification is isomorphic to a particular specification of risk aversion and thus, in that sense, one can be agnostic about the two explanations. Specifically, we can define preferences based solely on ending wealth states and assume that preferences exhibit a kink that occurs at the point where an individual's wealth at the end of a period is exactly  $r$ . When fitting the model to the data, we vary the reference point with natural risk in the outside option. Thus, the fitted model is not isomorphic to risk aversion. Forcing the reference point to be identical across treatments worsens model fit.

26. We suppose that when only one contestant enters her utility does not include a joy-of-winning term. Adding a joy-of-winning term in this case would have a negligible effect on our results as there are very few cases where only one subject enters. Also, we suppose that the joy-of-winning motive does not operate in our Baseline or Shares treatment.

provided  $\alpha_H > 2.24$ , this is the case. Relative to parameter estimates of loss aversion in the extant literature, this value is above average, as one would expect, but not so high as to be inconsistent with the notion that 1/6th of the population might have such a value.

To estimate  $B$  and  $\alpha_L$ , we use a quadratic scoring rule giving equal weight to each treatment and equal weight to investment and entry. To score entry, we compute the squared difference between the gain/loss utility from not entering and that from entering, using the formula for expected payoffs in a symmetric loss-averse equilibrium derived in Morgan and Sisak (2015).<sup>27</sup>

Given  $n$  entrants, all entrants invest up to the point where the marginal benefit, the increased chance of winning multiplied by the associated utility from this event (measured in gain/loss space) equals the marginal cost of investment, again measured in gain/loss space. The precise amount of equilibrium investment (and hence associated gain/loss payoffs) depends on the equilibrium number of entrants, which we took to be the average number of active entrants of a given treatment computed over the last ten rounds of play,  $n_t$ . The investment score consists of the squared difference between the predicted investment in a symmetric equilibrium and the average investments of active entrepreneurs (i.e., those investing 5 or more tokens) using data from the last 10 rounds of the game. Because the number of active entrants varies, we used data from (a) the integer floor and (b) the integer ceiling of average active entrants to score investment, weighting each condition by the observed frequency of decisions.

To be precise about our estimation procedure, let  $X_{FL(nt)}$  be the estimated investment among active players under treatment  $t$  when the number of active entrepreneurs takes the value of the integer floor of  $n_t$  and  $x_{FL(nt)}$  denote the average investment from active players in the data under this same condition. Let  $X_{CE(nt)}$  and  $x_{CE(nt)}$  be analogously defined for the integer ceiling of  $n_t$ . Let  $\phi_t$  denote the fraction of integer floor observations under treatment  $t$  conditional on all floor or ceiling observations under this treatment. Finally, let  $U_t$  be the estimated gain loss utility from the entrepreneurship game among the average number of active players in the data and  $u_t$  the outside option expressed in gain loss utility terms. The calibrated values of  $B$  and  $\alpha_L$  solve:<sup>28</sup>

$$\min \sum_{t \in T} \phi_t (X_{FL(nt)} - x_{FL(nt)})^2 + (1 - \phi_t)(X_{CE(nt)} - x_{CE(nt)})^2 + (U_t - u_t)^2.$$

One difficulty with this scoring rule is that it applies the same score to different units of measure. Thus, we divide by  $x_t$  (resp.  $u_t$ ) to obtain the scoring rule:<sup>29</sup>

$$\min \sum_{t \in T} \phi_t \left( \frac{X_{FL(nt)}}{x_{FL(nt)}} - 1 \right)^2 + (1 - \phi_t) \left( \frac{X_{CE(nt)}}{x_{CE(nt)}} - 1 \right)^2 + \left( \frac{U_t}{u_t} - 1 \right)^2.$$

27. In the Dual treatment, we computed the expected gain/loss utility from entering the large prize versus the small prize contest, respectively. The expression for gain/loss utility as a function of the number of entrants  $n$  and the reference point  $r$  equals  $EU(n, r) = \frac{R_s + B + (W-r)((n-1)\alpha_i + 1)^2}{(2n-1) + \alpha_i(n-1)^2}$  as derived in Morgan and Sisak (2015). Recall that  $R_s$  equals the prize value,  $B$  the utility of winning,  $W$  the initial endowment, and  $\alpha_i$  the degree of loss aversion. Equilibrium investment in a symmetric equilibrium equals  $x_i(n, r) = \frac{(n-1)(R_s + B + (\alpha_i - 1)(r - W))}{(2n-1) + \alpha_i(n-1)^2}$ .

