

UCLA

UCLA Electronic Theses and Dissertations

Title

Essays on Strategic Risk Taking Under Competition

Permalink

<https://escholarship.org/uc/item/2rn9g0zn>

Author

Ostler, James Owen

Publication Date

2013

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

Essays on Strategic Risk Taking Under Competition

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Management

by

James O Ostler

2013

ABSTRACT OF THE DISSERTATION

Essays on Strategic Risk Taking Under Competition

by

James O Ostler

Doctor of Philosophy in Management

University of California, Los Angeles, 2013

Professor Marvin Lieberman, Chair

This thesis explores how competition impacts risk taking in three essays. Chapter 2 explores the role competition plays in motivating risk-taking in an entrepreneurial setting. Traditional entrepreneurship research holds that a role of entrepreneurs is to bear risk and that entrepreneurs are risk seeking, or at least less risk averse than others. Using a tournament model we show that, due to competitive effects, even risk-neutral entrepreneurs appear to be risk seeking and will take on significant levels of risk. To explain this we introduce the concept of strategic risk, which we define as rational risk taking that arises due to competition. We show that the traditional view may

have it backwards: we do not observe risky behavior because entrepreneurs have a taste for risk, but rather the structure of some markets induces rational strategic risk taking, and it is the presence of risk and uncertainty that allows entrepreneurship to exist. The model predicts that industries with higher uncertainty and riskier strategies available to entrepreneurs will have higher levels of entrepreneurial entry. Thus, we offer an alternative explanation to why radical innovations disproportionately come from small entrepreneurial firms, and why certain industries are more innovative than others.

Chapter 3 tests the empirical predictions of Chapter 2 in the liver transplant market. Using a policy change to identify risky illegal behavior in the liver transplant market we find support for the model's predictions. The liver transplant market offers an ideal setting to look at how competition impacts risk taking and firm entry as it offers a setting with: substantial variation in levels of market competition, a change in policy that allows identification of risk taking in the form of illegal activity (Snyder, 2010), and a growing market with entry occurring over time. We find support for the predictions that: increased competition increases strategic risk taking, new entrants will take more strategic risk, and that the presence of risky strategies increases an entrepreneurial entrant's ability to compete leading to increased entry.

Finally, in Chapter 4 the risk taking behavior predicted in Chapter 2 is tested in a laboratory experiment. We find that actual behavior deviates from the theoretical optimal for the majority of players even though players would universally be better off playing as the model prescribes. We also explore how the framing of the competitive situation influences behavior. We find that general quantitative ability and being less risk averse predicts play closer to the optimal predicted behavior.

The dissertation of James O Ostler is approved.

Florian Ederer

Suzanne Shu

Lynne Zucker

Marvin Lieberman, Committee Chair

University of California, Los Angeles

2013

Contents

1	Chapter 1	1
1.1	Introduction	2
2	Chapter 2	3
2.1	Introduction	4
2.2	Literature Review	7
2.3	The Model	9
2.4	Optimal Risk Taking Among Identical Firms	11
2.4.1	Optimal risk taking with symmetrical risk distributions	11
2.4.2	Asymmetric risk distributions	15
2.5	Optimal Risk Taking with Heterogeneous Firms	21
2.6	Extensions	25
2.6.1	Extensions	25
2.6.2	Empirical implications and support	28
2.7	Applications and Conclusion	30
2.7.1	Applications	30
2.7.2	Conclusion	33
2.8	Omitted Proofs	34
3	Chapter 3	41
3.1	Introduction	42
3.2	Literature Review	43
3.3	Empirical Setting: The Liver Organ Transplant Market	46
3.4	Empirical Hypotheses	48
3.5	Data and Empirical Analysis	51
3.6	Conclusion	57
4	Chapter 4	58
4.1	Introduction	59
4.2	Experimental Procedure	60
4.3	Hypotheses	61
4.4	Analysis and Results	64
4.4.1	Competition based on the number of winners vs players	64
4.4.2	Competition with an (dis) advantage	70
4.5	Conclusion	75
4.6	Appendix	77
4.6.1	Additional figures	77
4.6.2	Instructions for the experiment	79
	References	93

List of Figures

1	The impact of the number of competitors, n , and the number of winners, m , on the probability of winning with a given performance	13
2	The log normal distribution with a constant mean and differing variance	16
3	Values of the median, ζ , and the probability of an outcome less than the mean, $Pr(X < 1)$, for mean preserving spreads for the Log Normal Distribution with $E[x] = 1$	17
4	Equilibrium risk for log normal distributed risk with m winners and changes in n .	18
5	Equilibrium risk for log normal distributed risk with n entrants and changes in the number of winners, m	19
6	Equilibrium risk for a given λ as the number of participants increases	20
7	Map of Organ Procurement Organization (OPO) boundaries in the US	47
8	On average entrants ICU use was higher and dropped more after the MELD policy was implemented in 2002 compared to incumbents	49
9	The number of entering firms drops after MELD policy introduced	51
10	Comparison of theoretically predicted behavior and actual player behavior	65
11	Comparison of theoretically predicted behavior and actual player behavior when m is increasing	66
12	Comparison of theoretically predicted behavior and actual player behavior for when m is increasing, and when broken comparing the top quartile based on performance	67
13	Comparison of theoretically predicted behavior and actual player behavior for when n is increasing, and when broken comparing the top quartile based on performance	69
14	Comparison of theoretically predicted behavior and actual player behavior for when they are ad an advantage or disadvantage.	70
15	Comparison of theoretically predicted behavior and actual player behavior for expected payoffs and subsequent bids to play asymmetric games when the maximum variance is reduced.	73
16	Comparison of theoretically predicted behavior and actual player behavior for when m is increasing, and when broken down by quartiles based on performance .	77
17	Comparison of theoretically predicted behavior and actual player behavior for the top and bottom quartile of performance when n is increasing	78

List of Tables

1	Liver transplants are a \$3.75 billion/year market	46
2	ICU use by new entrants and centers in highly competitive OPOs	54
3	Model for liver transplant entry	56
4	Parameters for the different rounds of the game	62
5	Impact of the number of winners and the number of players on risk-taking	68
6	Impact of competing with an (dis)advantage on risk-taking	71
7	Performance prediction and learning	74

Acknowledgments

This research was supported by The Harold and Pauline Price Center for Entrepreneurial Studies at UCLA Anderson School of Management.

James O Ostler

EDUCATION

- 2010 **UNIVERSITY OF CALIFORNIA, LOS ANGELES**
MA, Economics
- 2004 **BRIGHAM YOUNG UNIVERSITY**
MBA, Emphasis: New Product Development
MS, Engineering
- 2002 **BRIGHAM YOUNG UNIVERSITY**
BS, Chemical Engineering

RESEARCH IN PROGRESS

- “Swinging for the Fences: Strategic Risk-Taking in Entrepreneurship”
“Competition and Unethical Behavior in Entrepreneurship” with Jason Snyder
“The Inside View, Risk Preferences and Strategic Risk-Taking Under Uncertainty” with Suzanne Shu
“The Role and Optimal Size of Venture Capital in New and Growing Industries and Product Markets”
“Learning by Doing Research? The Impact of Physicians’ Research on Outcomes in Practice” with Sara Parker and Subramaniam Ramanarayanan
“Learning to Work Together: Coordination and Firm Performance”
“Institutional Inertia: When do Small Startups have an Advantage?”
“The Impact of High-Temperature Superconductors on New and Pre-Existing Industries”

INVITED PRESENTATIONS

- 2012 “Learning by Doing Research? The Impact of Physicians’ Research on Outcomes in Practice”, *Workshop on Disambiguation (UIUC)*
- 2012 Swinging for the Fences: Strategic Risk-Taking in Entrepreneurship, *CRES Foundations of Business Strategy Conference (Washington University in St. Louis)*
- 2011 Swinging for the Fences: Strategic Risk-Taking in Entrepreneurship, *Fourth Annual Searle Center Conference on the Economics of Entrepreneurship and Innovation (Northwestern University)*
- 2011 Swinging for the Fences: Strategic Risk-Taking in Entrepreneurship, *Innovation and Creativity Workshop (UCLA)*

HONORS AND AWARDS

- 2012-13 UCLA Dissertation Year Fellowship (\$21,000 stipend, \$500 research budget and all tuition and fees)

- 2011-12 Price Center research grant for research project “Swinging for the Fences: Strategic Risk-Taking in Entrepreneurship” - \$10,000
- 2010-11 Price Center research grant for research project “The role of venture capital in picking winners” - \$9,000
- 2008-12 UCLA Anderson Fellowship (\$12,000 stipend; \$12,000 from TA/RA; \$1,000 research support; tuition and fees)
- 2008 UCLA Deans award - \$6,000
- 2003-04 Ernest L. Jeppsen Memorial Endowment Honorary Scholarship (faculty nominated and awarded to the top graduate student in the School of Technology each year)

PROFESSIONAL MEMBERSHIPS

Academy of Management, Strategic Management Society

WORK EXPERIENCE

- 2006-08 Avery Dennison, Mentor, OH. *Service Programs Coordinator* Responsible for all service programs, and to develop new service offerings for customers
- 2004-06 Vivecon, Mountain View, CA. *Business Consultant* Vivecon was a venture capital backed startup that applied real options thinking to strategic planning, supply contracts and capacity investment decisions. This was accomplished both through consulting engagements and developing software for various customers. Key engagements included: Estee Lauder, ON Semiconductor, Alcoa, Daimler Chrysler, Ford, GM

1 Chapter 1

Introduction

1.1 Introduction

This thesis explores how competition impacts risk taking in three essays.

Chapter 2 explores the role competition plays in motivating risk-taking in an entrepreneurial setting. Traditional entrepreneurship research holds that a role of entrepreneurs is to bear risk and that entrepreneurs are risk seeking, or at least less risk averse than others. Using a tournament model we show that, due to competitive effects, even risk-neutral entrepreneurs appear to be risk seeking and will take on significant levels of risk. To explain this we introduce the concept of strategic risk, which we define as rational risk taking that arises due to competition. We show that the traditional view may have it backwards: we do not observe risky behavior because entrepreneurs have a taste for risk, but rather the structure of some markets induces rational strategic risk taking, and it is the presence of risk and uncertainty that allows entrepreneurship to exist. The model predicts that industries with higher uncertainty and riskier strategies available to entrepreneurs will have higher levels of entrepreneurial entry. Thus, we offer an alternative explanation to why radical innovations disproportionately come from small entrepreneurial firms, and why certain industries are more innovative than others.

Chapter 3 tests the empirical predictions of Chapter 2 in the liver transplant market. Using a policy change to identify risky illegal behavior in the liver transplant market we find support for the model's predictions. The liver transplant market offers an ideal setting to look at how competition impacts risk taking and firm entry as it offers a setting with: substantial variation in levels of market competition, a change in policy that allows identification of risk taking in the form of illegal activity (Snyder, 2010), and a growing market with entry occurring over time. We find support for the predictions that: increased competition increases strategic risk taking, new entrants will take more strategic risk, and that the presence of risky strategies increases an entrepreneurial entrant's ability to compete leading to increased entry.

Finally, in Chapter 4 the risk taking behavior predicted in Chapter 2 is tested in a laboratory experiment. We find that actual behavior deviates from the theoretical optimal for the majority of players even though players would universally be better off playing as the model prescribes. We also explore how the framing of the competitive situation influences behavior. We find that general quantitative ability and being less risk averse predicts play closer to the optimal predicted behavior.

2 Chapter 2

Swinging for the Fences: Strategic Risk Taking in Entrepreneurship

2.1 Introduction

One of the key characteristics of entrepreneurship is the high level of uncertainty and associated risk. This uncertainty comes in many different shapes and sizes, and any entrepreneurial venture will face multiple sources of uncertainty. Thus, in order to understand the role that uncertainty¹ and risk taking play in entrepreneurship it is essential to examine these different aspects and explore what impact different types of uncertainty and risk have on the performance and actions of entrepreneurs.

An example of where distinguishing between different types of risk is important can be seen in the venture capital community. Venture capitalists often distinguish between technical risk, where there is uncertainty about whether they can get the technology to work, and market risk, uncertainty about whether a market exists even if they solve all the technical issues and have a good product. For example, a potential cure for cancer would likely have high technology risk, but low market risk. Clearly, the strategies for dealing with these different types of risk should not be the same. Demonstrating the importance of differentiating between different types of risk in entrepreneurial decision making venture capitalist Beth Seidenberg stated:

“We look for companies serving large markets. We are willing to take a lot of technical technology risk. A lot of people are surprised by this. They think that venture capital would be low technology and building markets. We think about it in a different way. We want big markets[...] Markets that are ripe and ready for creation and we will take a lot of technical risk and we do all the time.”—Beth Seidenberg, Kleiner Perkins Caufield & Byers²

Obviously, the difference between what Beth Seidenberg refers to as technology risk and the implicit risk associated with whether or not a market exists is very important in evaluating the strategy

¹ We use the definition of uncertainty as a lack of certainty, not Knightian uncertainty. Risk is defined as the potential of undesirable outcomes due to uncertainty.

²“A VC Perspective on the Life Sciences” (Seidenberg, 2008)

of a company, and the ultimate chances of survival.

In addition, entrepreneurship is often characterized by stiff competition where only the best firm(s) will survive. March (1991) points out competition where only a firm's relative performance determines success implies that the returns to increases in knowledge depends critically on the number of competitors and the variability of their performance. This is because when relative performance determines who the winners are it is not the average outcome of firms that matters, rather the extreme outcomes determine who wins (Gaba et al., 2004; Cabral, 2003; Gilpatric, 2009). A firm with a great outcome benefits not at all if its competition has even better outcomes, so in a market with a large number of competing firms, only firms with outcomes in the extreme right-hand-side of the tail of a distribution can hope to win. Thus, choices impacting the variability of performance are an important part of a firm's strategy.

To better understand the role of risk and how its role can differ across various contexts we differentiate between financial risk and strategic risk. We define financial risk traditionally, that is variance in financial returns. For example, entrepreneurial risks such as the risk of leaving a job, or of putting one's own wealth into a company are financial risks– the risky element of the decision is whether or not you will recoup your investment. Strategic risk arises from the strategic choices that impact the variability of performance which will in turn change the probability of beating the competition. An increase in strategic risk taking increases the probability of extreme product outcomes, both positive and negative, and is desirable when the only way to recoup your investment is to beat the competition. For example, in a winner-take-all competition whether you finish second or last your payout is the same. The level of strategic risk taking that is optimal maximizes the probability of beating the competition, and for a firm or individual is independent from personal risk tolerance. In a winner take all competition with 100 competitors, only an extremely good outcome has the chance of winning. Playing it safe is not being safe at all; it is only ensuring that you will lose. From the venture capital example above, market risk is a financial risk as it does not impact the chances of beating your competition. Instead, it influences the ultimate size of a market, which will impact the expected financial return. On the other hand, technical risk would likely be strategic risk in that it is what would determine the likelihood that the chosen technology will work better than the competition. In general, financial risk will determine the variance of the expected

financial returns while strategic risk impacts the variance of a firm's performance impacting the probability of winning.

This paper explores how strategic risk taking interacts with market structure to influence which, when, and why firms undertake risky projects. We develop a simple model of competition and risk taking where entrepreneurs choose whether or not to compete in a contest where the firm(s) with the best product quality or efficiency win. Entrepreneurs can take risks whether technological, organizational, regulatory, etc., that allow them to potentially be in a better position than their competition. To isolate strategic risk taking, we fix the market size and the subsequent reward that goes to the winners of the contest: fixing the market size ensures that the risks taken are how to meet market demand, not whether market demand exists. Whether or not the market exists is a financial risk; we want to isolate the factors driving strategic risk taking.³The market for cancer drugs is a good example of a market that fits our criteria where the best solution wins the market. For every cancer drug currently prescribed, there are scores of others that never made it to market because they could not improve on the efficacy of existing drugs or pass regulatory barriers. Whatever drug does the best job will capture almost all of its respective market if it performs marginally better than the next best alternative.

In this case, financial risk is solely a function of the cost of entry, the probability of winning if the firm acts optimally, and the profits that accrue to the winner. Strategic risk is determined by the level of risk, technical or otherwise, that a firm rationally chooses due to competitive effects. For the remainder of this paper the general term of risk will refer to strategic risk unless otherwise indicated.

³ Including market size as an endogenous factor that is influenced by the quality of a firm's product may strengthen the incentives to take risk, as even more emphasis is put on having higher outcomes, but confounds the reasons for doing so as risk taken to increase market demand would be financial risk, not strategic risk. This does not mean the market size cannot be uncertain, since the same results are found if the profits are expected profits given the uncertainty of the market since entrants are risk neutral, it just means that the entering firms have no influence over what the actual market size is.

The model shows that, due to competition, the optimal strategy for entrepreneurs is usually to take large amounts of strategic risk independent of their individual risk taking preferences. In fact, the only rational way a firm can expect to win if many homogeneous firms are competing in a market where only a few are expected to survive is to take significant amounts of risk. Further, the incentives for risk taking are increasing in the number of entrants relative to the number of winners the market will ultimately support. Conversely, if the number of competitors is very close to the number of winners, like occurs when the only real competition for a new market is between a few incumbents, firms will minimize the risk that they take.

We also model competition among heterogeneous firms representing the case where incumbents have an advantage over new entrepreneurial entrants due to complementary assets or superior capabilities. In this case, strategic risk taking disproportionately helps new entrepreneurial firms as opposed to incumbents. Consequently, the availability of risky strategies improves the competitive position of entrepreneurs with respect to incumbents, and accordingly enables higher entrepreneurial entry. The model also provides insight about which firms are most likely to produce radical innovations under various market conditions. The model's predictions are consistent with patterns of innovation by small and large firms found by Acs and Audretsch (1988). Thus, we offer an alternate explanation to why radical innovations disproportionately come from small entrepreneurial firms and why certain industries are more innovative than others.

2.2 Literature Review

From a modeling standpoint the paper most similar is Gaba et al. (2004). They use similar methods to analytically look at the benefits of different choice levels of variability and correlation of contestants performance in tournaments. They find similar results to ours for how the number of winners as a proportion of contestants impacts the optimal choice of variance. In fact, while the proofs are mathematically different, their Proposition 9 is essentially the same as Proposition 2 in this Chapter. They computationally look at the impact the interaction between how risky strategies and how correlated a contestant's performance is with the other contestants has on winning using

the multinomial normal distribution.

Similarly, Cabral (2003) explores the idea around risk taking due to heterogeneity in ability using a two person game where the laggard has an incentive to take risks when they choose the variance of their R&D portfolio. He also looks at the dynamic effects of either falling further behind or jumping further ahead of the other player over time by using an infinite horizon model.

Gilpatric (2009) has a model that entails agents who are able to choose both the effort and the variance of their output in a labor tournament model. He shows that for $n > 2$, contestants prefer higher variance. However, he only looks at the case where there is one winner with variance represented by a normal distribution, and he focuses on the contest designer's optimal prize structure to incentivize effort given the interplay between effort and variance. In his model the reason contestants choose high variance is at least partially to avoid costly effort. Gilpatric also considers the situation where there is a cost associated with increasing the variance by having the firms incur a monetary search cost. In contrast, we add this cost by using an asymmetric distribution. Gilpatric, avoids using an asymmetric distribution pointing out that it increases the complexity of the problem because the associated cost is indirect, but he hypothesizes that the implications would be similar.

From a conceptual perspective, March (1991) examines the importance of extreme outcomes when looking at relative performance. He explores the effects of organizational learning on performance and the importance of relative performance by determining the probability a firm will outperform all other firms using simulations, showing that only extreme performance matters when the number of competitors is high.