28. The Dual contest must be handled slightly differently. Because it consists of investments in small and large prize contests, we treat these investments as separate scores, each given half the weight compared to the other treatments. Also, the utility comparison compares payoffs in small versus large contests rather than against the outside option.

29. Because  $u_t$  is endogenous in the Dual contest, we divide by the theoretical value of the outside option, 10 in this case.

**TABLE VIII.**  
**ENTRY AND INVESTMENT BEHAVIOR—LAST 10 ROUNDS: ACTUAL VS.**  
**JOY OF WINNING PLUS LOSS AVERSION ( $B = 25.5$ ,  $\alpha_L = 1.48$ )**

Treatment	Active Entry		Normalized Investment Investment- Prize/(Active Entrants)	
	Predicted	Actual	Predicted	Actual
Baseline	2	2.3	–	–
Shares	2	2	–10	–8.2
WTA	2.2	2.3	–6.1	–4.3
Coin Flip	3.1	2.6	–5.5	–7.4
Dual (Small)	2.0	2.3	–7.1	–6.3
Dual (Large)	3.4	3.1	–24.9	–22.9

This procedure yields parameter estimates of  $B = 25.5$  and  $\alpha_L = 1.48$ , which both appear reasonable in view of the extant literature and the size of the prize.<sup>30</sup> Our loss aversion estimate is lower than 2, the usual rule of thumb when calibrating loss aversion in models, but within the range found in other studies.<sup>31</sup> Recall that  $\alpha_L$  represents a lower bound on loss aversion in the population. Average loss aversion in the population weighs both  $\alpha_L$  and  $\alpha_H$ . Because  $\alpha_H$  is a partially free parameter in the estimation (constrained only to exceed 2.24), the population, the population average can be set to any value above  $\alpha_L$ .

Our love of winning estimate increases the perceived value of winning the small prize contest by about 50% but increases the perceived prize value by only 13% in the large prize contest. By way of comparison, performing a similar analysis using the data contained in Sheremeta (2010) for his treatment where no prize was offered in a contest, produces an estimate of  $B = 262$ , about ten times as large as in our setting.<sup>32</sup> There are many differences between the two experiments, but perhaps the most important is that Sheremeta publicly announced the identity of the winning contestant whereas we do not. This announcement presumably enhances the perceived prestige value of winning. In addition, subjects in Sheremeta only played the game once whereas our subjects experience 50 iterations. This repetition might cool their ardor for winning.

Because we used the number of passive entrants in the data to deduce the fraction of  $\alpha_H$  types in the population as well as to determine the threshold value of  $\alpha_H$ , we derived our estimates only from the population of active entrants. As such, we restrict attention to this population in assessing the performance of the model. Table VIII compares actual and predicts active entry and normalized investment (dividing by the number of *active* entrants) using our estimates.

The calibrated model produces predicted entry that is reasonably close to what we observe in all treatments save for Coin Flip, where it predicts too much entry. The model

30. One obtains similar figures using an unweighted scoring rule:  $B = 25.2$  and  $\alpha_L = 1.42$ . The resulting estimated investments and participation are also similar.

31. For instance, Schmidt and Traub (2002) report an average loss aversion coefficient of 1.43.

32. To make this calculation, we determined the implied value of the prize under equilibrium play in a contest consisting of four players making the average contribution based on Sheremeta's data. We then converted this implied value, using the exchange rates from both experiments, into comparable point values in our setting. Detailed calculations are available upon request.



also explains the pattern of under entry in the Dual treatment, large prize setting, which stems from loss aversion and the attenuation of love of winning motives.

The estimates for the ROI from entrepreneurship tend to be higher than what is observed save for Coin Flip. Investment in the two factor model only depends on the number of entrants and the reference point. Thus, the ROI under Coin Flip is lower than Dual (Small) owing to greater entry. A higher reference point reduces ROI, all else equal, because investments become more aggressive to secure gains. This explains why the ROI under Winner-Take-All is lower than Dual (Small).