In contrast to these papers, we show that for homogenous competitors when the number of winners is small compared to the number of competitors taking the maximum amount of risk is a dominant strategy. This is required for a unique equilibrium. The analysis also differs from existing literature in that we consider the general case of all symmetric distributions, look at the non-symmetric log-normal distribution and explore heterogeneous contestants.

None of the above papers look at the impact of risk in an entrepreneurial setting, nor do they distinguish between different types of risks faced by contestants. Similar papers in the entrepreneurship literature that use the concepts of risk and uncertainty to explain the roles of entrepreneurs in

the market are Bhide (2003) and Baumol (2010). Bhide (2003) considers entrepreneurs as taking risks that larger companies don't want, but he never formalizes or develops when and why this occurs, while Baumol (2010) focuses on a model where entrepreneurs take on risks that large firms don't want to due to their intrinsic risk seeking nature. We offer an alternative explanation that is made possible by our distinction between financial and strategic risk. We formalize when and why entrepreneurs that are no more risk seeking than incumbents will take risk, and we show that this risk taking is essential to their ability to compete.

In general little work decomposing the different types of risks that entrepreneurs face has been done. The main exception is Wu and Knott (2006) who differentiate between demand uncertainty and ability uncertainty. They find that entrepreneurs are risk averse when faced with market uncertainty, but exhibit overconfidence and are risk seeking with respect to ability uncertainty.

From an entrepreneurial competition perspective, Spulber (2009) looks at how competition and innovation interact to determine technological progress and industry structure. He allows firms to invest in innovation, but his model differs as firms do not choose the variance of their strategies. The driving factor is asymmetric information about competitors innovations and price competition. He is able to show that due to asymmetric information conditions exist under which competition can lead to Schumpeterian creative destruction and that firm heterogeneity can persist.

The outline of the rest of the chapter is as follows. Section 3 describes the general model. Section 4 looks first at symmetric risk distributions and the impact of competition on strategic risk taking among identical firms. Then the symmetric assumption for the risk distribution is relaxed and asymmetric skewed distributions are considered. Section 5 allows for heterogeneity of entrants, capturing the dynamics between incumbents and entrepreneurial entrants. Section 6 discusses the robustness and extensions of the model. Section 7 then considers applications of the model and concludes.

2.3 The Model

Consider a rank order tournament (contest) between n risk-neutral firms with m , $1 \leq m \leq n - 1$, winner(s) receiving the right to compete in a market and the associated profit, $\pi_i^W \in (0, \infty)$, $\pi^W = (\pi_1^W, \dots, \pi_n^W)$. The losing players receive π_i^L , $\pi^L = (\pi_1^L, \dots, \pi_n^L)$. We let the number of entrants,

n , be determined by free entry with a fixed cost of entry, $c \in (0, \infty)$. Let N denote the set of all entrants. Players are ranked according to their product quality (or efficiency), q_i . Player i 's product quality⁴ is given by

$$q_i = a_i + t_i \quad (1)$$

where a_i is the ability of firm i , $A = (a_1, \dots, a_n)$, and level of technology, t_i . The level of a firm's technology is a realization of a random variable where $f(t)$ is the PDF of t . The variance of $f(t)$ is σ^2 , where σ^2 is additively determined by the irreducible industry riskiness, η , which is assumed to be exogenous, and firm i 's choice of risk as part of its individual firm strategy, s_i , such that $\sigma^2 = \eta^2 + s_i^2$ and $s_i \in [0, s_{max}]$, $S = (s_1, \dots, s_n)$. Changes in σ imposed by different firm strategies are assumed to be mean preserving increases in risk with the CDF's meeting the single crossing property as defined by Diamond and Stiglitz (1973). Thus, a firm doesn't choose its t_i , rather it chooses the variance of the distribution from which t_i is chosen. In this sense, t can be interpreted as a measure of innovation and increases in efficiency of a firm's product.

Profits are a function of the number of winners. It could be the case that the winners just split a constant profit pool, π^T , such that $\pi^W(m) = \frac{\pi^T}{m}$, another scenario would be where competition drives down profits for all winners such that $\pi^W(m') > \pi^W(m)$ for $m > m'$. The variables m , c , η , s_{max} , π^W , and the distribution $f(t)$ are all exogenously determined by industry characteristics. A firm is characterized by the firm specific measure a_i . The firm's only choice variable is s_i .

After each firm realizes its value of q_i , the firms with the top m values of q win the right to compete and the associated profit, π^W . Firm i is ranked higher than firm j if $t_i > t_j + a_j - a_i$. In the case of a tie, the tie breaking rule is that each of the tied firms win with equal probability.

Let $G_i(x; N_{-i}, m, A_{-i}, \eta, S_{-i})$ be the probability that firm i is a winner in the tournament if $t_i = x$. Since entrant i wins if q_i is in the top m values of q , the distribution $G_i(x; N_{-i}, m, A_{-i}, \eta, S_{-i})$ is just the CDF of the $(n - m)$ th order statistic. Thus, the probability that firm i is a winner is given by

$$P_i = \int_{-\infty}^{\infty} f_i(x + a_i; \eta, s_i) G_i(x; N_{-i}, m, A_{-i}, \eta, S_{-i}) dx \quad (2)$$

⁴ A firm's production efficiency could be used instead of product quality without making any changes to the model.

The timing of firms choices occurs in two stages. In the first stage, firms decide whether or not to enter. In the second stage, those firms that entered observe the total number of entrants and choose their level of risk, s_i . Firms know who their competitors are and who else is entered into the new market. The parameters $\pi^W(m)$, $\pi^L(m)$, m , c , A , s_{max} , η and the distribution $f(t)$ are all common knowledge throughout the game.

2.4 Optimal Risk Taking Among Identical Firms

This section analyzes competition among homogeneous entrants. Thus, without a loss in generality we can assume $a_i = 0$, for all i . We assume there are infinite potential entrants, all of which have an outside option of 0. We start with the case where $f(t)$ is a symmetric distribution. The analysis is then extended to the case when there exists an indirect cost to increasing the individual variance component of $f(t)$, s_i , by allowing for asymmetric distributions that are positively skewed.

2.4.1 Optimal risk taking with symmetrical risk distributions

Let m be the number of “winners” with all winners splitting the value equally so $\pi_i^W(m) = \frac{\pi^T}{m} > 0$ and the losers getting nothing, $\pi^L = 0$. The firms’ profit maximization problem is then

$$\max_{s_i} \pi_i = \pi_i^W(m)P_i - c \quad (3)$$

In the first stage firms decide whether or not to enter. With homogeneous entrants $E[P_i] = \frac{m}{n}$, and entry will occur until the point where one more entrant would cause the expected profits to become negative.

Proposition 1. *The number of entrants is weakly increasing in profits, $\pi^W(m)$, weakly decreasing in the entry cost, c , and the number of entrants can be characterized by,*

$$n = \lfloor \frac{m\pi^W(m)}{c} \rfloor \quad (4)$$

Once entered, firms observe the total number of entrants and choose their level of risk, s_i . From Equation 3 we can see that, once entered, profits are strictly increasing in P_i , so the maximization decision for the firm is to maximize the probability that they win, P_i .

The probability of firm i winning is

$$\begin{aligned}
P_i &= \int_{-\infty}^{\infty} f_i(x; s_i) G_i(x; n, m, S_{-i}) dx \\
&= F_i(x; s_i) G_i(x; n, m, S_{-i}) \Big|_{-\infty}^{\infty} - \int_{-\infty}^{\infty} F_i(x; s_i) g_i(x; n, m, S_{-i}) dx \\
&= 1 - \int_{-\infty}^{\infty} F_i(x; s_i) g_i(x; n, m, S_{-i}) dx
\end{aligned}$$

then

$$\frac{\partial P_i}{\partial s_i} = - \int_{-\infty}^{\infty} \frac{\partial F_i(x; s_i)}{\partial s_i} g_i(x; n, m, S_{-i}) dx \quad (5)$$

by symmetry $F_i(-x; s_i) = 1 - F_i(x; s_i)$ so

$$\frac{\partial P_i}{\partial s_i} = \int_0^{\infty} \frac{\partial F_i(x; s_i)}{\partial s_i} g_i(-x; n, m, S_{-i}) dx - \int_0^{\infty} \frac{\partial F_i(x; s_i)}{\partial s_i} g_i(x; n, m, S_{-i}) dx \quad (6)$$

From Equation 6 we can see that the directional impact of changing s_i will depend on the relationship between $g(x)$ and $g(-x)$. The intuition of how $g(x)$ impacts the is best illustrated by first considering a contest that has only one winner. With only one winner, a firm that does not have the best product of all the competitors loses independent of whether that firm has a great or a terrible product. If there are only 2 players, the distribution of a player winning given a certain performance is just whether or not it is better than the other player, or $F_{-i}(x)$. For mean preserving changes in risk about a symmetric mean, the probability of winning with two symmetric distributions does not change with an increase in the variance as $g(x) = g(-x)$. However, when $n > 2$, the distribution of a player winning with a given performance changes to be a left skewed distribution, with more weight on the upper end (right hand side). The larger n is, the more skewed the distribution becomes. This is illustrated in the first graph in Figure 1 Because of this, the weight on the upper end of the distribution matters increasingly more than on weight on the low end and

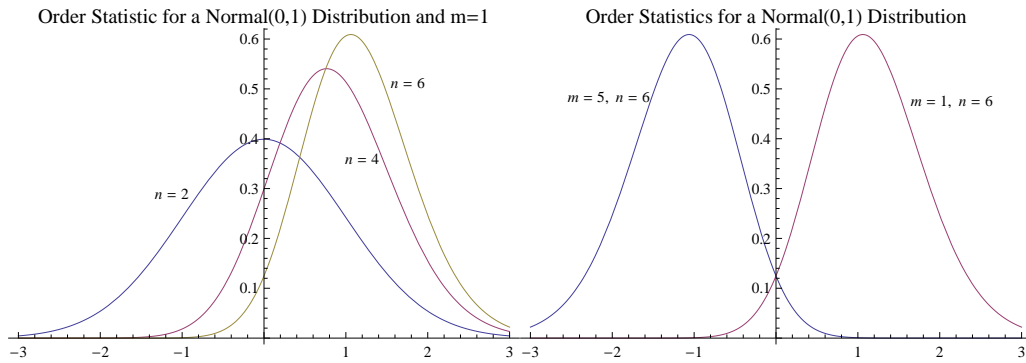


Figure 1: The impact of the number of competitors, n , and the number of winners, m , on the probability of winning with a given performance

middle as n increases. Increases in variance increase the weight in the tails, at the expense of the weight in the middle of the distribution. Thus, an increase in variance comes at a cost of an increase in bad outcomes, and a decrease in mediocre outcomes, but since the cost of both is the same if the entrant loses, and the chances of winning with either are slim, the net impact of increasing variance in these regions is slim. However, the increase in the weight of the right tail significantly improves an entrant's chances at winning, so entrants are better off taking higher variance strategies.

This leads firms to focus on increasing the probability of extremely good outcomes at the expense of experiencing extremely poor performance more often. In this way competition drives rational, risk neutral entrepreneurs to take the maximum amount of risk. *It is not that the entrepreneur is risk seeking, rather competition drives extreme risk taking behavior, and the only rational way to expect to win is to take as much risk as possible.* This can make it appear that risk neutral players are risk seeking when considering their decisions and outcomes in isolation. Thus, there is a certain amount of risk taking that successful entrepreneurs engage in not because they are risk seeking or want a high risk/return ratio, but because risk seeking in choosing larger mean preserving spreads is the rational choice to maximize the probability of success. It is true that entrepreneurs risk preferences could impact the risks they take associated with entry depending on parameters such as the cost of entry, c , expected profits etc., but none of these have to do with the amount of strategic risk taken by an entrant. Examining strategic risk separately allows us to understand better what the types of risks entrepreneurs face and how the strategies to deal with each can vary.

Interestingly, the same forces that drive risk taking when there are few winners with many competitors also drive firms to avoid risk when the number of competitors is close to the number of winners the market will support. An example of this is when you have four incumbents that all have the necessary abilities to enter a new market, and the new market can support three of them. If the market structure and potential advantage these incumbents have over entrepreneurs leads to no new entry, then the firms would compete to not be the worst firm, as opposed to trying to be the best firm. All firms would then minimize variance and choose the safest strategy. Here competition leads to less risk taking, and subsequently to less innovation. Figure 1 illustrates how when there is only one winner the incentives are to take strategic risk when $n > 2$, as well as the symmetric argument for firms to minimize risk when there is only one loser firms by looking at the distribution of the order statistic under these conditions.

To develop the intuition behind this result think of the case where $\eta = 0$. For $n = 4$ and $m = 2$ if an entrant chooses $s_i = 0$ then $q_i = a_i$. If all firms choose the same, then by the tie breaking rule each wins with a probability of $\frac{1}{2}$. If firm i sets $s_i > 0$ then $q_i > q_j$ for all $j \neq i$ with a probability of $\frac{1}{2}$ since by symmetry half the time they will obtain a value greater than the average and half the time less than the average. Thus, the choice of s_i has no bearing on whether or not they win. Now, suppose $m = 1$. If all firms choose $s_i = 0$, then they all win with a probability of $\frac{1}{4}$. However, if one firm chooses $s_i > 0$ it will win with a probability of $\frac{1}{2}$ as its q_i will be greater than the mean half of the time. All other firms face the same choice, and they all end up taking the maximum amount of risk. On the other hand, if $m = 3$, then if all entrants choose $s_i = 0$ they win with probability $\frac{3}{4}$. By choosing $s_i > 0$ when all other entrants choose $s_i = 0$, an entrant will now be less than the average half the time, and his probability of winning drops from $\frac{3}{4}$ to $\frac{1}{2}$. Thus, none of the entrants will choose to take any risk. One way to think of the differences is that if $\lambda = \frac{m}{n}$ then when $\lambda < \frac{1}{2}$ firms are choosing their strategy “to win”, whereas when $\lambda > \frac{1}{2}$ firms are choosing a strategy “to not lose”.

The following proposition formalizes the impact of λ on the optimal amount of strategic risk a firm should take.

Proposition 2. *Let λ be the proportion of entrants that win, so $\lambda = \frac{m}{n}$. Then for any symmet-*

ric, continuous and differentiable distribution of risk, $f(t)$, the unique equilibrium strategy for n identical firms is such that:

- (i) when $\lambda < \frac{1}{2}$ firms choose the maximum amount of strategic risk possible such that $s_i = s_{max}$;
- (ii) when $\lambda > \frac{1}{2}$ firms choose the minimum amount of strategic risk possible such that $s_i = s_{min}$;
- (iii) when $\lambda = \frac{1}{2}$ the choice of strategic risk, s_i , has no impact on the probability of winning, P_i

2.4.2 Asymmetric risk distributions

The ability to increase the variance may come with a cost. Gilpatric (2009) investigates the case where there is a monetary cost associated with finding mean preserving increases in the spread of the distribution while maintaining the assumption of a normal distribution. Often though, this may not be possible due to time/cost constraints or that symmetric increases in the spread are just not available. Also, in some cases such as Cabral (2003), entrants have a fixed R&D budget but can compete by choosing which projects, and their associated risks, to fund. In these cases spending more money to preserve the mean may not be possible. A lot of technological risk is in this category where it is possible to shoot for a better solution, but only by increasing the probability of failure. This type of cost can be represented by a right skewed distribution by capturing the case where while you increase the upside, or probability of a better outcome, it only comes at an increased probability of failure. Thus, while increasing the variability doesn't impact the mean, it shifts down the median, whereas in the symmetric case the mean and median are always equal. An example of this would be the log-normal distribution shown in Figure 2, where a mean preserving increase in variance comes at the cost of a greater probability density to the left of the mean, which increases the chances of a poor outcome and subsequent failure.

Using the log normal distribution, $f_T(t; \mu, \sigma) \sim \ln N(\mu, \sigma)$, as an example we see that firms may not want to choose s^{max} . As the variance increases the value of the CDF at the mean increases as well, and for the log normal you reach a point where increasing variance has a detrimental impact on your chances of winning. For example, take the case where $a_i = 0$, $m = 1$, $n = 3$, and $\bar{\mu} = 1$. By choosing zero variance a firm obtains a value of 1 with certainty. Now, initially if all firms have

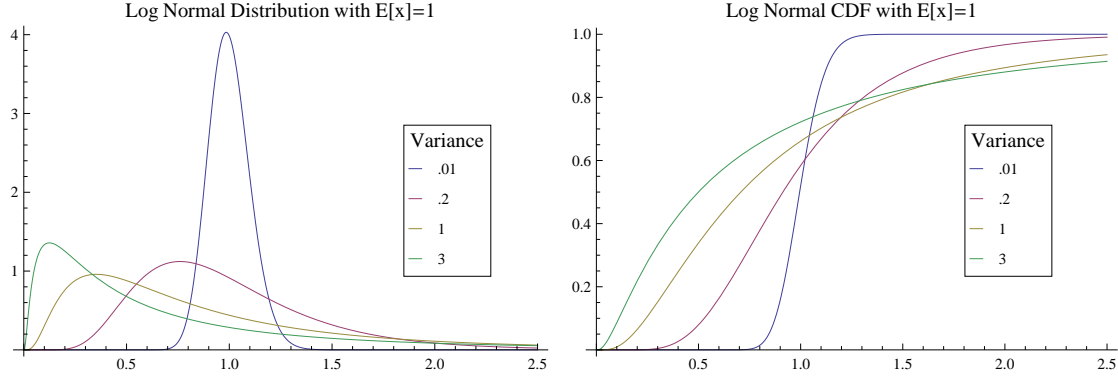


Figure 2: The log normal distribution with a constant mean and differing variance

chosen zero variance, a firm can choose a very small amount of variance such that the probability of achieving a value greater than 1 is $.5 - \varepsilon$. The firm would now win approximately one-half the time, while choosing no variance would lead to winning $\frac{1}{3}$ of the time. So there is an incentive to take on risk. On the other hand, once firms choose variance you eventually reach a point where the probability of winning is lower with an increase in variance. This is illustrated by Figure 3. As the variance increases, the CDF evaluated at the mean approaches one. At high variances, the firm could always do better by choosing zero variance, and obtaining the mean value with certainty.

Since there is no dominant strategy in this case we need to use the firm's reaction function to find the equilibrium. The reaction function for firm i is

$$\max_{s_i^*} \int_{-\infty}^{\infty} f_i(x; s_i) G_i(x; m, n, S_{-i}) dx$$

with the FOC

$$\frac{\partial P_i}{\partial s_i} = \int_{-\infty}^{\infty} \frac{\partial f_i(x; s_i)}{\partial s_i} G_i(x; m, n, S_{-i}) dx = 0$$

For a symmetric equilibrium, we can reduce the problem to a case where the order statistic probability can be represented as the sum of a binomial probability function

$$G_i(x; m, n, S_{-i}) = \sum_{i=m}^{k-1} \binom{k}{i} [F(x)]^i [1 - F(x)]^{k-1}$$

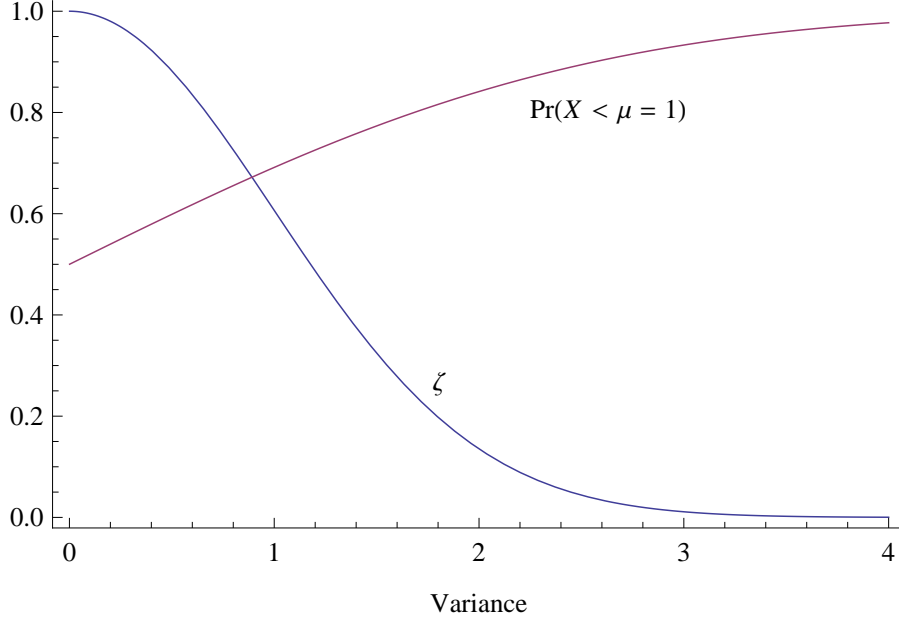


Figure 3: Values of the median, ζ , and the probability of an outcome less than the mean, $\Pr(X < 1)$, for mean preserving spreads for the Log Normal Distribution with $E[x] = 1$.

where $k = n - 1$. This is equivalent to the regularized incomplete beta function

$$I_{F(x)}(a, b) = \frac{B(F(x); a, b)}{B(a, b)}$$

where $B(F(x); a, b)$ is the incomplete beta function, $B(a, b)$ is the beta function, $a = n - 1 - m$, and $b = m + 1$.

Using this, we can solve for the Nash equilibrium. Figure 4 illustrates the equilibrium choices of risk for the log normal and $m = 1$, while varying n . As the number of entrants rises, the benefit from taking risks increases as the expected outcome needed to win also increases. It takes a higher and higher realization to beat the competition as n increases. Since n is increasing in π^W , and decreasing in c , $\frac{\partial s_i^*}{\partial c} \leq 0$ and $\frac{\partial s_i^*}{\partial \pi} \geq 0$.

Even though we don't know exactly how changes in m will impact risk taking since it enters both directly, as well as indirectly through the profit function, we can still obtain directional results. Consider where $\pi^W(m) = \phi(m)\pi^W$ and $\phi(m) \in [0, 1]$, then as shown in Figure 5 the extreme case where $\phi(m) = 1$, as m increases the equilibrium level of risk decreases. We can take any other case where $\phi(m) < 1$ and the impact would be to decrease π^W , further reducing the equilibrium level of

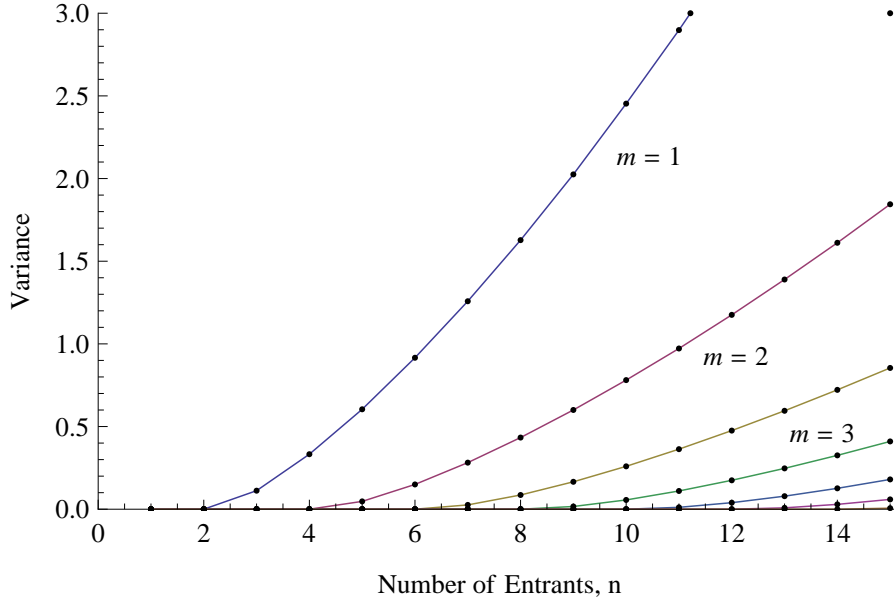


Figure 4: Equilibrium risk for log normal distributed risk with m winners and changes in n

risk. Under these conditions then, $\frac{\partial s_i^*}{\partial m} \leq 0$. In this context m can be interpreted as being a function of the efficient size of a firm due to economies of scale.

The intuition behind these comparative statics is relatively straightforward. The number of other entrants that you have to beat increases in n and decreases in m , and the impetus behind taking risks once $\frac{m}{n}$ is determined is that all decisions are about winning and being in the top m of entrants. Thus, λ , the ratio of winners to entrants, is going to drive the number of other entrants you have to beat.

However, λ alone is not enough to predict risk taking. For any given λ , where $s^* > s_{min}$, s^* is increasing in n . The reasoning for this is similar to that of the Law of Large Numbers since probability of a certain percent of firms being above a certain threshold for a given λ decreases as the overall number of entrants increases. This increases the benefits of choosing higher risks as the chances of all firms getting a rather high valuation decreases with n . Thus, the reward for taking more risk increases with n , as the increased density in the right hand of the tail from taking more risks is more likely to lead to winning.

This is illustrated in Figure 6. This represents a situation where an economy is effectively replicated as it gets larger. An example of where this would apply could be to different geographic markets. While it may be the case that λ is the same across the different markets in an industry,

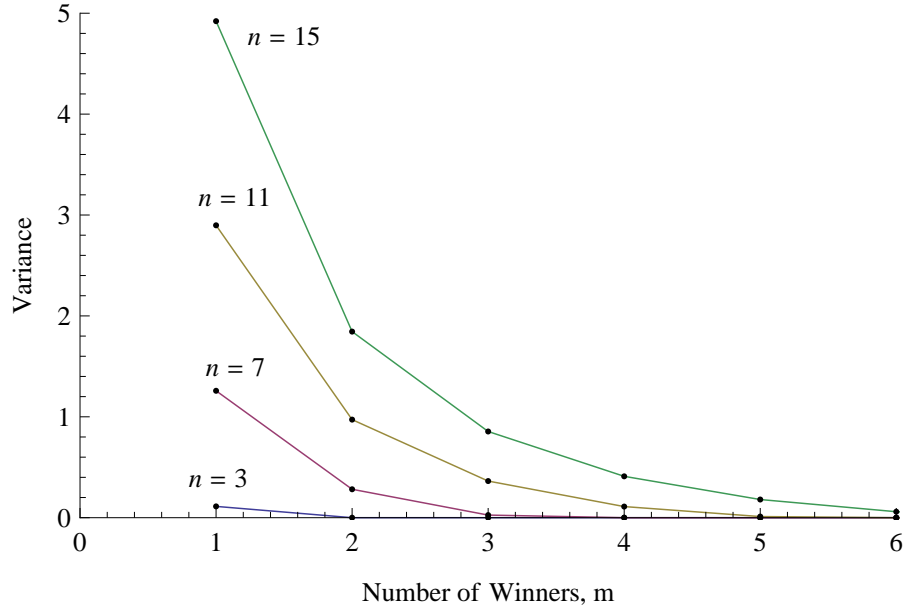


Figure 5: Equilibrium risk for log normal distributed risk with n entrants and changes in the number of winners, m

entrepreneurs in larger markets would take larger risks in equilibrium.

To help understand the impact of various variance choices associated with the above comparative statics Figure 3 shows how the median and probability of obtaining a value below the mean, the risk-less outcome, change. For example, for a Log Normal distribution with a mean of one, if the equilibrium variance is two, then $\zeta = .13$ and $Pr(X < 1) = .84$.

As far as the economic feasibility of these values, Venture Capital firms investing in new firms in emerging industries are usually considered successful if they have two or three out of ten investments succeed. Further, these investments are usually only given to the better firms, so industries where λ is in the range of one-fifth or one-seventh, or even higher, seems to be well within reason for high technology and similar industries. Similarly, other industries may not be as conducive to risk taking if the ratio of winners to entrants is higher.

We can use these results to examine how industry structure influences innovation. For example, if the potential profits are quite high, you would expect that there would be very high entry driving λ to a relatively small value and subsequently a high level of risk taking. While this would be the classical high risk/high return story, the risk taken in entering is correctly identified as financial risk, but this is very different from the choice of strategic risk which is also very high in this case.

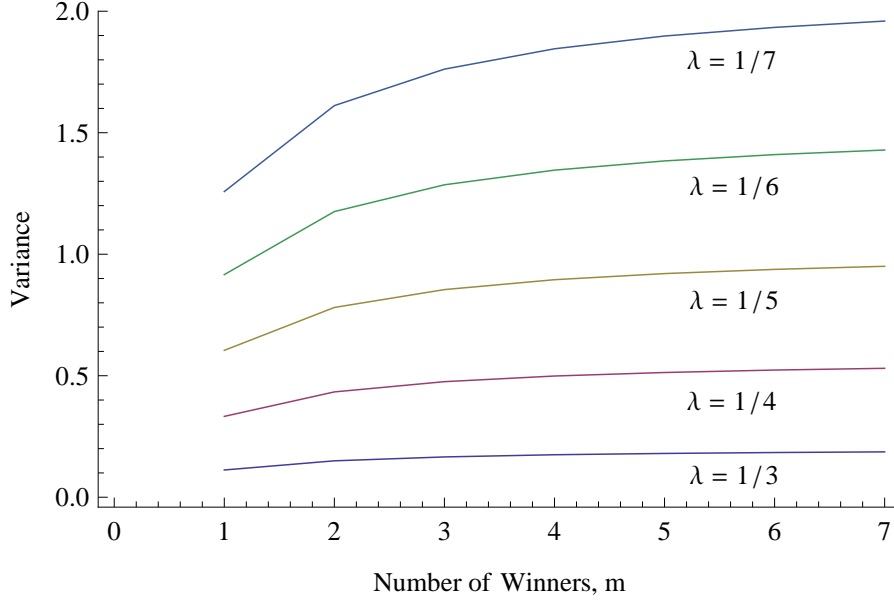


Figure 6: Equilibrium risk for a given λ as the number of participants increases

Strategic risk taken in this situation is not taken due to the high risk/high return from actions, but because the large number of entrants drives competitors to take high levels of strategic risk. Similarly, low barriers to entry drive entry, and the subsequent competition increases risk taking and subsequent innovation.

Proposition 3 formalizes the intuition around the equilibrium choice of strategic risk for asymmetric distribution. Because of the discrete nature of the number of entrants and winners it is not possible to use comparative statics to see how the equilibrium changes with the number of entrants, n , and winners, m . Thus in order to formalize the intuition on asymmetric distributions, for this proposition we assume that there is a mass of players, n , and that a mass of entrants, m , will survive. The proportion of entrants that survive is given by $\lambda = \frac{m}{n}$, and this is a continuous parameter with $\lambda \in [0, 1]$.

Proposition 3. *Let λ be the proportion of entrants that win, so $\lambda = \frac{m}{n}$. Then for the case where the firms technology level is determined by the log normal distribution, $f(t; \mu, \sigma) \sim \ln N(\mu, \sigma)$, the unique symmetric equilibrium strategy for n identical firms is:*

(i) when $\lambda < \frac{1}{2}$: Firms choose strategic risk such that $s_i = \sqrt{2}\Phi^{-1}[1 - 2\lambda] - \eta^2$ and $s_i = 0$ if $\eta^2 > \sqrt{2}\Phi^{-1}[1 - 2\lambda]$. The choice of strategic risk, s_i , is increasing in n , $\frac{\partial s_i}{\partial n} > 0$, and decreasing

in m , $\frac{\partial s_i}{\partial n} < 0$.⁵

(ii) when $\lambda \geq \frac{1}{2}$: Firms choose the minimum amount of strategic risk possible such that $s_i = 0$.

2.5 Optimal Risk Taking with Heterogeneous Firms

This section analyzes competition among heterogeneous firms to gain insight into the dynamics that arise when incumbents and new entrants can compete for the same market. It is fairly well understood that in many competitive settings the underdog prefers to have a riskier game, or at least is more likely to take risks to try and catch up (Cabral, 2003). Further, often incumbents have different cost structures and abilities which may lead to different risk strategies. Following the established tournament literature in labor economics we break tournaments between heterogeneous competitors into unfair and uneven tournaments. In an unfair tournament, a player has the lead and will beat their opponent given identical efforts and outcomes. In our model, entrant i having this type of advantage is represented by $a_i > a_j$. This can occur because of assets or skills that incumbents possess such as access to distribution channels or superior manufacturing ability. In an uneven tournament, players have different costs or preferences. An example of this occurs when π^W and π^L vary amongst players. An example of an uneven tournament is when incumbents value losing with a high value more than losing with a low value as it could help in the negotiations and ease of acquiring a winning firm. This is the case found by Henkel et al. (2010) in their study of the electronic design industry, where new entrants competed on the riskiness of their R&D approach, and incumbents acquired the best firm. In this case the incumbents would still perform R&D and try to develop the best product themselves, but unlike the entrants they valued losing with a higher value as it increased their bargaining position when acquiring one of the entrants. Similarly, an incumbent can obtain value from R&D to help in knowledge transfer even if it lost and had to acquire the technology of one of the entrepreneurial entrants.

⁵ Φ is the standard normal CDF

To capture the intuition of an incumbent with an advantage in the simplest and most intuitive way, we will focus on unfair tournaments, but we recognize that there are many variations of uneven tournaments that could impact risk taking as well.

Incumbents usually have a significant resource advantage over entrepreneurs. This advantage can be in the form of complementary assets, R&D resources and/or superior capabilities. To model this let $a_i = a^I$ for incumbents, and let $a_i = a^E$ for new entrepreneurial entrants with $a^I > a^E$. This is an unfair tournament where $a_i \neq a_j$ and firm i wins the tournament if $t_i > t_j + a_i - a_j$ for all $j \neq i$. The winners' profits are the same for all regardless of whether an incumbent or entrepreneur wins. Also, the cost of entry is the same for incumbents and entrepreneurs. Similar to section 4.1, to help simplify the analysis and to gain insights into the underlying forces at play, we look only at symmetric distributions.

For $s^{max} < \infty$ the probability an incumbent wins is greater than an entrepreneur, and given equal entry costs, incumbent firms will always have the advantage over new entrants. Because of this and the fact they already are present in the industry, we allow them to credibly commit to enter any new profitable markets first. Thus, new entrepreneurial firms will enter only if there is room for more entrants above the level of incumbents. If there is room for more entry after all of the incumbents have entered, then entrepreneurial firms will evaluate their chances of success against the incumbents. They will then choose whether or not to enter based on how big the market is, the size of the advantage that incumbents hold, etc. In the first stage when entrepreneurial firms are deciding whether or not to enter, the only relevant question is whether or not they will make positive profits. Because firms are not divisible, positive profits will occur in the form of the remainder that occurs from dealing with integer division. Entry occurs until one additional firm results in negative profits.

Proposition 4. *For an industry where $a^I > a^E$, $s^{max} < \infty$, and N^I incumbent firms exist, if*

$$n = \lfloor \frac{m\pi^W(m)}{c} \rfloor < N,$$

then n will be the unique equilibrium number of entrants, and only Incumbents will enter. If

$$n = \lfloor \frac{m\pi^W(m)}{c} \rfloor > N,$$

then all incumbents will enter and a unique subgame equilibrium exists with respect to the number of entrants, n^* .

In contrast to the homogeneous case, incumbents now have to factor in how their choice of risk will impact their competitive position against other incumbents as well as entrepreneurs. For example, when $\lambda > \frac{1}{2}$ it is beneficial for incumbents to minimize risk given competition against other incumbents and entrepreneurs. However, for $\lambda < \frac{1}{2}$ an incumbent increases his odds against other incumbents by taking more risk, but by doing so the incumbent may increase the chances that it is beat by the entrepreneurial competition. As you would expect by the symmetry of the model, for entrepreneurs the choice is similar but reversed. Whenever the impact of taking more risk will help them against other entrepreneurs, it will also help against incumbents. However, for $\lambda > \frac{1}{2}$ there are two competing forces. While competition with other entrepreneurs pushes entrepreneurs to minimize risk, entrepreneurs increase the odds of beating incumbents by choosing more risk. Which of these two forces wins depends on the size of the advantage incumbents possess and number of entrepreneurs and incumbents. The one constant however, is that in all cases entrepreneurs risk strategies are riskier than or equally risky than the strategies of incumbents. Proposition 5 formalizes this intuition.

Proposition 5. *Let f be a symmetric distribution $f(\cdot)$. If $\lambda < \frac{1}{2}$, entrants choose $s_E = s_{max}$; and if s_{max} is small relative to $a^I - a^E$, incumbents choose $s_I = 0$. When s_{max} is not small relative to $a^I - a^E$, incumbents will choose $s_I > 0$. If $\lambda > \frac{1}{2}$, incumbents choose $s_I = 0$; entrepreneurs choose $s_E > 0$ if $a^I - a^E$ is sufficiently large. Thus, incumbents will choose to take less strategic risks than entrepreneurs, and $s_I \leq s_E$ for all λ .*

Because entrepreneurs can use risky strategies to help reduce an incumbents advantage, the inherent level of risk in an industry as well as how available risky strategies are has a direct impact on entrepreneurial entry and success.

Proposition 6. *Entrepreneurial entry is weakly increasing with respect to the maximum available strategic risk, s_{max} , and the underlying industry uncertainty, η^2 .*

The probability that an entrepreneurial firm wins when competing with incumbents increases with s_{max} . When $s_{max} = \infty$, the problem reduces to the homogeneous firm case with the incumbents advantage completely lost. Similarly, increases in η^2 force the incumbent to take risks that diminish his advantage. Once again, in the extreme when $\eta^2 = \infty$ the incumbents' advantage vanishes when $\lambda < \frac{1}{2}$. Proposition 5 confirms the intuition that disadvantaged firms benefit more from luck than do firms in an advantageous position. Thus, the higher the potential role that luck can play in an industry, the more attractive it is to entrepreneurial entrants. Moreover, entrepreneurial entry can actually induce incumbents to take riskier strategies thereby increasing innovation. For example, in an industry with no uncertainty, if $N^I > m$ there is no entrepreneurial entry. Take the case where $m = 2$ and $N^I = 3$. Then even if the ratio $\frac{\pi^W}{c}$ is quite large, no entrepreneurs enter, and incumbents take no risk as $\lambda > \frac{1}{2}$. However, if s_{max} is large, then entrepreneurial entry occurs. In the case $s_{max} = \infty$, the entry and risk taking of the entrepreneurs forces incumbents to take maximum risks as well, as they no longer have an advantage and λ is less than one-half.

Uncertainty and the ability to take risky bets enables entrepreneurship. This once again calls into question the direction of causality of the link between risk taking and entrepreneurs. Instead of wondering why entrepreneurs persist despite high failure rates, our model suggests that high failure rates of entrepreneurs may be a sign of entrepreneurial opportunity. Entrepreneurship is enabled by the opportunity to take risks when competing against established incumbents.

When looking at entry this has interesting implications. In general, incumbents have many advantages over entrepreneurs. In the context of our model, a high value of a_i could be interpreted as a firm having an advantage in the necessary complementary assets (Teece, 1986), or as the firm having better R&D capabilities or financing raising the expected outcome of its R&D. When the

advantage is conferred by complementary assets, an incumbent firm can win the market even if it has an inferior technology. In this case, we anticipate that the incumbent will acquire the loser's technology. In fact, this is a very common occurrence in many industries. If an entrepreneur wins necessarily it is because he has a vastly superior technology. This leads us to expect that entrepreneurs indeed have a disproportionate number of major innovations.