The discrepancies between the predicted and actual ROI stem mainly from the heterogeneity of investment amounts across treatments, even after controlling for the reference point and number of active entrepreneurs. Because we estimate one love of winning and loss aversion parameter applied to *all* treatments, compromises in fit are inevitable. Especially noteworthy is investment under Coin Flip compared to the other treatments. The model assumes that the number of passive investors is known whereas, in reality, this is unlikely. Because passive investors play a major role in Coin Flip, the result is that actual investment is more conservative than the model predicts producing an underestimate for ROI for that treatment and overestimates for the other treatments.

The broader lesson here is that, not only are behavioral motives needed to explain the patterns in the data, but these motives must be heterogeneous and *countervailing*. Love of winning motive spurs entry and investment, with a larger effect in the small prize contest. At the same time, loss/risk aversion pushes in the opposite direction. This opposing force is needed to explain the influx of passive investors in Coin Flip as well as conservative entry and investment in the large prize Dual treatment.

Such a *mix* of motives seems plausible, but the explanation suffers from being *post hoc* with no out of sample testing. Fortunately, sharp out of sample predictions are available. For instance, raising the value of the prize in the Winner-Take-All treatment should reduce overinvestment by diluting the love of winning motive. In earlier work, Morgan et al. (2012), we observed precisely this pattern. When the outcome of the entrepreneurship game is more sensitive to relative investments, this increases risk and hence should reduce overinvestment. Publicly announcing or otherwise recognizing the winner of the game should increase overinvestment by making love of winning more salient. These last two treatments separately test the two motives out of sample, but remain for further research.

## 5. DISCUSSION AND CONCLUSIONS

The decision to become an entrepreneur is fraught with peril. One risk that entrepreneurs face, what we term strategic risk, stems from the interactive nature of payoffs—an entrepreneur's fate is not solely under her control, but rather depends on the strategy decisions of rivals in the same market. Natural risk also plays a key role. Despite her best efforts, an entrepreneur's success or failure is determined by the whims of fate. Random fluctuations in tastes, fads, and fashions are often the difference between a winning venture and a losing one.

Using laboratory experiments, we isolate these two types of risk and examine their effects on entry and investment. Our setting also allows us to observe the "life cycle" of entrepreneurship—how choices and strategies evolve as an entrepreneur gains experience in the market.

In settings primarily characterized by strategic risk, standard economic theory performs well in predicting the entry and investment decisions of entrepreneurs. Although payoffs from entrepreneurship are initially depressed compared to the returns from a safe outside option, with experience, individuals sort themselves into entrepreneur and non-entrepreneur groups. Because there are no barriers to switching between groups, it is hardly surprising that the expected payoffs between the two groups approximately equalize.

Adding natural risk to the setting changes matters considerably. Individuals are now slightly more inclined to pursue entrepreneurship and much more inclined to invest aggressively post-entry. This depresses the returns from entrepreneurship to the point where they badly lag those from an outside option, regardless of whether it is safe or risky. Even with experience, these returns differences persist. Our experiment thus nicely complements the empirical findings of Hamilton (2000), showing that the pecuniary returns to entrepreneurship are negative.

We do observe an important exception to this pattern however: When subjects are required to pursue entrepreneurship and can only control the stakes of the game in which they are participating, we find little appetite for risk. Compared to the risk-neutral prediction, too few subjects opt for the high stakes path and those that do invest less aggressively than theory predicts. This produces the largest returns difference between the two alternatives among all our treatments—more than 15 percentage points.

We can explain these patterns in the data through a combination of loss aversion and a non-pecuniary love of winning motive, inspired by the findings of Sheremeta (2010). Love of winning helps explain the lagging returns to entrepreneurship in low stakes settings whereas loss aversion explains the conservative entry and investing in high stakes settings. Allowing for heterogeneity in loss aversion additionally explains passive investing in the face of a risky outside option.

Natural risk also reduces the sorting of individuals into entrepreneurs and non-entrepreneurs. In effect, entrepreneurship becomes a revolving door. Those who enter and are unlucky leave only to be replaced by individuals previously on the sidelines now willing to take a chance. Lucky entrepreneurs, on the other hand, remain in the market, and seem to confuse luck for skill in this setting. These results are consistent with the empirical findings of Mazzeo (2004) who notes that, in riskier settings, there is less specialization between the entrepreneur and non-entrepreneur classes.

Entrepreneurship is widely viewed as a key national growth driver and, indeed, many countries have policies put into place to reward this activity. Our findings shed light on some aspects of these policies. First, for small stakes entrepreneurship, the problem may be one of too much rather than too few. The combination of too little specialization, too much entry, and too aggressive a level of investment may well prove socially wasteful rather than socially beneficial. In large stakes settings, the opposite problem arises and here policy can clearly help. In effect, our subjects are somewhat capital constrained in entering markets with large prizes. They have no ability to hedge or offset their risk and, to be successful, they need to wager a significant portion of their endowment. Our results suggest that initiatives designed to create liquidity and offset some risk could prove beneficial.

Of course, there is a vast gulf between the much simplified entrepreneurial settings we study in the lab and real-world entrepreneurship. Nonetheless, laboratory settings are crucial in understanding reactions to different sources of risk and benchmarking relative to the predictions of economic models. Thus, we view our findings as

informative, but hardly the last word, on strategic and natural risk and their effect on entrepreneurship.

## APPENDIX A

### INSTRUCTIONS FOR THE EXPERIMENT

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 50 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 50 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

**[Baseline, Shares, Winner-Take-All:** 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.]

**[Coin Flip:** If you select option A, your final point earnings for the round will depend on the outcome of a computerized coin flip. The coin is equally likely to come up heads or tails. If the coin comes up heads 35 points will be added to your initial point balance and your final point earnings for the round will be 135 points; if the coin comes up tails 15 points will be subtracted from your initial point balance and your final point earnings for the round will be 85 points.]

**[Dual Market:** If you select option A you will have a chance to win a prize of 200 points.

First, if you are the only group member to select option A, 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 A 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.

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.]

## OPTION B

**[Baseline:** If you select option B you will receive some additional points depending on how many players choose option B.

If you are the only group member to select option B 50 points will be added to your initial point balance. Your final point earnings for the round will be 150 points.

If you and one other group member selects option B 13 points will be added to your initial point balance. Your final point earnings for the round will be 113 points.

If you and two other group members select option B 6 points will be added to your initial point balance. Your final point earnings for the round will be 106 points.

If you and three other group members select option B 3 points will be added to your initial point balance. Your final point earnings for the round will be 103 points.

If you and four other group member selects option B 2 points will be added to your initial point balance. Your final point earnings for the round will be 102 points.

If you and five other group member selects option B 1 point will be added to your initial point balance. Your final point earnings for the round will be 101 points].

**[Shares:** If you select option B you can receive a share of a prize of 50 points.

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

Second, if more than one group member selects option B there will be a contest among these group members to determine how the prize is shared. 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 receives any of the prize. Otherwise, your share of the prize will equal your share of all tokens bought times 50 points, rounded to the nearest point.

For example, if all players (including you) bought a total of 100 tokens and you bought 25 of these your share of all tokens bought is 25%. Your share of the prize is 25% of 50 points or 12.5 points, which is rounded to 13 points.

Thus, your share of the prize increases with the number of contest tokens you buy. Conversely, the more contest tokens the other players buy, the lower will be your share of the prize.

Your share of the prize will be added to your point balance. Your final point earnings for the round will be  $(100 - \text{the number of contest tokens you bought} + \text{your share of the prize})$  points.]

**[Winner-Take-All, Coin Flip:** 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.

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.

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.

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.]

**[Dual Market:** 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 point balance. Your final point earnings for the round will be 150 points.

Second, if more than one group member selects option B there will be a contest to determine who wins the prize. This contest works in the same way as that described for option A, except that the prize is 50 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.