2.6 Extensions

In this section we first look at the robustness of results to a few simple extensions. To keep the discussion at an appropriate level and not go beyond the scope of this paper we keep the mathematical formalities to a minimum. We also look at empirical implications and discuss some applications of our findings.

2.6.1 Extensions

Unequal Profits and Endogenous Market Share

The model can be extended to either have different profits for the m firms that win with the higher ranked firms being more profitable, or to endogenously let the profits of a firm be reflected by the market share captured which is a function of its realized q_i , which can be interpreted as the firms technology efficiency or attractiveness. In both of these cases the general intuition remains. In the first case, we can say that an industry where profits are split unevenly among the top m firms will have higher risk taking than if the profits were split evenly. For example, take the case where $m = 4$. When m firms split profits evenly each gets $\frac{\pi}{m}$ or 25% of the profits. Now instead let 70% of the profits go to the highest ranked firm, and each of the other 3 winners gets 10%. Ex ante profit expectation would be the same so n remains the same. It is obvious that the incentives to finish first are increased, which in turn increases the optimal amount of risk in comparison to when profits are split evenly.

Similarly, when profits are a function of market share and determined endogenously ex ante entry should remain the same. This will occur as long as there is either a fixed number of winners that share, or a cost of operations going forward so firms with lower market share drop out you. Likewise, if an industry has a minimum level of performance or volume required the number of ultimate winners, m , is determined endogenously if firms gain market share based on their performance or ability. In both of these cases you can compare the expected number of winners, m , to the case where m winners share evenly and risk taking will always be higher in the case of uneven profits as the incentive to have higher realizations of quality is increased. In this way, relative market shares will be determined endogenously similar to traditional models of entry and exit by Hopenhayn (1992), Jovanovic (1982), and Lippman and Rumelt (1982) where firms enter and then learn how efficient they are. In all of these models they assume a random realization of entrants efficiency or cost function. In this case with the assumption of identical firms with a normal distribution on risk, the the entry distribution equilibrium would be for all firms to choose the max risk leading to endogenous heterogeneity.

Remark 1. Competition drives ex ante identical entrepreneurs to take risky strategies, endogenously leading to heterogeneity of firm performance.

This result provides a nice alternate explanation for the observed heterogeneity of entrants in a new industry that is assumed in many Industrial Organization models. In the case of firms taking technological risk the firms the heterogeneity would also persist to the extent that the different technological outcomes are protected from imitation by secrecy, intellectual property rights and/or causal ambiguity.

From an industry perspective higher heterogeneity of firm performance would exist when risky strategies available, and the number of winners is small compared to the number of entrants. Perhaps many of the most successful firms are in the position they are because of a few lucky outcomes in highly uncertain industries.

Costly Changes to Variance

While asymmetric distributions added an indirect cost to increasing a firm's variance it may be the case that there is a direct cost in finding and implementing mean preserving spreads. Gilpatric (2009) looks at a similar example where agents that are compensated according to a labor tournament can increase the variance of their output through mean preserving spreads of risk, but at a cost. An example of such a cost is a search cost that is incurred to find these mean preserving spreads of risk. Similarly, a firm may want to reduce the variance of its performance if it has an advantage, or if $\lambda > \frac{1}{2}$. The firm's new profit maximization problem is then

$$\max_{s_i} \pi_i = \pi_i^W(m)P_i - c_{entry} - c_{variance}(s_i)$$

The intuition of how much risk a firm would want to take would be similar to what was found in Section 4, where risk taking increases in n , and decreases in m .

Dynamics

While the model presented was static, we can still gain insights into implications in a dynamic setting. For example, if we take the traditional industry evolution models as discussed in the previous section on endogenous market share, the first period would be identical to the case of homogeneous competitors. For subsequent periods, the insights from Section 5 where we looked at heterogeneous competition would hold if we took the previous period's realization of q_i and made that a_i in the subsequent period.

This would be analogous to how firms evolve over time in the traditional models of entry and exit by Hopenhayn (1992), Jovanovic (1982). Firms would either exit or stay each period based on their realization, and incumbent firms with good realizations in the previous period would be at an advantage. The results from Section 5 then dictate the level of entry of new entrepreneurial firms, the comparative level of risks taken, and the fact that uncertainty would help these new firms disproportionately compared to incumbents.

Interestingly, if we allow firms to vary in their ability to change variance as discussed in the previous section where firms must pay a cost to change the variance of their strategy, it is feasible that

some firms would have capabilities in finding ways to increase variance while others capabilities to reduce variance. Firms that had the capabilities to succeed as an entrepreneurial entrant would then be ill suited to maintain their position as an incumbent that would want to reduce variance. This implies that different skill sets are required over the life cycle of a firm.

Individual ability to differentiating between different types of risk

Another interesting avenue is to explore how new entrepreneurs view the difference between different risks that they take, and whether or not some entrepreneurs are ignorant of competitive effects. If so, when the rational equilibrium is to take high levels of risk, those that are less risk averse will have the advantage under many circumstances. Only if players do not take competition into account will they view strategic risk taking as increasing the risk of the game. Behavioral economics has shown that entrepreneurs are susceptible to various behavioral biases that lead them not to take into account competition and its impact on the optimal choice of risk. Two of these are the “inside view” and the “illusion of control” (Camerer and Lovallo, 1999; Kahneman and Lovallo, 1993). Also, traditional business finance is generally taught using NPV and related measures that would make risk appear to be a choice independent of what the competition is doing. The implications of our model are prescriptive, thus entrepreneurs that do take into account competition and take appropriate strategic risks would have an advantage. It would also be interesting to see if experienced and more successful entrepreneurs better distinguish between these types of risk.

2.6.2 Empirical implications and support

The first implication of the model is that you would expect greater risk taking when the number of winners is small compared to when the number of winners is larger compared to the total number of entrants. For example, you would expect that risk taking increases as the efficient scale, or natural size of firms the industry can support increases. As the efficient scale increases the number of winners would decrease, but for a given market size the number of entrants should remain constant if the cost of entry is held constant.

Similarly, you would expect cases where a market is originally dominated by incumbents, and relatively little risk taking since the ratio of winners to competitors is high. However, this would

change when a shock to the system either lowers the cost of entry or the risk available to entrepreneurs. Entrepreneurial entry would increase and entering entrepreneurs would take more risks than the incumbents. Further, as the number of entrepreneurial entrants increases you would eventually see the incumbents start to take more risks as well. The model's predictions are consistent with the empirical patterns of innovation found by Acs and Audretsch (1988) when they looked across industries to determine when innovation occurred in small rather than large firms. In particular they find that innovation is highest when an industry is dominated by a few large firms, but that the innovations primarily come from small firms. Further, this innovation and successful entry of new firms predominately occurs in industries where there are new unroutinized technologies and where skilled labor plays an important role (Audretsch, 1991; Acs and Audretsch, 1988). This is exactly what the model predicts. Propositions 5 and 6 shows that the availability of risky strategies to entrepreneurs will influence entrepreneurial entry, and that industries with higher technological uncertainty will see higher levels of entrepreneurship. The model predicts that if an industry is going through technological change that you would expect an increase in entrepreneurial entry, and that the development of the new and radical technologies would be predominately performed by new entrepreneurial entrants.

Similar support for the model are found in industry specific studies. In the cancer drug market when the new but highly risky gene-therapy drugs became possible there was a split where new entrepreneurial entrants tried to introduce new products using gene therapy while incumbents focused on more proven technology (Sosa 2011). New entrants choosing to invest in gene therapy were taking an extremely risky bet, as while the potential for these drugs is quite high, it has proven extremely difficult to pass the safety requirements and regulation barriers for these drugs.

In the optical disk drive industry Khessina and Carroll (2008) found that *de novo* entrants' products are on the technology frontier, but stay on the market for a much shorter time, while *de alio* firms' products are on the interior of the frontier, but survive much longer. While the reasoning that they used to explain this finding relied on firm identity, this paper would offer the alternate explanation that *de novo* firms were taking more risk due to being at a competitive disadvantage. This would explain why *de novo* entrants were more likely to be on the technological frontier, as well as why *de alio* firms had higher survival rates, but with less technologically advanced

products.

Strategic risk taking is also evident in the finance industry. With a limited stock of capital, funds compete over future investment. Reputation of funds is dependent on relative performance and influences future capital contribution, and a funds survival often depends on outperforming its rivals. Chevalier and Ellison (1997) show that mutual funds take more risks when they are under-performing other funds late in the year, and that the propensity to take risks is higher for new mutual funds.

2.7 Applications and Conclusion

2.7.1 Applications

Venture Capital

As previously discussed many in the venture capital industry already understand that there exists a difference between market risk and technology risk. Thus, we have helped formalize the way that many venture capitalists and experienced entrepreneurs already think and make their decisions. We also clarify why and when these different perspectives on risk are important. In discussing his strategy for his new venture capital firm, Vinod Khosla expressed his opinion that many in the industry do not understand the importance of differentiating between different types of risk thusly:

“This is the 1980s style of venture capital — real technical risk with small amounts of money and small teams. Clean-tech companies taking large amounts of money — that’s project finance, not technical risk. That’s a differentiation most people have lost.” —Vinod Khosla, Principal Khosla Ventures and co-founder Sun Microsystems.⁶

⁶ New York Times, August 1, 2009 (Miller, 2009)

The strategy that different venture capital firms employ will be dependent upon what types of risk they have to deal with in the industries they are investing in. As Vinod Khosla points out, there is a big difference between trying to invest in what may be the next big technology, and what he call project finance. In new and heavily competitive industries taking large strategic risks by investing in companies with high technical upside is necessary. Venture capitalists trying to choose which firms to invest in for a given industry would invest in firms that are taking a lot of risk and have potential to produce a superior product, even if they are also more likely to fail. This would be due to competitive pressures and corresponds to when $\lambda < \frac{1}{2}$ in our model.

Incumbents Efforts to Reduce Uncertainty

Interestingly, we see in many industries incumbents trying to reduce availability of risk/uncertainty in the industry through standards, technology platforms, regulation, etc. In general incumbents will do what they can to maintain the status quo, and reduce any uncertainty in the industry. This can inhibit growth. On the other hand entrepreneurs will want to try and increase uncertainty and find ways to disrupt current platforms or regulation that reduces uncertainty. This is a direct result of Proposition 6, that entrepreneurial firms benefit disproportionately more from uncertainty and available risky strategies than do incumbents.

R&D Management

While the options faced by managers may not always be to choose “variance”, the insights of this model still hold. For example, if a firm has a discrete number of options to choose from, this model would indicate that they choose one of the riskier options if the competition for the intended market is high. Similarly, Banal-Estañol and Macho-Stadler (2010) show that firms can incentivize R&D personnel in a way to either increase or decrease the variance of a firms R&D. This paper complements their work in showing when and why firms would want to use these strategies.

Entrepreneurial Opportunity

In the absence of risk entrepreneurs most often can not compete with established incumbents. Risk taking allows entrepreneurs a chance to succeed. Hence, entrepreneurs seek out risky environments: risk is an enabling factor of entrepreneurship. This insight helps give clarity to what an entrepreneurial opportunity looks like in many cases. Entrepreneurs can judge which industries they are most likely to succeed in, as well as what type of strategies they need to take to maximize the chances that they survive.

Policy

Incumbents may have incentives to minimize technological uncertainty even though this may not be in the best interest of social welfare. This paper adds a new wrinkle to the impact of competition on innovation and social welfare by showing that competition is not just important because it drives down costs and prices, but also because it may also encourage socially beneficial risk taking. As demonstrated risk taking is increasing in the number of entrants, n , thus, government policies to help lower entry costs may spur innovation not only by the new firms that enter, but also in all other existing and entering firms by increasing competition.

Similarly, as risk taking decreased in the number of expected winners, m , perhaps the government should actually encourage monopolies to increase the incentives to take risks in innovation intensive industries. This is already accomplished to a certain degree with patent rights. On the other hand, as shown in the liver transplant market(Snyder, 2010), risk taking is not always beneficial to society. For example, competition may drive many firms to take legal risks. If breaking the law allows a firm to compete, the potential benefit of doing so will outweigh the costs incurred if caught. Entrepreneurs are more likely to perform unethical practices when competition is intense and/or when competing against incumbents.

Understanding the potential influence competition and new entry can have is an important aspect that need to be considered when determining optimal policies, and the expected outcome may be either positive or negative.

2.7.2 Conclusion

Uncertainty and therefore risk taking is an inherent part of entrepreneurship. To truly understand entrepreneurship, and the valuable role it plays in our economies, we need to better understand how different types of uncertainty and risk taking impact entrepreneurial strategy. This paper shows that there are fundamental differences in the types of risks entrepreneurs face. The first type of risk is the traditional concept of risk concerned with the distribution of financial return. We introduce strategic risk as risk taking that arises from the impact of competition. We examine the role that risk taking has on the probability a firm has of succeeding against its competition, and find that under ordinary conditions the only rational way an entrepreneur can expect to win is to take as much risk as possible. We further show that market structure has a large influence on the amount of risk firms are willing to take, and that the presence of risk and uncertainty enables entrepreneurial entry.

We believe that there is great opportunity for entrepreneurship scholars to better decompose the types of uncertainty that entrepreneurs face, and to learn about how it is entrepreneurs do and should go about dealing with this uncertainty.

We show through formal modeling that risk is an enabling factor of entrepreneurship. Further exploration of how risk taking enables entrepreneurs to compete will help us better understand entrepreneurship, and how it is that new firms compete with incumbents.

2.8 Omitted Proofs

Proof of Proposition 1

Proof. The number of entrants is independent of their choices of risk due to symmetry. Rationality and profit maximization imply that $E[\pi_i] \geq 0$, so entry would occur until $E[\pi_i; n] \geq 0$ and $E[\pi_i; n+1] \leq 0$. With n identical entrants and m winners symmetry implies that $P_i = \frac{m}{n}$ for all i . Using Equation 3, we see that $E[\pi] = \frac{m\pi^W(m)}{n} - c$ so the number of entrants in equilibrium is $n = \lfloor \frac{m\pi^W(m)}{c} \rfloor$. \square

Proof of Proposition 2

Proof. Without loss of generality we assume that the mean of $f(t)$ is 0.

$G_i(x)$ in equation 6 is the CDF of the $(n-m-1)$ th order statistic. Vaughan and Venables (1972) show that the density function of k independent non-identically distributed random variables for the r th order statistic, $X_{r:k}$ ($1 \leq r \leq k$), can be represented by

$$g_{r:k}(x) = \frac{1}{(r-1)!(k-r)!} \begin{vmatrix} F_1(x) & F_2(x) & \cdots & F_k(x) \\ \vdots & \vdots & & \vdots \\ F_1(x) & F_2(x) & \cdots & F_k(x) \\ f_1(x) & f_2(x) & \cdots & f_k(x) \\ 1-F_1(x) & 1-F_2(x) & \cdots & 1-F_k(x) \\ \vdots & \vdots & & \vdots \\ 1-F_1(x) & 1-F_2(x) & \cdots & 1-F_k(x) \end{vmatrix}^+ \quad (7)$$

Let the matrix in Equation 7 be denoted by the matrix A , such that $g_{r:k}(x) = \frac{1}{(r-1)!(k-r)!} |A|^+$, then $|A|^+$ denotes the permanent of a matrix⁷ A with $\{F_1(x), F_2(x), \dots, F_k(x)\}$ for the first $r-1$

⁷ The permanent of a matrix is just the sum of all diagonal products of the matrix (Minc and Marcus, 1984). For the special case of a $n \times n$ square matrix, it is defined just like the determinant, except all signs of the summation are positive instead of alternating between positive and negative.

rows, and $\{1 - F_1(x), 1 - F_2(x), \dots, 1 - F_k(x)\}$ for the last $k - r$ rows. So for $g_i(x)$, $k = n - 1$ and $r = n - m$.

If $\lambda = \frac{1}{2}$, then $r - 1 = k - r$. By symmetry $F_i(-x) = 1 - F_i(x)$, so $g(x) = g(-x)$, so by Equation 6, $\frac{\partial P_i}{\partial s_i} = 0$ which completes the proof for $\frac{m}{n} = \frac{1}{2}$.

Now for the case where $\lambda < \frac{1}{2}$. An increase in s_i is a mean preserving spread of $F(x)$ where the single crossing property as defined by Diamond and Stiglitz (1973) holds, so $\frac{\partial F_i(x; s_i)}{\partial s_i} > 0$ for $x < 0$, and $\frac{\partial F_i(x; s_i)}{\partial s_i} < 0$ for $x > 0$. This implies that the first term in Equation 6 is negative and the second term is positive. To finish the proof, we now have to do is show that $g(x) > g(-x)$ since by Equation 6 this insures that $\frac{\partial P_i}{\partial s_i} > 0$.

Take the matrix A and delete the first $n - 2m$ rows so we have $m - 1$ rows of both $\{F_1(x), F_2(x), \dots, F_{n-1}(x)\}$ and $\{1 - F_1(x), 1 - F_2(x), \dots, 1 - F_{n-1}(x)\}$. Call this matrix Z . Then by symmetry we have that $g_Z(x) = g_Z(-x)$. Now, we add a row of $\{F_1(x), F_2(x), \dots, F_{n-1}(x)\}$, and call this matrix W . Let each diagonal product of Z be indexed by j , where $j \in J$ and J is the set of all one-to-one functions from $\{1, \dots, n - 1\}$ to $\{1, \dots, 2m - 1\}$ such that $z_j(x)$ then refers to the corresponding diagonal product of matrix Z . Then the permanent of W can be written as

$$|W|^+ = \sum_{j \in J} \sum_{d=1}^{n-1} z_j(x) F_d(x)$$

and this process of adding a row can be repeated $n - 2m$ times until we end up with

$$|A|^+ = \sum_{j \in J} z_j(x) \sum_{D \in \Omega} \prod_{d \in D} F_d(x)$$

where Ω is the collection of all subsets of N_{-i} that are of size $n - 2m$. Due to the symmetry of Z , and since $F(x)$ is weakly increasing everywhere and strictly increasing somewhere on the interval $[0, \infty]$ we can say that

$$\begin{aligned} \sum_{j \in J} z_j(x) \sum_{D \in \Omega} \prod_{d \in D} F_d(x) &\geq \sum_{j \in J} z_j(-x) \sum_{D \in \Omega} \prod_{d \in D} F_d(-x) \quad \text{for all } x \in [0, \infty] \\ \sum_{j \in J} z_j(x) \sum_{D \in \Omega} \prod_{d \in D} F_d(x) &> \sum_{j \in J} z_j(-x) \sum_{D \in \Omega} \prod_{d \in D} F_d(-x) \quad \text{for some } x \in [0, \infty] \end{aligned}$$

which implies that $g(-x) < g(x)$ when $\lambda < \frac{1}{2}$. By symmetry we can also have the result for $\lambda > \frac{1}{2}$. \square

Proof of Proposition 3

Proof. (i) The probability that firm i wins is

$$P = \int_{-\infty}^{\infty} f_i(x; s_i) G_i(x; m, n, S_{-i}) dx$$

For a mass of entrants $G_i(x; m, n, S_{-i}) = 1$ if $x > F^{-1}(1 - \lambda)$ and $G_i(x; m, n, S_{-i}) = 0$ if $x < F^{-1}(1 - \lambda)$. (Arnold et al., 2008) Thus,

$$\begin{aligned} P_i &= \int_{F^{-1}(1-\lambda; s_{-i})}^{\infty} f_i(x; s_i) dx \\ &= 1 - F(F^{-1}(1 - \lambda; s_{-i}); s_i) \end{aligned}$$

For the Log Normal the first order condition is

$$\begin{aligned} \frac{\partial P_i}{\partial s_i} &= \frac{1}{2\sqrt{2\pi}(s_i + \eta)^2} e^{-\frac{((s_i + \eta)^2 + 2(s_{-i} + \eta)\sqrt{2}\Phi^{-1}(1 - 2\lambda) - (s_{-i} + \eta)^2)^2}{8(s_i + \eta)^2}} \\ &\quad \left((s_i + \eta)^2 + 2(s_{-i} + \eta)\sqrt{2}\Phi^{-1}(1 - 2\lambda) - (s_{-i} + \eta)^2 \right) \\ &\quad e^{-\frac{(s_{-i} + \eta)^2}{2} + (s_{-i} + \eta)\sqrt{2}\Phi^{-1}(1 - 2\lambda)} = 0 \end{aligned}$$

Solving for s_i we get the reaction function for firm i we get

$$s_i = \sqrt{2} \sqrt{\sqrt{2}(s_{-i} + \eta)\Phi^{-1}(1 - 2\lambda) - \frac{1}{2}(s_{-i} + \eta)^2 - \eta^2}$$

and this is a concave function in s_{-i} as

$$\frac{\partial^2 s_i}{\partial s_{-i}^2} = -\frac{2(\Phi^{-1}(1-2\lambda))^2}{\left(-s_{-i}^2 - 2s_{-i}\sqrt{2}\Phi^{-1}(1-2\lambda)\right)^{3/2}} < 0.$$

Thus solving for the symmetric equilibrium we get

$$s_i^* = \sqrt{2}\Phi^{-1}[1-2\lambda] - \eta^2.$$

If $\eta^2 > \sqrt{2}\Phi^{-1}[1-2\lambda]$ then since the derivative is negative after crossing 0 we get $s_i^* = 0$.