## APPENDIX B

### A MODEL OF CONTINUOUS TIME ENTRY

There are  $N$  potential entrepreneurs in the game. Each individual chooses to either enter or not enter into entrepreneurship. This decision is made once, and cannot be changed over the course of the game, which occurs during the time interval  $[0, T]$ . Each individual  $i$  has a private awareness time,  $r_i$ , drawn independently (in each round) from a common atomless distribution  $F$  with support  $[0, \varepsilon]$ , where  $T > \varepsilon > 0$  is some small value. Awareness time represents the period at the start of the game where an individual's attention is elsewhere. Formally, at any time  $t < r_i$ , an individual is unaware that the game has begun and can make no decision about entry or exit. Once  $t \geq r_i$ , individual  $i$  is fully aware of the state variable,  $n(t)$ , the number of individuals entering up to time  $t$ , and can execute her entry/exit decision instantaneously at time  $t$ .

We parameterize the preferences of each agent  $i$  by a type  $\theta_i$ , which is increasing in  $i$ . An agent knows her own type and the set of all realized types (i.e., that there exists some agent  $j$  with type  $\theta_j$ ).<sup>33</sup> The type  $\theta_i$  represents the degree of risk or loss aversion of an individual. Individuals with higher types are more risk/loss averse than those with lower types, that is, for all  $i < j$ ,  $\theta_i < \theta_j$ .

Let  $C$  denote the list of index numbers of all those individuals who entered at time  $T$ .<sup>34</sup> For each agent  $i \in C$ , let  $C_{-i}$  denote the indices of her competitors. Suppose that  $i \in C$ , then  $\pi_i(C)$  is the payoff lottery that  $i$  receives when with others  $j \in C$ . Agent  $i$  derives

33. This assumption is essentially the same as the more usual condition that an individual knows her own type and the distribution from which all other types are drawn (rather than the realizations of these draws) provided that  $n$  is large.

34. Note that such a list is not directly observable to any agent because she only knows the time of each entrant (after the inattention period has elapsed) but not the index number. Nonetheless, in certain equilibria, she will be able to perfectly anticipate the index numbers contained on the list  $C$ .

expected utility  $U(\pi_i(C); \theta_i)$  from this payoff lottery. When  $i$  chooses not to enter, her expected utility is  $U(\pi_n; \theta_i)$ . Let  $V(\pi_i(C); \theta_i) = U(\pi_i(C); \theta_i) - U(\pi_n; \theta_i)$ , that is,  $V$  represents the utility difference between entry and exit (given other entrants' indices). Because this difference is the relevant comparison for all choices, we describe everything in terms of  $V$  in the analysis that follows.

Assumptions 1 and 2 guarantee that the entry game is "interesting" in the sense that it is valuable enough to be worth contesting but not so valuable that everyone prefers to enter. Formally,

**ASSUMPTION 1 (Viability):** For some  $i, j$   $V(\pi_k(\{i, j\}); \theta_k) > 0$ , where  $k \in \{i, j\}$ .

**ASSUMPTION 2 (Congestibility):** For all  $i$ ,  $V(\pi_i(N); \theta_i) < 0$ .

Assumption 3 merely ensures that greater competition reduces utility for all entrants.

**ASSUMPTION 3 (Competition):** For all  $i \in C$  and any  $j \notin C$ ,  $V(\pi_i(C); \theta_i) > V(\pi_i(C \cup \{j\}); \theta_i)$ .

As described above, individuals are ordered by their type  $\theta$ . The following condition describes the meaning of this ordering:

**CONDITION 1:** For all  $C$  with  $i \in C$ , it holds that:

(1)  $V(\pi_i(C); \theta_i) \geq V(\pi_i(C_{-j} \cup \{k\}); \theta_i)$  for all  $k < j$  where  $j \in C$  and  $k \notin C$ , that is, an individual's net utility from entry is higher when competing with "weaker" players.

(2)  $V(\pi_i(C); \theta_i) \geq V(\pi_j(C_{-i} \cup \{j\}); \theta_j)$  for  $j \notin C$  where  $i < j$ . A "weaker" player receives a lower net utility from entry against a given set of competitors.