The last step to show that this is a unique equilibrium is to determine that $s_i = 0$ when $\eta^2 = 0$ is not an equilibrium as the definition of the Log Normal is only defined for $\eta > 0$, but we allow for zero variance as a possibility.

To see that $s^* > 0$, assume that $s^* = 0$ for all firms is an equilibrium. Let $\bar{\mu}$ be the mean and ζ be the median. For the log normal $\bar{\mu} \equiv e^\mu + \frac{\sigma^2}{2}$ and $\zeta = e^\mu$. Then, all firms will with certainty receive the mean, $\bar{\mu}$, of the log-normal distribution and will then win with a probability of $\frac{m}{n}$.

If a firm chooses a small amount of variance, then $P_i = Pr(\bar{\mu} < q_i) = .5 - \varepsilon$. Then $\varepsilon = \Phi\left(\frac{\ln(x)-\mu}{\sigma}\right)\Big|_{\zeta}^{\bar{\mu}} = \Phi\left(\frac{\sigma}{2}\right) - \Phi(0)$. Since Φ is continuous then ε can be chosen to be arbitrarily small such that $.5 - \varepsilon > \lambda$ and the firm is better off than when $s^* = 0$ contradicting the assumed equilibrium.

The fact that the choice of strategic risk, s_i , is increasing in n , $\frac{\partial s_i}{\partial n} > 0$, and decreasing in m , $\frac{\partial s_i}{\partial m} < 0$ follows directly from $s_i^* = \sqrt{2}\Phi^{-1}[1-2\lambda] - \eta^2$ since $\lambda = \frac{m}{n}$.

(ii) Suppose $\lambda \geq \frac{1}{2}$ and all firms choose $s^* = 0$. If a firm chooses any positive amount of risk, $P_i = Pr(q_i > \zeta) < \frac{1}{2} \leq \lambda$ and the firm would do better by choosing $s^* = 0$ and winning with a probability of λ , so $s_i^* = 0$ for all i is an equilibrium.

To show uniqueness, assume that there exists an equilibrium in which all firms choose $s^* > 0$. If firm i were to choose $s_i^* = 0$, entrant i will always have a value of $\bar{\mu}$. Then $Pr(q_j < q_i) > \frac{1}{2}$ for all j . Taking Equation 2 we have

$$\begin{aligned}
P_i &= \int_{-\infty}^{\infty} f_i(x; s_i = 0) G_i(x; m, n, S_{-i}) dx \\
&= G_i(x = \mu; m, n, S_{-i}) \\
&\geq G_i(x = \zeta; m, n, S_{-i}) \\
&\geq \lambda
\end{aligned}$$

which is a contradiction to the assumed equilibrium. □

Proof of Proposition 4

Proof. If the number of incumbents is greater than the free entry number of entrants under the assumptions of homogeneous firms then by Proposition 3 we obtain n as the number of entrants.

If the free entry number of entrants exceeds incumbents then as incumbents dominate all will enter. Since entry occurs in discrete jumps, then $\pi_i > 0$ and unless profits are negative firms will enter. We obtain uniqueness of entry using backward induction, as entrepreneurial firms will enter if it is profitable to do so insuring that in the first stage the equilibrium with the largest n will occur. Thus, even if multiple equilibrium exist, only the one with the largest n is subgame perfect and will ever be chosen in the first stage. □

Proof of Proposition 5

Proof. The proof that entrants will always choose $s_E = s_{max}$ for $\lambda < \frac{1}{2}$ follows the same logic as Proposition 4 if we normalize everything around a^E we have that $g_Z(x) > g_Z(-x)$ by the combined facts of symmetry and that incumbents are offset by $a^I - a^E$. Then, everything goes through the same.

To show that incumbents will at times choose $s_I = 0$ even when $\lambda < \frac{1}{2}$ we give a simple example. Suppose $f(t)$ is normally distributed. Take the case where $m = 1$, $N^I = 2$, $\pi^W = 100$, $c = 2$, and $s_{max} < 1$. Then if $a^I - a^E > 1.96$ the probability that the entrepreneurial entrant wins if the incumbents take no risk is 2.5%. Then one entrepreneur will enter. To show this is an equilibrium, by Proposition 2 the two incumbents choices have no impact on each other winning, and increasing the variance for the incumbents will decrease their probability of winning due to symmetry, and the fact that the entrepreneurs distribution is decreasing around a_i . This holds for all choices of variance since $f(t + a_i) < f(-t + a_i)$ by symmetry of $f(t)$. This example easily generalizes for any symmetric unimodal distribution $f(t)$.

To show that if s_{max} is not small relative to $a^I - a^E$ that incumbents will still choose $s_I > 0$, consider when $s_{max} = \infty$, then the incumbents advantage is erased and both firms will choose s_{max} .

For $\lambda > \frac{1}{2}$, the proof that incumbents will always choose $s_I = 0$ follows by symmetry. To show that at times $s_E > 0$ if $a^I - a^E$ take the case where $s_{max} = \infty$. Clearly $a^I - a^E$ can be so large that the only way for an entrepreneurial entrant to win is to choose high variance, and by taking infinite variance they can have a quality measure that is above any incumbent half the time, so they would obviously choose to take risk even though $\lambda > \frac{1}{2}$.

□

Proof of Proposition 6

Proof. For s_{max} , from Proposition 5 $\frac{\partial P_i}{\partial s_i} > 0$ for entrepreneurs when $\lambda < \frac{1}{2}$, so when this is the case as s_{max} increases the probability of an entrepreneur winning increases. Entry occurs as long as $E[\pi_i] \geq 0$. By Equation 3 we have that $E[\pi_i]$ is increasing in P_i , thus weakly increasing entry. Entrepreneurs are never hurt by an increase in s_{max} as the only times it is beneficial for for incumbents to choose any risk is when $\lambda < \frac{1}{2}$.

Since entrepreneurs always choose $s_i = s_{max}$ increasing sigma does not impact entrepreneurs. However, the proof of Proposition 5 shows that incumbents at times choose $s_i = 0$. Thus when η^2 increases it will force incumbents in this situation to take more risk than is optimal, and decreases the probability that they win, increasing the probability that an entrepreneurial firm will win, which

weakly increases entry.



3 Chapter 3

Ethical Risk-Taking as an Enabling Competitive Strategy for New Entrants

3.1 Introduction

Entering a new market is one of the most difficult and risky challenges a firm can face, and firms often have to resort to different strategies than incumbents in order to compete Geroski (1995). Often this is in the form of cost competition or trying to innovate their way to higher quality. This is one of the reasons why entrepreneurship and small firms are often associated with higher levels of innovation (Audretsch, 1991; Acs and Audretsch, 1988) and price competition (Bresnahan and Reiss, 1991). However, there also exists a darker side of competition when it drives unethical behavior (Cai and Liu, 2009; Münster, 2007; Shleifer, 2004).

While the impact of competition increasing the effectiveness of unethical strategies has been examined by looking at the level of competition as measured by the number of competitors (Shleifer, 2004; Snyder, 2010; Cai and Liu, 2009), its role in enabling entrants to enter new markets is less developed. However, as was shown in Chapter 2, the importance of how unethical behavior influences entry goes beyond general competition as entrants will benefit more from the presence of ethical and/or illegal risks than incumbents. Thus, the presence of corrupt business strategies as an option will disproportionately benefit new entrants over incumbents and should enable entry. In this paper we show that the presence of unethical or illegal business options can facilitate entry. This is a stark contrast to the way that entrants and entrepreneurs are usually viewed - as entities that fulfill the role of the “invisible-hand” and promote innovation (Schumpeter, 1994). Instead of bringing about creative destruction, entrepreneurs may actually introduce socially destructive behavior.

Perhaps one of the reasons that this side of entrepreneurship is less salient is that while firms market and promote their latest innovations, corrupt behavior is by its very nature buried deep and hidden from sight. This poses obvious challenges for empirical work, but utilizing a policy change to identify strategic manipulation of intensive care unit (ICU) enrollment in the liver transplant market we are able to identify such practices. Further, the liver transplant market offers a setting where we can test how competition impacts new entrants behavior as it offers a setting with variation in competition, substantial entry opportunity, the ability to identify potential market entrants and a policy change that allows identification of unethical behavior.

Using data from the liver transplant market we test the three main predictions of the model

presented in Chapter 2: strategic risk taking will be higher in highly competitive markets, small entrepreneurial entrants will take more strategic risk than incumbents, and in established markets the presence of risky strategies will enable entrepreneurial entry. In this case the strategic risk is the decision to misrepresent patients health to manipulate waiting list priority.

Utilizing a policy change in 2002 in how Intensive Care Unit (ICU) status was used in determining patient priority to identify strategic manipulation of the ICU waiting list(Snyder, 2010) we find support for these predictions in that: (1) illegal manipulation of the ICU list is higher in more competitive markets even when controlling for the increased likelihood of new entrants to manipulate the list, (2) new entrants were more likely to illegally list patients in the ICU than incumbents, and (3) entry significantly decreased after the law change reflecting the enabling effect the availability of a risky illegal option had on entrepreneurial entry.

The outline of the rest of the chapter is as follows. Section 2 reviews the pertinent literature, section 3 describes relevant details of the liver transplant market, section 4 develops the theoretical hypotheses, section 5 describes the data and empirical analysis and section 6 concludes.

3.2 Literature Review

While competition often leads to productive risk taking leading to socially desirable outcomes such as innovation, risk-taking is not always beneficial to society. For example, competition may drive firms to break the law if doing so allows the firm to compete. When competition is intense the potential benefit of breaking the law could outweigh the costs incurred if caught.

Shleifer (2004) contends that in competition drives firms to unethical behavior and uses the cases of child labor, corruption in the form of bribing officials in developing countries, high executive pay, earnings manipulation, and commercialization of education to argue his point. Clearly, all of these different practices are objectionable, and he demonstrates the wide variety of undesirable behavior that may be driven by competition.

In a study looking more specifically at drivers of illegal behavior, Staw and Szwajkowski (1975) argue that the scarcity-munificence environment that competition creates will lead firms to adopt illegal practices, and they look at examples of firms across many industries that have been identified

as performing illegal acts and find support for their hypothesis. Cai and Liu (2009) look more deeply at the specific issue of tax avoidance of Chinese firms, and find that competition drives firms to misrepresent earnings. Further, they show that firms in more disadvantaged positions are more likely to try to illegally misrepresent profits to avoid taxation. This issue of firms in disadvantaged positions being more likely to perform illegal acts is similar to what we argue is why entrants would be more likely to adopt corrupt practices. Similar findings have been found in laboratory experiments work. Schwieren and Weichselbaumer (2010) find that competition increases cheating, and that participant ability predicts who will cheat, with those less able more likely to cheat. In a similar study, Harbring et al. (2004) look at sabotage in tournaments, and find that participants at a disadvantage, defined as a less advantageous cost curve, are more likely to turn to sabotage and a strategy to compete in the tournament.

In a study using the same industry setting as this paper, Snyder (2010) also looks at how competition influenced the manipulation of patients ICU status. In this paper Snyder found that the manipulation of patient status did not cause a significant decrease in social welfare and that unethical misrepresentation was positively associated with how competitive the market a center was in. This paper builds on that work by looking at competition in not just the one dimension of the number of competitors a center faces, but by also considering the fact that new entrants and smaller firms are at a disadvantage against established incumbents. As the existence of new entrants is obviously related to the number of firms in a market, it is not clear which dimension is driving the behavior. We complement Snyder (2010) work by finding support for his finding that competition as defined by having multiple firms in a market drives unethical misrepresentation, as even when controlling for the increased propensity of new entrants to misrepresent patients health, the absolute number of firms in a market drives unethical behavior. We also differ in that we look at the misrepresentation of patient status as a strategy new firms use to compete, and focus on how this enables firms to enter into a new market.

New entrants are at a disadvantage when competing against incumbents. Most don't survive, and even those that do survive generally take years, if ever, to approach the volume and or profitability of incumbents (Geroski, 1995). Barriers to entry seem to even be present when the traditional measures do not detect them (Geroski, 1995). In the case of liver transplants, the regulatory

regime effectively creates a minimum efficient scale, and significant learning effects are present that hamper new entrants (Lieberman, 1984, 1987).

Further, while traditionally new entrants can attempt to compete on price (Bresnahan and Reiss, 1991), advertising (Sutton, 1991), or quality (Hung and Schmitt, 1988), none of these options are available for new entrants in the liver transplant market. In reality this is often the case, as incumbents are better funded as well as more experienced so entrants are left without any dimensions that they can conceivably compete on with new entrants. This often leads to non traditional strategies such as “judo economics” (Gelman and Salop, 1983) where entrants try to avoid direct competition with incumbents in a variety of ways.

Another option for new entrants is to use “stepping stones” to enter a new market. Lee and Lieberman (2010) explore this strategy looking at how firms use acquisitions into nearby markets as a way to enter into a target market. In the Liver transplant market there is a parallel where all firms enter into the kidney transplant market first as it is an easier procedure with higher volumes making it easier to enter. We exploit this fact in our empirical work as a way to identify new entrants in our model of entry.

In this paper we unite the findings from the literature on the effects of competition on corrupt business practices with the literature looking at entry strategies and how new firms compete by examining whether firms use unethical and illegal behavior as means to effectively enter and compete with established incumbents. The model in Chapter 2 shows that the same competitive forces that drive homogenous firms to take ethical risks will also drive new entrants and entrepreneurs to take the risks associated with corrupt business practices when competition is intense and/or when competing against incumbents. The model further showed that because of the heterogeneous response to competition, that the presence of risky choices will benefit new entrants, and enable entry.

In the only study we are aware of to specifically look at new entrants and if they are more likely to perform unethical or illegal acts due to competition with incumbents, Bennett et al. (2013) find that in the vehicle emissions testing market the effect of competition in increasing the likelihood of misrepresenting emissions data is stronger for new entrants than incumbents. They show that even though new entrants are initially, and while in the absence of competition, actually less likely to misrepresent emissions data, they react more strongly and are more likely to increase misrep-

Transplant	30 Days Pre-transplant	Procurement	Hospital Transplant Admission	Physician During Transplant	180 Days Post-transplant Admission	Immuno-suppressants	Total
Heart Only	\$47,200	\$80,400	\$634,300	\$67,700	\$137,800	\$30,300	\$997,700
Single Lung	\$10,300	\$73,100	\$302,900	\$33,500	\$117,700	\$23,700	\$561,200
Double Lung	\$21,400	\$90,300	\$458,500	\$56,300	\$142,600	\$28,200	\$797,300
Heart-Lung	\$56,800	\$130,500	\$777,700	\$81,000	\$169,100	\$33,300	\$1,148,400
Liver	\$25,400	\$71,000	\$316,900	\$46,600	\$93,900	\$23,300	\$577,100
Kidney	\$17,000	\$67,200	\$91,200	\$18,500	\$50,800	\$18,200	\$262,900
Pancreas	\$17,000	\$65,000	\$108,900	\$17,800	\$61,400	\$19,300	\$289,400
Intestine	\$55,100	\$78,500	\$787,900	\$104,100	\$146,600	\$34,600	\$1,206,800

Table 1: Liver transplants are a \$3.75 billion/year market

resentation when under competition. This differs from this paper in that it is not clear that these firms are using the option of illegal behavior to level the playing field to justify entry, or if they are just reacting to industry norms once they have entered. We also differ in that we build an empirical model of entry, and use this to explore how unethical risk taking can facilitate entry.

3.3 Empirical Setting: The Liver Organ Transplant Market

There are currently approximately 6,500 liver transplants per year in the US market, and the highest volume centers have well over 200 liver transplants per year.

The liver transplant market is a potentially lucrative market for hospitals that have transplant centers. Each liver that is transplanted represents around \$600,000 of revenue for the hospital, and is a \$3.75 Billion/year Market⁸. Table 1 shows the revenue that goes to hospitals for transplant procedures broken down by transaction.

All hospitals belong to a regional OPO (organ procurement organization). When an organ becomes available transplant centers within the OPO have first rights to the organ. Allocation of the organ is done according to priority on a waiting list within the OPO, and the potential match

⁸<http://www.transplantliving.org/before-the-transplant/financing-a-transplant/the-costs/>

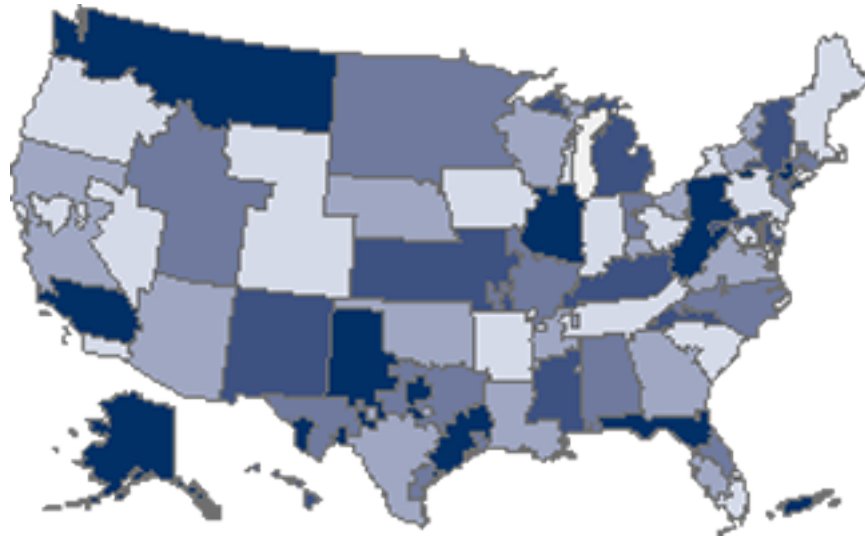


Figure 7: Map of Organ Procurement Organization (OPO) boundaries in the US

depending on the distance, type of organ etc. Figure 7⁹ shows the boundaries of the Each OPO is nested within an organ transplant region and if no match or claim is made on the organ within the OPO then transplant centers within the appropriate region have access to the organ. Over 75% of all livers remain within the original OPO and virtually all remain within the region. Competition over livers is high and each year thousands of individuals die while on the waiting list for a new liver.