To proceed, it is convenient to denote the case where  $i$  competes against the  $n-1$  strongest competitors by writing  $C_{-i} = n_{-i}$ . For example when  $i > n-1$ , then  $n_{-i} = \{1, 2, \dots, n-1\}$ . Using this notation, define the *threshold* market size for individual  $i$  as the unique set  $n_{-i} \cup \{i\}$  solving

$$V(\pi_i(n_{-i} \cup \{i\}); \theta_i) \geq 0.$$

$$V(\pi_i((n+1)_{-i} \cup \{i\}); \theta_i) < 0.$$

where uniqueness follows immediately from Assumptions 1–3. Using this value of  $n_{-i}$ , we say that the largest size market  $i$  is willing to face is  $n_i^* = n_{-i} \cup \{i\}$ , which has a cardinality of

$$\#n_i^* = \#[n_{-i} \cup \{i\}].$$

One can think of  $\#n_i^*$  as representing the "demand curve" for entry, that is, it expresses the highest "price" in terms of the amount of competition that  $i$  is willing to "pay" to enter. We next show that Condition 1 implies that this demand curve slopes downward. Formally,

**LEMMA 1:** Let  $\#n_i^*$  be defined as above. Provided Condition 3 holds, then  $\#n_i^*$  is weakly decreasing in  $i$ .

**PROOF:** Suppose to the contrary that, for some  $j > i$ ,  $\#n_j^* > \#n_i^*$ . There are several cases to consider

a)  $j \leq n_j^*$ : By Part (1) of Condition 1,  $V(\pi_i(n_j^*); \theta_i) \geq V(\pi_i(n_j^* \setminus \{j\} \cup \{i\}); \theta_i)$  where we have created a "duplicate" of  $i$  in the set  $n_j^* \setminus \{j\} \cup \{i\}$ . Part (2) of Condition 3 implies  $V(\pi_i(n_j^* \setminus \{j\} \cup \{i\}); \theta_i) \geq V(\pi_j(n_j^*); \theta_j) \geq 0$ . Hence,  $V(\pi_i(n_j^*); \theta_i) \geq 0$ , which is a contradiction.

b)  $i < n_j^* \equiv k < j$ : Because  $V(\pi_j(n_j^*); \theta_j) \geq 0$ , then if we replace  $j$  by  $k$ , it must still be the case that  $V(\pi_k(n_j^* \setminus \{j\} \cup \{k\}); \theta_k) \geq 0$  because  $k < j$ . Finally, notice that, from the perspective of  $i$ ,  $n_j^* \setminus \{j\} \cup \{k\} = n_{-i} \cup \{i\}$ , where  $n_{-i} = \{1, 2, \dots, i-1, i+1, \dots, k-1, k\}$  and,

because  $i < k$ , then  $V(\pi_i(n_{-i} \cup \{i\}); \theta_i) \geq V(\pi_k(n_j^* \setminus \{j\} \cup \{k\}); \theta_k) \geq 0$ , which is a contradiction.

c)  $i \geq n_j^*$ : Part (2) of Condition 3 implies  $V(\pi_i(n_j^*); \theta_i) \geq V(\pi_i(n_j^* \setminus \{j\} \cup \{i\}); \theta_i) \geq V(\pi_j(n_j^*); \theta_j) \geq 0$ , which is a contradiction.

An equilibrium,  $n^*$ , is the unique value of  $i$  such that  $\#n_i^* \geq i$  and  $\#n_{i+1}^* < i+1$ . Uniqueness follows from the fact that the sequence of indices,  $\{i, i+1, \dots\}$ , is strictly increasing in  $i$  although the sequence  $\#n_i^*$  is weakly decreasing. We now relate  $n^*$  to the number of entrants. There are two cases to consider depending on whether "demand" is rationed or not.

**Non-contested entry:** Suppose that, for all  $i > n^*$ ,  $\#n_i^* < n^*$ . In this case, the "strongest"  $n^*$  individuals enter with probability one and all others never enter. Because there is no "excess demand" at  $n^*$ , entry can occur at any time—individuals do not need to react quickly to ensure themselves a slot in the contest.