Competition over livers impacts centers in two different ways. First, each liver is competed over so either a center “wins” the liver or they do not. Second, as centers compete they must reach a certain threshold of livers to be competitive. The reason for this is that a centers ability to perform successful transplants is largely dependent on the volume of transplants they perform both cumulatively as well as yearly. For this reason centers reputation and mortality/complication rates drop after a certain threshold of transplants is met. Medicaid requires a center to perform a minimum of 12 transplants per year in order to receive certification. Some states such as New Jersey require 15 or more per year. In New Jersey a center that fails to meet that threshold within

⁹<http://www.srtr.org/>

two years after entry will not receive certification and licensing. Further, this is just the minimum volume needed. Centers with higher volume benefit from lower costs due to learning and high fixed costs. In this way centers not only compete over individual livers, but they must meet a certain level of performance or exit the market. This is similar to the extension in section 6 where the number of successful entrants is endogenously determined due to a performance threshold. This required level of performance is obviously most important to new entering centers as established centers (incumbents) generally are able to meet these performance levels. However, even for large established centers, competition over individual livers should drive risk taking behavior. In the case of the liver transplant market strategic risk taking may occur by unethical manipulation of reported patient health.

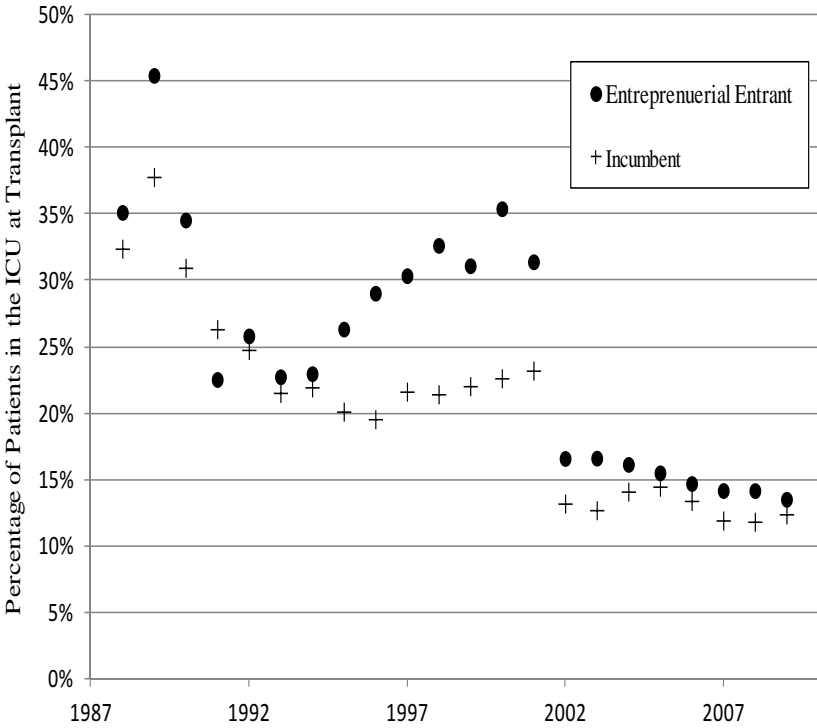
3.4 Empirical Hypotheses

The liver transplant market offers a unique opportunity to test strategic risk taking. In 2002 the rules determining the allocation of livers changed. Before 2002 if an individual was in the intensive care unit (ICU) she would receive priority and could jump ahead of others on the liver waiting list. Centers could improperly, yet strategically, place relatively healthy individuals on the ICU list even while they went about their daily life. A high profile case of this was when the University of Illinois was sued by medicaid and had to pay a fine of 2 million dollars for their unethical misrepresentation of patients on their ICU list¹⁰. However, in 2002 the liver allocation process changed such that livers were allocated according to a patient's MELD score which only relies on clinical indicators of a patient's sickness. Figure 7 illustrates that ICU dropped sharply for all firms after the MELD policy was implemented in 2002. Further, the decrease in ICU use is greater for entrant firms compared to incumbents.

The model from Chapter 2 predicts that new entrants will take more risks than incumbents as they are at a disadvantage. This suggests the following hypothesis:

¹⁰ http://www.justice.gov/usao/iln/pr/chicago/2003/pr111703_01.pdf

Figure 8: On average entrants ICU use was higher and dropped more after the MELD policy was implemented in 2002 compared to incumbents



Hypothesis 1: New entrants will have a larger decrease in the rate of ICU use than incumbents after the policy change in 2002.

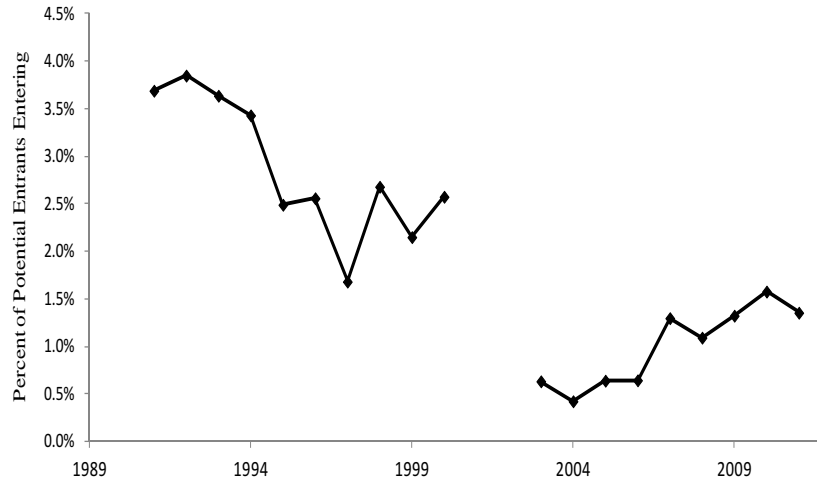
Similarly, competition within an OPO should increase risk taking. Snyder (2010) showed that ICU use after the policy change dropped more in multicenter OPOs. However, an OPO has only one center nearly half of the time so whether the results are driven by competition, or whether the fact that OPOs with more centers will invariably have more entrants drives the result is not clear. However, the model predicts that as entry increases at some point even incumbents will begin to take more risk, suggesting the following hypothesis:

Hypothesis 2: The decrease in the rate of ICU use will increase with the number of centers in an OPO even when controlling for whether a firm is a new entrant.

The liver transplant market is a unique opportunity to look at entry as the pool of potential entrants can be identified from looking at already established transplant centers. Centers will start performing simpler organ transplants first and then over time expand into more complicated organs. A transplant center may perform transplants such as heart, lung, or kidney transplants. In particular, kidney transplants are a stepping stone to get into the liver transplant market as they are much easier and less risky. This allows us to consider the current kidney transplant centers as the pool of potential entrants into liver transplants. The ability to take strategic risks helps entrepreneurs to compete, and the model shows that entry is increasing in the available strategic variance a firm can choose. Thus, you would expect that entry was higher when new entrants had the ability to game the system by placing patients in the ICU. Figure 8 illustrates that the number of entering firms dropped after the MELD policy was introduced. This leads to the following hypothesis:

Hypothesis 3: The likelihood that a kidney transplant center will enter the liver transplant market will decrease after the policy change in 2002 and new entrants no longer have the ability to illegally game the system.

Figure 9: The number of entering firms drops after MELD policy introduced



3.5 Data and Empirical Analysis

The data come from the UNOS (United Network for Organ Sharing) which has data on every transplant since the middle of 1988. The data contains patient characteristics, transplant details and outcomes.

The data begin in 1988 with 54 operating centers, which increases to 114 centers by 2010. To determine whether or not new entrants will take greater risk than incumbents we first need to define centers as either an entrant or an incumbent. The two simplest ways to do this is to look at which firms are in the data set at the beginning of 1988 and use those as incumbents. However, this may miss the point if there is one very large center and another small fledgling that just started. To accommodate this we determine incumbents and entrants in two steps. First any center that exists in 1988 or is the first to enter in their respective OPO is considered an incumbent. Second, we look at the five years previous to the policy change and if a center has less than one fourth of the volume of the largest center in its respective OPO it is coded as an entrant, and any center that has more than 66% of the total volume in an OPO is considered an incumbent. As robustness checks other definitions were used such as looking at total volume percentage of the market, or only considering an firm an entrant until they reach a certain volume etc. The results are robust to various different interpretations of incumbent that were tried, including a blind judgment analysis done on the data by someone that had not seen any other related data. We use the definition we do for its simplicity

and clarity.

To determine the level of competition we utilize the way that markets are legally constructed. The liver transplant markets are determined geographically¹¹. There are 11 geographic regions. Each region is further segmented into Organ Procurement Organizations (OPOs) with a total of 54 OPOs. Each hospital with a transplant center belongs to only one OPO, and an OPO may have anywhere from 1 to 7 associated transplant centers. Some pediatric hospitals will share a transplant center with its associated general hospital. In these cases this is coded as a single center. There are two veterans hospitals that share a transplant center and they are coded as one center in a similar way. These changes are made to try and better capture true competition, and the changes are biased against our hypothesis so they are a conservative approach to measuring both competition and entry.¹² When a liver becomes available, the associated OPO has first priority at the liver. If no match is found within the OPO all centers within the region then compete over the liver. The majority of livers stay within the OPO, and virtually all stay within the region.

Table 1 shows the regression results looking at the likelihood a patient is in the ICU prior to receiving a liver transplant. We generate clustered errors by clustering at the OPO level. This is necessary to avoid the regression taking all observations as independent which would introduce serial correlation. We do find that this is a major issue as all results are much less significant once clustered errors are used. Ideally we would cluster at the center level, but given the large size disparity among centers this would not produce a reliable estimate. Clustering at the OPO level is more conservative than clustering at the center level since it avoids the issues associated with unbalanced cluster size as well as the fact that it is a higher level of clustering with centers nested within OPOs.

Columns (1) and (2) show that incumbents were significantly less likely to sue the ICU before the policy change, whereas there is no significant difference between incumbents and new entrants

¹¹ For a more in depth description of the liver transplant market see Snyder (2010). The data used is from 1988-2009

¹² Information about centers and which region/OPO they are associated with was downloaded from the UNOS website.

after the policy change. Columns (3) and (4) show the difference between columns (1) and (2) is significant with new entrants having a larger decrease in ICU use after the policy change (Hypothesis 1). Year and center fixed effects are used as well as various patient demographic and health controls.

One concern is that larger firms are just less likely to manipulate the ICU list. This may be due to better controls within the hospital, or due to inertia that inhibits them from taking advantage of the opportunity. Given that all liver transplant centers are part of large hospitals, and all are already operating at a minimum as kidney transplant centers as well this is unlikely. Also, when controlling for new entrants competition increases risk taking by all firms including incumbents as predicted. Further evidence is found by looking at the direct impact of firm size. Columns (5)-(7) show that liver transplant volume has no significant impact on ICU use.

Columns (6) and (7) show support for Hypothesis 2. Column (6) shows that being a new entrant is still significant in driving strategic ICU use, but the firm count variable is also significant even when controlling for the impact of new entrants on ICU use. Snyder (2010) found that the majority of the ICU use driven by competition was captured by comparing OPOs with only one center to OPOs with 2 or more centers. In contrast, the model predicts that risk taking should increase with the number of competitors. Column (7) finds that only looking at whether an OPO has more than one center does not produce a significant result, and supports the hypothesis that risk taking is increasing in the number of competitors when controlling for incumbency status.

Table 2 shows the results for the tests of Hypothesis 3, and we find support for the prediction that risk taking enables entrepreneurial entry. The table show results for OLS regressions. We also performed the regressions using both probit and logit. The OLS results were chosen as they are the most conservative, as well as for the ease of interpretation of the results. In testing whether the change in policy in 2002 impacted entry there is some question about when firms first started to react. The change was decided a year before it was enacted, so firms may have already been taking this into account in 2001. We test the results both with and without 2001, and find the results are robust to either specification. In Table 2, we see in column (1) that a simple test of whether entry has significantly changed from before to after the policy change is highly significant. However, concern over omitted variables that would lead better centers to enter early, or that the

Table 2: ICU use by new entrants and centers in highly competitive OPOs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ICU	ICU	ICU	ICU	ICU	ICU	ICU
New Entrant	0.0483** (0.0224)	-0.00256 (0.0194)	0.0521 (0.0210)	Absorbed	Absorbed	Absorbed	Absorbed
Meld era x new entrant			-0.0576*** (0.0188)	-0.0630** (0.0272)	-0.0691** (0.0286)	-0.0508** (0.0223)	-0.0603** (0.0257)
MELD era x center volume					-0.000144 (0.000115)	-0.000117 (0.000132)	-0.000113 (0.000103)
Meld era x firm count by OPO						-0.0176** (0.00784)	
Meld era x firm count 2 or more							-0.0292 (0.0195)
Meld era	Pre	Post	Both	Both	Both	Both	Both
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Absorbed	Absorbed	Absorbed	Absorbed
Center fixed effects	No	No	No	Yes	Yes	Yes	Yes
Demographic controls	No	No	Yes	Yes	Yes	Yes	Yes
Patient health controls	No	No	Yes	Yes	Yes	Yes	Yes
Observations	52406	43923	93258	93258	93258	93258	93258
Clusters	54	54	54	54	54	54	54

Standard errors in parentheses. SEs clustered at the OPO level. Main effects are included in all specifications with interactions.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

trend would be expected to decrease over time can not be addressed with this simple test. To address this concern we constructed a simple linear trend of the years since 1988. In column (2) we find that including this trend does reduce the level of significance as would be expected given the co-linearity of these measures, but the coefficient on MELD era is still significant whereas the coefficient for the linear trend is not.

Columns (3)-(5) show various specifications predicting entry utilizing both center level variables such as kidney volume and the count of kidney center by OPO, as well as liver market variables such as OPO demand and a normalized HHI measure of OPO competition. Other factors that should drive entry such as increases in transplant volume, number of centers already in an OPO, and whether any other centers have recently entered are also included. We use these factors to construct measures that should be more robust to the concerns around unobserved variables that may have changed over time. Not only would we expect that overall entry would decrease, but the nature of competition as well. Column (6) looks at the interaction between the average volume of a center in an OPO and the MELD era policy change. The fact that this interaction is significant suggests that before the policy change having a few centers with large volume attracted entry as entrants could expect to steal transplant volume from the incumbents. However, after the policy change the presence of larger incumbents changed to be a detriment to entry. This supports the idea that the strategic use of the ICU enabled new entrants to compete with established incumbents.

One concern would be that the coefficients from Table 1 indicating an approximate increase in ICU use of 5-6% would not be enough to drive entry. However, that is an average measure, and we are only concerned about entry at the margin. To get a better grasp of whether strategic manipulation of ICU enrollment could have helped new entrants we can look at those firms that had the biggest changes between the pre and post policy eras. If we order firms by the amount that their ICU use changed we get that for the top 5% (which all happen to be entrants) they have a drop of 39%. If we take the top 10% there is a drop of 33%. Now taking those firms in the top 5%, if we look individually and compare the new entrants change in the rate of ICU use compared to the incumbent they were competing against we can get a better idea of how a new entrant could benefit. The firm with the biggest change entered 5 years previous to the policy change and average 17.4 transplants per year and had a pre/post ICU rate that was 48 percentage points higher than the

Table 3: Model for liver transplant entry

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entry	Entry	Entry	Entry	Entry	Entry	Entry	Entry
Meld era	-0.0170*** (0.00402)	-0.0165** (0.00787)	-0.0175*** (0.00469)	-0.0217*** (0.00535)	-0.0228*** (0.00450)	-0.0185** (0.00796)	-0.0200*** (0.00613)	-0.0238*** (0.00877)
Linear Year Trend		-0.0000438 (0.000490)				-0.000389 (0.000634)		-0.000188 (0.000649)
HHI			0.0311*** (0.0108)	0.0970*** (0.0174)	0.0951*** (0.0212)	0.0948*** (0.0212)	0.0249*** (0.00908)	.0537*** (0.0958)
Lagged average center volume by OPO			-0.000368** (0.000142)	-0.000361*** (0.000120)	-0.000350** (0.000157)	-0.000342** (0.000157)	-0.000273** (0.000108)	-0.0000456 (0.0000963)
Lagged OPO count			-0.00875*** (0.00296)	0.0133*** (0.00425)	0.0131*** (0.00447)	0.0134*** (0.00445)	-0.00796*** (0.00274)	0.0118*** (0.00385)
Lagged OPO volume			0.000202*** (0.0000643)	0.000263*** (0.0000638)	0.000231*** (0.0000786)	0.000174*** (0.0000783)	0.00363*** (0.0000538)	0.0000936* (0.0000519)
HHI x Lagged OPO count				-0.0803*** (0.0132)	-0.0782*** (0.0154)	-0.0780*** (0.0154)		-0.0518*** (0.00958)
Lagged kidney volume					0.000486*** (0.000104)	0.000487*** (0.000103)		0.00327*** (0.0000615)
Lagged kidney OPO count					0.000777 (0.000948)	0.000679 (0.000929)		0.0000735 (0.0008568)
Specification	OLS	OLS	OLS	OLS	OLS	OLS	Probit	Probit
Clustered SE level	OPO	OPO	OPO	Center	Center	Center	Center	Center
Number of Clusters	58	58	58	216	216	216	216	216
Observations	4167	4167	3942	3942	3942	3942	3942	3942

Standard errors in parentheses. For probit specifications, marginal effects at the average values are taken.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

incumbent which averaged 189 transplants per year. This clearly shows that strategic use of the ICU was critical for the entrant to compete, whereas it was not for the incumbent in this case. This is similar to the other new entrants that utilized the ICU. While it is not possible to empirically evaluate exit given its relatively low frequency, it is interesting to note that some of these entrants in the top 5% exited shortly after the policy change.

3.6 Conclusion

In this paper that we have shown that not only can competition lead to firms adopting unethical business practices, but that the presence and subsequent adoption of unethical options by entrants can actually be what enables entry by these firms.

This result contrasts with the often espoused stance that competition is good and will promote the social good. Instead of entrepreneurs and entrants helping push society to more efficient levels by taking productive risks that larger companies will not, we show that often these risks may be in the form of unethical or illegal behavior. We believe that this has significant potential to help inform policy as most policies are around helping new firms and entrepreneurs and focusing on making sure markets are “competitive”. We show that the reality is a bit more complicated and those in positions to set policies need to be aware of the potential negative influence encouraging competition and entrepreneurship may have.

We also offer insight into the process of opportunity recognition, and that opportunities for entering firms can take the form of risks can disproportionately help new entrants over incumbents.

In general we show that understanding the role of corrupt behavior in market entry is an important and under researched area and entry strategy, and that more generally how the presence of risky strategies enables disadvantaged firms to compete, and in particular entrepreneurs and firms entering new markets may be enabled by the presence of these risky strategies.

4 Chapter 4

Experimental Analysis of Risk-Taking Behavior under Competition

4.1 Introduction

Tournaments where individuals compete against each other for a set number of prizes have been analyzed as models of economic behavior many different ways since they were introduced by Lazear and Rosen (1981). In almost all of these the focus has been on effort choices of participants. More recent work has begun to look at risk-taking as a choice variable (Hvide and Kristiansen, 2003; Kräkel, 2008; Kräkel and Sliwka, 2004; Gilpatric, 2009). These models most often model both effort and risk taking in two stages. The level of risk is first chosen, and then in the second stage the optimal effort is chosen. In these models the level of risk taken is driven by two main factors. First, the fact that the optimal effort level is decreasing in uncertainty of performance, which leads players to increase risk taking to minimize costly effort in equilibrium. Second, using two player games, risk taking by heterogeneous players shows that players with an advantage prefer less risk, while disadvantaged players prefer risky strategies as this allows the possibility of making up the difference between them and the leader.

Hvide and Kristiansen (2003) and (Gaba et al., 2004) explore tournament behavior when the only choice variable available to participants is the choice of risk. Hvide and Kristiansen (2003) look at the selection effect risk taking has on who eventually wins, and proposes strategies for making tournaments where the choice of risk is present more likely to select the best competitors. (Gaba et al., 2004) look at symmetric mean preserving increases in risk, and find results similar to Proposition 2 in Chapter 2. They also further explore the interaction between levels of covariance and risk choices.

In Chapter 2 we extended the ideas of (Gaba et al., 2004) in looking at asymmetric distribution, and combining this with the models of heterogeneous competitors. We showed that competition often takes the form of the number of winners compared to the number of competitors, as well as explored the context of heterogeneous competition with multiple winners and competitors. This is in contrast to previous work that focused on two player games.

In experimental work the focus has been on two player games as well. Nieken and Sliwka (2010) look at a game where between heterogeneous players choose between a safe and risky option and vary the correlation of outcomes under the risky option scenario. They show that risk taking depends on the level of correlation, as well as the size of advantage the participant has.

Nieken (2010) looks at the choice of effort and risk in two stages. The first stage the level of risk is chosen, and then in the second stage participants decide on their level of effort.

In our experiment we explore how competition derived from many competitors competing for a few fixed number of prizes drives risk taking, and compare this to competitive effects that arise from heterogeneous competitors. We also look at how the framing of these competitive situation matters by comparing player reactions when the number of winners changes and the number of competitors changes to when the number of winners stays constant and the number of competitors changes. We also look at the difference in reactions of players to when they are at a disadvantage as compared to when they have an advantage. We find that while many competitors do not respond strongly to competition in any form, that those that do, as represented by the top quartile of performers, respond differently to these framing issues. Specifically, that players respond more strongly to the number of winners changing than to the overall number of competitors, and that having an advantage elicits a stronger response than being at a disadvantage.

The outline of the rest of the chapter is as follows. Section 2 reviews the experimental procedure, section 3 discusses the associated hypotheses, section 4 analyzes the results of the experiment, and section 5 concludes.

4.2 Experimental Procedure

We implemented a risk-taking tournament in a experimental lab setting. The study was conducted by the Anderson Behavioral Lab at UCLA. The study was completed by 82 participants recruited online through the lab and primarily consisted of undergraduate students. Each participant played 21 rounds of the game, and then took a survey to elicit risk preferences and determine quantitative ability. The exact instructions and questions are available in the appendix. During the experiment individuals were given money to make decisions with, and at the end of the game converted at a rate of \$1 for every \$100,000 they won from one randomly selected round of the game, as well as one gamble used to elicit risk preferences. Each participant was paid a show-up fee of \$10 and a performance based bonus that averaged \$2.39 and ranged from \$1.01 to \$9.35. The participants were told to plan on one hour, and on average finished in 48 minutes.

The nature of the game was that of a lottery where a ball was selected from a basket, and the number on the ball was your score for that round. The scores of all players for that round were then ranked. Each round had a certain number of winners, m , and if a player was ranked in the top m they were given a prize for winning that round. The composition of the balls was determined by a player choosing the highest value ball they would like to determine the range, and the rest of the distribution of the balls was determined by this parameter to fit either the discrete normal or discrete log-normal distributions¹³. More details around how the distribution of balls was determined can be found in the appendix in the description and walk-through of the game.

At the start of each round the participant was informed that they were to assume they had \$100,000 to start with, and then shown the parameters of the game for that round. They were then asked how much of the \$100,000 they would pay to play the game. They were then shown a screen that asked how much risk they wanted to take. The participants were able to enter a value for the highest ball and then view the distribution of balls given that choice. Once they were happy with their choice they indicated that it was their choice for the game. Once the distribution was selected the players received their score, rank and payoff as well as this information for the other competitors.

Table 4 shows the parameters associated with each round. Rounds 1-3 used a normal distribution for the distribution of the balls, while all the other rounds used the log-normal. In rounds 12-21 2 players were given an advantage. The size of their advantage was added to whatever score they received from the selection of their ball. In rounds 18-21 the maximum value they could choose to be their highest valued ball was limited.

4.3 Hypotheses

To start, based off of the theoretical reasoning of Chapter 2 we have the following predictions.

¹³ The discrete distributions were determined by giving the value n , all of the density from $n-.5$ to $n+.5$ with a mean of 100. All choices were mean preserving increases(decreases) in variance. For the log normal, the 90 was added to a distribution with a mean of 10 so that 90 was the lower bound. Examples can be seen in the appendix.

Round ¹⁴	# of winners (m)	# of competitors (n)	# of players with an advantage	Size of advantage	Player has advantage	Max/Min of highest valued ball	Winner's prize
1	1	9	-	-	NA	130/100	\$900,000
2	4	9	-	-	NA	130/100	\$200,000
3	7	9	-	-	NA	130/100	\$100,000
4	1	9	-	-	NA	155/100	\$750,000
5	2	9	-	-	NA	155/100	\$300,000
6	3	9	-	-	NA	155/100	\$300,000
7	4	9	-	-	NA	155/100	\$100,000
8	2	5	-	-	NA	155/100	\$175,000
9	2	7	-	-	NA	155/100	\$300,000
10	2	9	-	-	NA	155/100	\$300,000
11	2	11	-	-	NA	155/100	\$433,000
12	2	9	2	5	no	155/100	\$400,000
13	2	9	2	5	yes	155/100	\$150,000
14	2	15	2	5	no	155/100	\$400,000
15	2	15	2	5	yes	155/100	\$350,000
16	2	9	2	10	no	155/100	\$400,000
17	2	9	2	10	yes	155/100	\$150,000
18	2	9	2	5	no	110/100	\$400,000
19	2	9	2	5	yes	110/100	\$100,000
20	2	9	2	5	no	120/100	\$400,000
21	2	9	2	5	yes	120/100	\$150,000

Table 4: Parameters for the different rounds of the game

1. Market structure and competition leads to strategic risk taking that is completely independent of financial risk preferences
2. Firms optimal choice of strategic risk is dependent on market structure. For mean preserving increases of risk that follow a symmetric distribution such as the normal distribution:
 - (a) If the ratio of winners to total competitors is greater than one-half than players should take as little risk as possible.
 - (b) If the ratio of winners to total competitors is less than one-half than players should take as much risk as possible.
3. For mean preserving increases of risk that follow a skewed, or log-normal distribution the optimal level of risk-taking:
 - (a) Increases with the total number of players, n .
 - (b) Decreases with the total number of firms that will ultimately survive, m .
4. Strategic risk is most important to players at a disadvantage
 - (a) Disadvantaged players will choose more risk than players with an advantage
 - (b) The presence of risk and uncertainty benefits players at a disadvantage, and their willingness to play the game should increase as the available strategies increase in risk.

However, as was mentioned in Chapter 2, individuals may not be able to differentiate between different types of risk, and some may be ignorant of competitive effects. Behavioral economics has shown that entrepreneurs are susceptible to various behavioral biases that lead them not to take

into account competition and its impact on the optimal choice of risk. Two of these are the “inside view” and the “illusion of control” (Camerer and Lovo, 1999; Kahneman and Lovo, 1993). Also, traditional business finance is generally taught using NPV and related measures that would make risk appear to be a choice independent of what the competition is doing. The implications of our model are prescriptive, thus entrepreneurs that do take into account competition and take appropriate strategic risks would have an advantage.

Further, thinking about outcomes as distributions and variance is not the natural way of thinking for many individuals. We hypothesize that individuals that are more comfortable with quantitative analysis and abstract thinking will better understand and stick to the prescriptive behavior generated by the model in Chapter 2.

4.4 Analysis and Results

We now test these hypothesis with the results from the lab study that we ran. Figure 10 shows the theoretically predicted results against the average choice of all players for all 21 rounds of the game.

The first observation is that it is clear that in the first three round with the normal distribution choices were not made according to theory. While this is a bit disturbing it could also be that they were still becoming comfortable with the game. Also, most situations in life may not be knife edged with the only the two extreme outcomes of taking either the maximum or minimum amount of risk as the best options. It may be that the average individual responds more in line with what was hypothesized for the log normal, where the amount of risk you take is relative to the competition.

4.4.1 Competition based on the number of winners vs players

Looking at Figure 11 we look at rounds 4-7, where the number of competitors is held constant at $n = 9$, but the number of winners increases each round. we still don't see strong evidence that

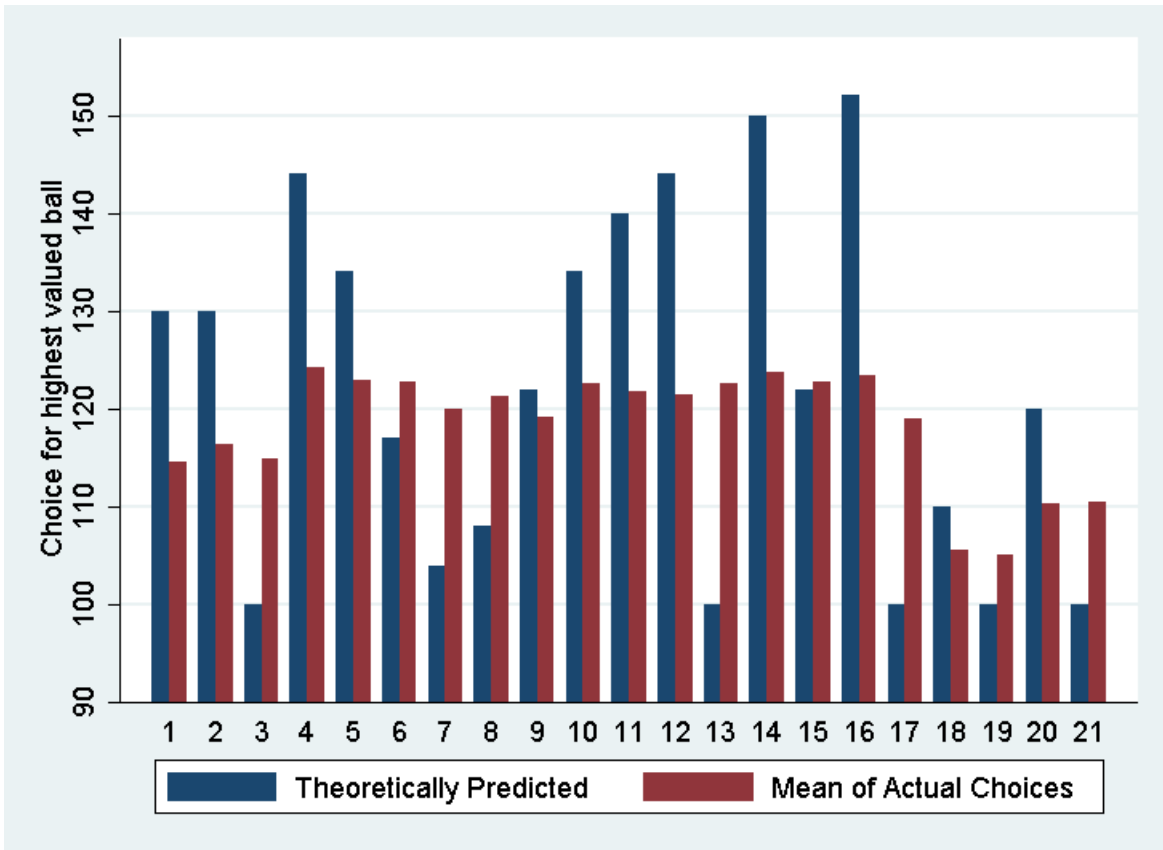


Figure 10: Comparison of theoretically predicted behavior and actual player behavior

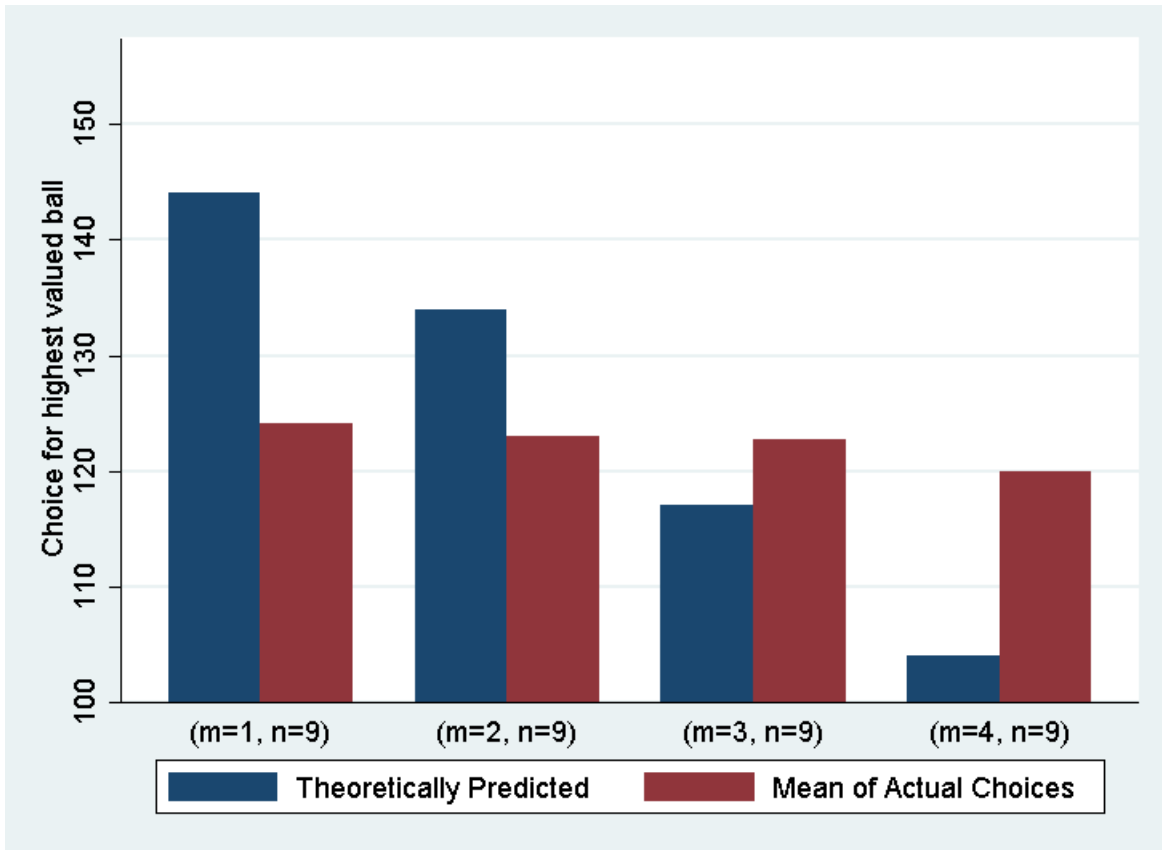


Figure 11: Comparison of theoretically predicted behavior and actual player behavior when m is increasing

players are playing as predicted. While we do see a drop from when $m = 1$ to when $m = 4$, the difference is fairly slight. This is statistically significant at $p < .05$ as is the difference between $m = 3$ and $m = 4$, however, the differences between $m = 1$, $m = 2$, and $m = 3$ are not. One thought would be that players are anticipating what others will do, in some sort of k-level reasoning Ho et al. (1998). Unfortunately this does not stand to scrutiny, as the nature of the equilibrium is such that it is quite robust to others choices. For example, if we assume that players will choose the highest valued ball to be 120 in the round with only one winner, the theoretical prediction only decreases from 144 to 140, hardly the observed discrepancy. However, we did predict that certain individuals would perform better than others, so perhaps we need to look more closely at how different groups behave.

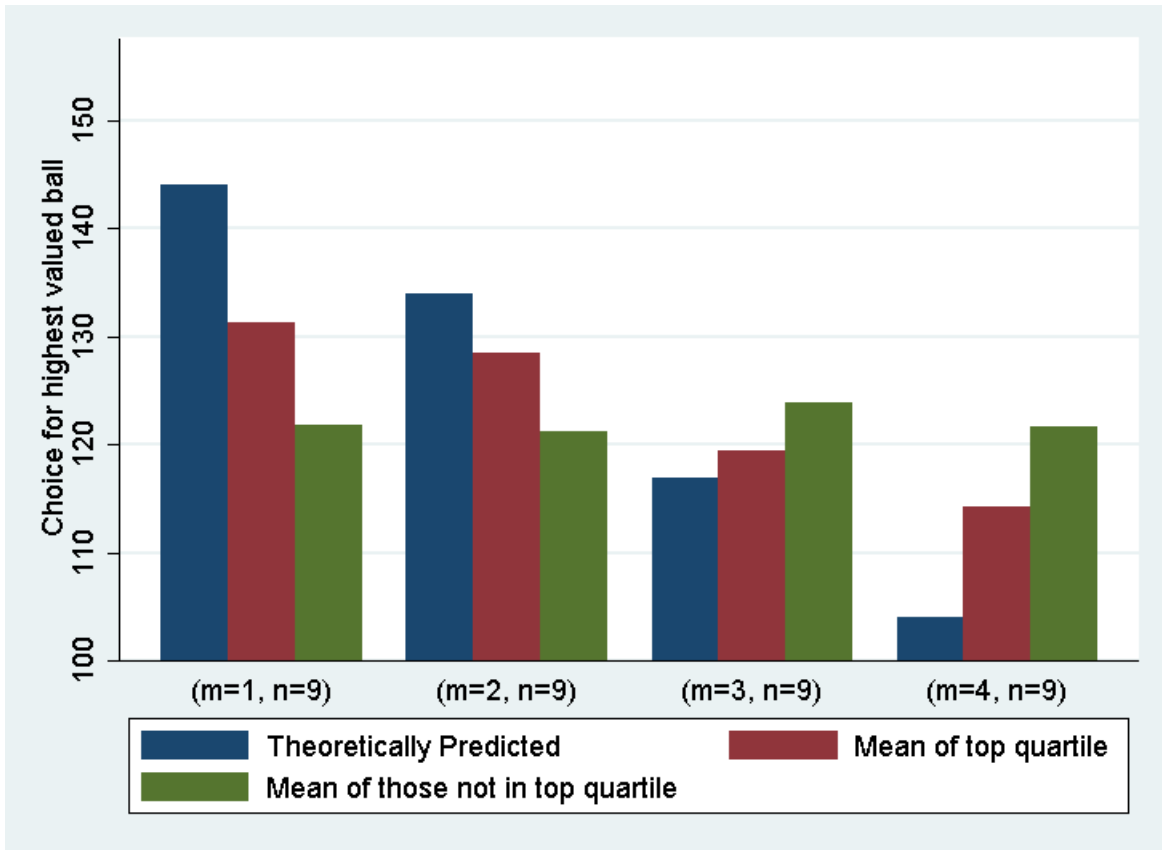


Figure 12: Comparison of theoretically predicted behavior and actual player behavior for when m is increasing, and when broken comparing the top quartile based on performance

To look and see how those that performed in the top quartile compare against others we create a measure of performance which is simply the quadratic error term of the difference between predicted and actual behavior. We create a measure over all 21 games that sums these quadratic errors to get a measure of overall performance. Figure 12 shows how the top, quartile along with the rest of the rest of the players combined compare to the theoretical predictions. If we focus on the top quartile, we see a clear trend that the choice of risk is decreasing in m as hypothesized. However, for the other players, there is no discernible pattern, and m seems to have no effect whatsoever on the choices of individuals in these groups¹⁵. Thus the statistical significance is driven by those in the top quartile.