Of course, excess demand at  $n^*$  is entirely possible. Because demand is only weakly downward sloping, it might well be the case that, for  $j = n^* + 1$ ,  $\#n_j^* = n^*$ . Here, some rationing rule is needed to determine entry. Under some conditions, the speed of entry acts as the rationing rule. We refer to these situations as contested entry and offer a sufficient condition below:

**CONTESTED ENTRY:** *Suppose that for  $i = 1, \dots, n^* + 1$ ,  $\#n_i^* = n^*$ . Then all competitors for whom  $\#n_i^* = n^*$  will seek to enter at the earliest possible moment provided  $n(t) < n^*$ . Else they will choose to stay out.*

**PROOF:** First, notice that entry must be contested. If not, then there exists some agent  $i \leq n^* + 1$  who is assigned to not enter in equilibrium and who can profitably deviate by entering at the earliest possible moment conditional on the fact that the current number of entrants is strictly less than  $n^*$ . By perfection, off equilibrium strategies of others must call for non-entry once the number of entrants is  $n^*$ .<sup>35</sup> Hence, entry will still be  $n^*$  under such a deviation and this improves on the outside option for the deviating agent  $i$ . Next, note that, under contested entry, all agents for whom  $i = n^*$  can do no better than to enter at the earliest possible time provided total entry is less than  $n^*$ . Waiting merely risks entry by another agent and, because entry is better than non-entry, any such deviation leaves the agent worse off. Finally, for all  $j$  such that  $\#n_j^* < n^*$  entry is clearly not profitably because any entry deviation will still produce a situation where the total number of entrants is  $n^*$ , and this is worse for  $j$  than not entering. This completes the proof.

To summarize: Rationing is a necessary but not sufficient condition for contested entry. If individuals are sufficiently heterogeneous, then belief-based equilibria can arise where entry is non-contested. Likewise, the absence of rationing is a sufficient but not necessary condition for non-contested entry. In the cases not covered by our two sufficient conditions, both rationing and preference heterogeneity are present; thus, entry may be contested or not. Precise characterization of all possible preference configurations is beyond the scope of this analysis.

35. Technically, we require a beliefs restriction as well as perfection. Specifically, all deviations are viewed as coming from some  $i \leq n+1$  who was assigned not to enter. Because such a type stands to gain the most from entry, divinity refinements support such beliefs.



### APPLICATION TO EXPERIMENT TREATMENTS

Let us now apply these results to our experimental setting, beginning with Baseline and Shares. Because our types are mainly associated with preferences over natural risk, which is absent in these treatments, the situation is one where all individuals are identical. Hence,  $\#n_i^* = 2$  for all  $i$  by our choice of parameters. This corresponds exactly to our contested entry conditions; hence, we expect that individual  $i$  enters immediately if  $n(r_i) < 2$  and stays out otherwise. Thus always exactly two entrants are observed, and entry occurs early in the game.

Let us now consider the WTA treatment. Essentially, this merely adds natural risk to Shares. In this case, parameters are no longer identical as risk/loss aversion reduces the perceived value of entrepreneurship relative to the outside option. This suggests that  $\#n_i^* \leq 2$  for all  $i$ . From Assumption 1 above  $n^* = 2$ ; however entry need not be contested.

For Coin Flip and Dual, the outside option now exhibits natural risk making entry more appealing. We can say little about such a situation other than to predict that at least two individuals enter. Whether equilibrium entry increases above two or is contested depends on both the modeling and the specific parameter values assigned to  $\theta$ .

## APPENDIX C

### CATEGORIZATION OF STUDY FIELDS FOR BUSINESS/ECONOMICS AND NUMERATE

#### NUMERATE:

Accounting, Architectural Engineering, Architectural Studies, Architecture, Biochemistry, Biochemistry and Biological Chemistry, Biology, Bioscience, Biotechnology, Business, Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Economics, Electrical Engineering, Electronic Engineering, Engineering, Environmental Engineering, Finance, Genetics, Industrial Economics, Information Technology, International Economics, Life Sciences, Management, Mathematics, Mechanical Engineering, Medicine, Molecular Diagnostics, Neuroscience, Pharmacy, Physics, Risk Management.

#### BUSINESS/ECONOMICS:

Accounting, Business, Business Management, Business Studies, Economics, Finance, Industrial Economics, International Economics, Management, Mathematics & Economics, Risk Management.

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