¹⁵The analysis is further broken down including the bottom quartile and shown in Figure 16 in the appendix

Now turning to rounds 8-11, we have the situation where m is held constant at $m = 2$, and we increase n each round. Once again we can see in Figure 10 there is no discernible pattern, so we look at the choices broken down by performance in the top quartile once again. Figure 13 shows that while the top quartile does show more inclination to follow the theoretical predictions it is much less pronounced than in the case where m was increasing. It may be that participants were focusing on the number of winners more than the overall level of competition. There is some evidence of this in the exit surveys. When asked how they made their choices many participants said they looked at the number of winners, and based it on that. Only a couple of participants stated in the exit surveys stated that they looked at the fraction or ratio of winners to losers.

To test whether or not increasing the number of winners and competitors impacts risk taking as well as if individuals react differently in the two conditions we run the regressions shown in Table 5.

Table 5: Impact of the number of winners and the number of players on risk-taking

	(1)	(2)	(3)	(4)	(5)
Choice of Highest Valued Ball					
Ratio	-11.65* (7.244)	-4.842 (8.557)	-11.65* (7.250)	2.032 (7.760)	-54.04*** (14.05)
Ratio x 8-11			6.803 (10.01)	-0.725 (12.02)	30.14** (16.78)
8-11			-3.187 (3.046)	-0.380 (3.547)	-11.89** (5.681)
Constant	125.7*** (2.528)	122.5*** (2.929)	125.7*** (2.530)	121.6*** (2.868)	138.5*** (4.363)
Rounds of Game					
Included (sample)	3-7	7-11	3-11	3-11	3-11
Observations	328	328	656	496	160
Clusters	82	82	82	62	20

Standard errors in parentheses

For one-sided hypothesis test * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

If we look at the regressions in Table 5 we see, that similar to what was graphically demonstrated, the for rounds 4-7 where m is increasing the effect of competition is borderline significant as shown by Column 1, whereas for games 8-11 there was less of a response to when n was in-

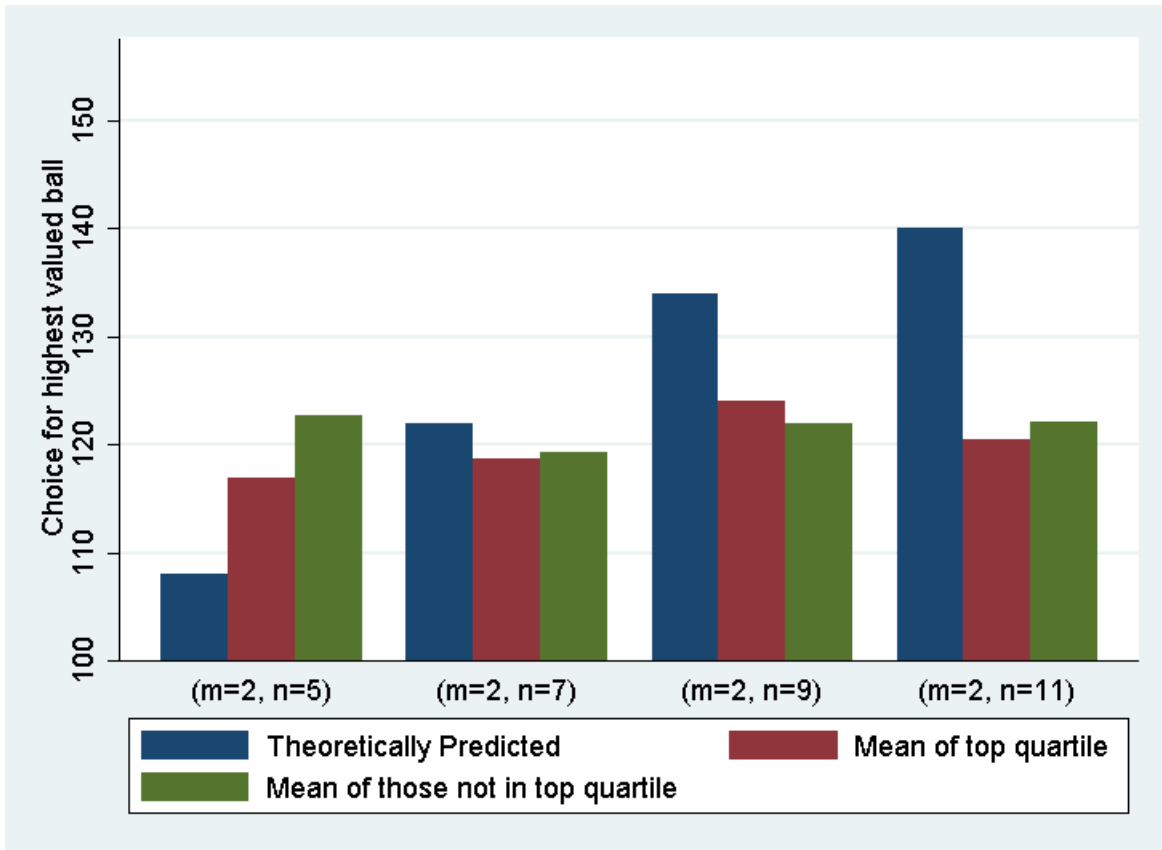


Figure 13: Comparison of theoretically predicted behavior and actual player behavior for when n is increasing, and when broken comparing the top quartile based on performance

creasing and the response was not significant as shown in Column 2. However, Column 3 shows that the difference between the ratio coefficient in the two regressions is not significant.

Figure 12 suggested that the top quartile based on performance followed the hypothesized directional behavior, while the rest of the participants did not. In Column 4 we see that not only is nothing significant for the participants outside of the top quartile, but that the response to competition is practically negligible. On the other hand, for the top quartile not only to the participants strongly react to competition as hypothesized, we do find a significant difference between rounds 3-7 and rounds 8-11 with a much stronger reaction to when increases in competition are of the form of more or less overall winners, m , as opposed to the number of competitors faced, n .

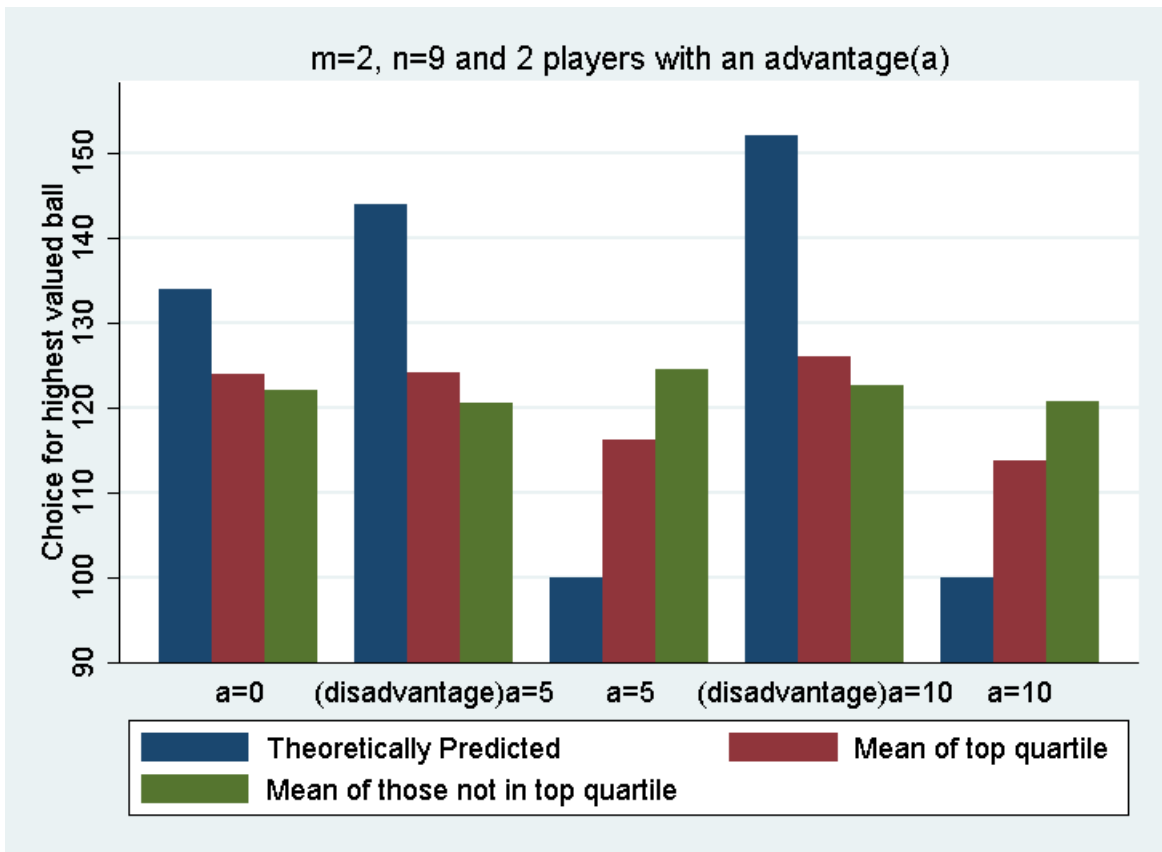


Figure 14: Comparison of theoretically predicted behavior and actual player behavior for when they are ad an advantage or disadvantage.

4.4.2 Competition with an (dis) advantage

In the games 12-21, there were players with an advantage as shown in Table 4. Theory predicts that risk taking increases when at a disadvantage, and decreases when at an advantage. Table 14 shows how experimental behavior compared to the theoretical prediction, once again with the top quartile as a separate group. Interestingly, players appear to have responded more strongly by decreasing their risk when they had an advantage than they did to responding to a disadvantage. Participants in the top quartile also seem to react more strongly, measured bigger difference between the choice when playing with an advantage vs when at a disadvantage, when the (dis)advantage is larger as the difference is larger when $a = 10$ than when $a = 5$.

If we compare rounds 12 and 13 where players had a disadvantage and advantage of 5 re-

spectively, Column 1 of Table 6 shows that there is not significant difference. However, when the advantage is increased to 10 as in rounds 16 and 17 the difference in strategies from when players had an advantage compared to when they had a disadvantage produces a significant difference.

Table 6: Impact of competing with an (dis)advantage on risk-taking

	(1)	(2)	(3)	(4)	(5)
Choice of Highest Valued Ball					
Advantage	1.122 (1.973)	-4.402** (2.062)			
Ratio			-10.41** (5.350)	0.812 (5.491)	-45.18*** (10.82)
Size of Advantage			-0.241 (0.188)	0.0384 (0.220)	-1.105*** (0.291)
Size of Disadvantage			0.0513 (0.200)	0.00401 (0.228)	0.198 (0.423)
Constant	121.4*** (1.934)	123.5*** (1.887)	124.7*** (1.970)	121.7*** (2.216)	134.1*** (3.610)
Rounds of Game Included (sample)	12-13	16-17	3-17	3-17	3-17
Observations	164	164	1148	868	280
Clusters	82	82	82	62	20

Standard errors in parentheses

For one-sided hypothesis test * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To be able to see how the impact of competition due to the number of winners as a fraction of the total number of players compares to competition driven by certain players having an advantage we run a regression on rounds 4-17 in Column 3 of Table 6. This regression shows that while across the rounds the significance of the ratio of winners to competitors increases compared to what we saw in Table 5, the coefficients for the size of the advantage or disadvantage a player has is not significant. In both cases the sign on the coefficients is in the right direction, but not significant.

To drill down a little more we once again run the regression broken down by those in the top quartile of performance and those that are not. For those not in the top quartile Column 4 shows that there is practically no effect of the hypothesized competitive influences on risk taking. On the other hand, Column 5 shows that both the ratio of winners to competitors as well as the size of an

advantage are both strong influencers and highly significant. Interestingly, being at a disadvantage still doesn't influence decisions. Even though not shown in the table, the difference between the impact of an advantage and an equally sized disadvantage is significant at the $p < .01$ level. Similarly, while not shown the difference between the top quartile and the rest of the participants is significant at the $p < .01$ level.

The presence of risk and uncertainty benefits players at a disadvantage, and their willingness to play the game should increase as the available strategies increase in riskiness. Figure 15 shows the bids for playing when the maximum value that could be chosen for the highest valued ball decreased. Theoretically players should see their willingness to pay decrease, but for games with the prize held constant at \$400,000, the observed behavior was actually if anything the opposite. While all effects are not significant, we refrain from showing any regressions as it is obvious from the Figure that play does not follow the hypothesized behavior.

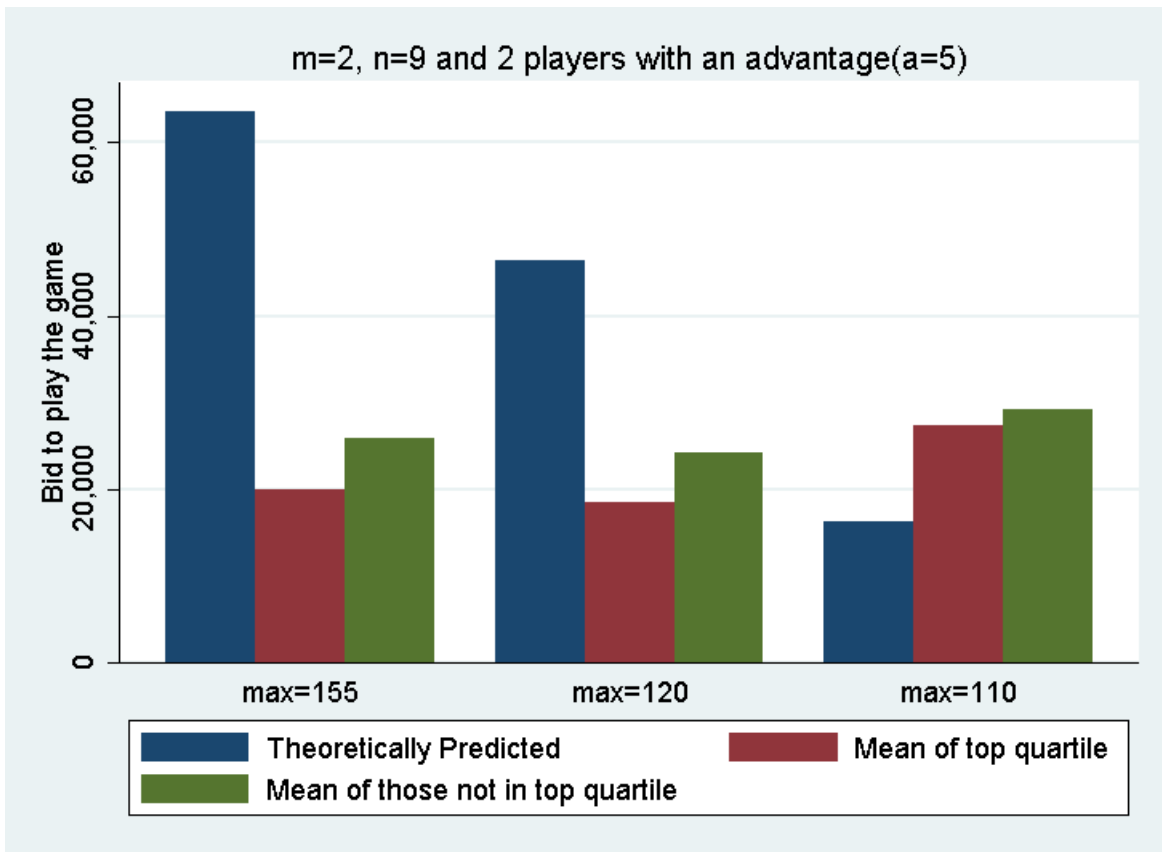


Figure 15: Comparison of theoretically predicted behavior and actual player behavior for expected payoffs and subsequent bids to play asymmetric games when the maximum variance is reduced.

As has been shown not everyone plays according to how theory would predict. This leaves the question of who plays strategies closer to the theoretical and prescriptive predictions. One of the questions raised earlier is if players are able to differentiate between risks and if risk aversion would impact risk taking under competition. Theoretically, the two aspects should be separate, but we hypothesize that an inability to differentiate exist. We also expect that quantitative ability would help players performance. Unfortunately, these two measures may be related as a greater quantitative ability may be related to being less risk averse. We also expect that players actually learn how to play as they gain experience playing the game, and that performance would improve in the later rounds.

To answer these questions we look at how the quadratic error changes over the time of the

Table 7: Performance prediction and learning

	(1) QD	(2) Total QD	(3) Total QD
Round	-10.11* (7.498)		
Quantitative ability	-19.91* (12.47)	-371.5** (221.3)	-352.76* (223.5)
ARA	0.369* (0.241)	6.107* (4.232)	5.67* (4.158)
LN	-233.9*** (54.00)		
Assymetric	352.4*** (61.29)		
Time spent reading instructions			-1.145 (1.801)
Constant	599.7*** (96.46)	10601.3*** (1261.7)	10753.1*** (1374.8)
Observations	1360	1680	1680
Clusters	80	80	80

Standard errors in parentheses

For one-sided hypothesis test * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

experiment. Column 1 in Table 7 shows a regression by error term for every round of the game. We also include a term for the score of a short quantitative measurement test given in the survey, as well as a calculated risk aversion measure, ARA. We also include dummies for whether the distribution was normal or log normal (distribution = 1 for log normal), and if it was during a round with an asymmetric game. For a one sided hypothesis test we find weak support for all measures at the $p < .1$ level. Players improvement by round is indicative of learning, but it is weak. We also find that players did much better in the task when the distribution of outcomes was in the form of a log normal distribution. Finally, players did much better when not playing in an asymmetric game.

We also look at overall performance by taking the total error over all rounds. Column 2 in Table 7 shows that similar to when looking round by round ARA is moderately significant, and for this specification an individuals quantitative ability is significant at $p < .05$. In Column 3 we include a measure of the time a player took to go over the instructions. This was included to see if players that took the time to understand the game did better. Unfortunately, it may also be that taking longer represents not understanding the game.

4.5 Conclusion

Competition can take many forms, and in this paper we have gone beyond 2 player games to look at the different aspects of competition that can drive risky behavior. Consistent with the literature and arguments laid out in the introduction the level and nature of competition can have a big impact on the levels of risk taking in a tournament setting.

Interestingly, it is not a natural setting for individuals to think about risk taking as a rational response to competition. While we did find significant effects, we also found that a large portion of participants did not respond as would be predicted by theoretical models. The fact that the models are prescriptive, and that in all cases that we tested participants would have been better off playing according to the theoretically predicted manner makes this finding particularly interesting. Perhaps in many settings the ability to recognize the level of competition and appropriate risks is a valuable and rare skill. In setting such as entrepreneurship this would certainly be the case, and perhaps

this is one of the reasons that the general public views entrepreneurs as risk takers, while many actual entrepreneurs would not consider themselves as such and many studies have failed to find a significant correlation between entrepreneurship and risk-taking attitudes.

We have also demonstrated that not only is the level of competition important to how individuals choose risk, but also how it is framed. Participants responded more to changing the number of winners than the number competitors, even though the response should be the same for equal levels of competition. Further, participants responded more strongly when they had a lead than when they were at a disadvantage. Why these framing issues make the difference offers the opportunity for further exploration. One thing that is clear is that since competition and risk taking is an integral part of society, a better understanding of how individuals make decisions around risks they want to take is an important research direction that needs to be explored.

4.6 Appendix

4.6.1 Additional figures

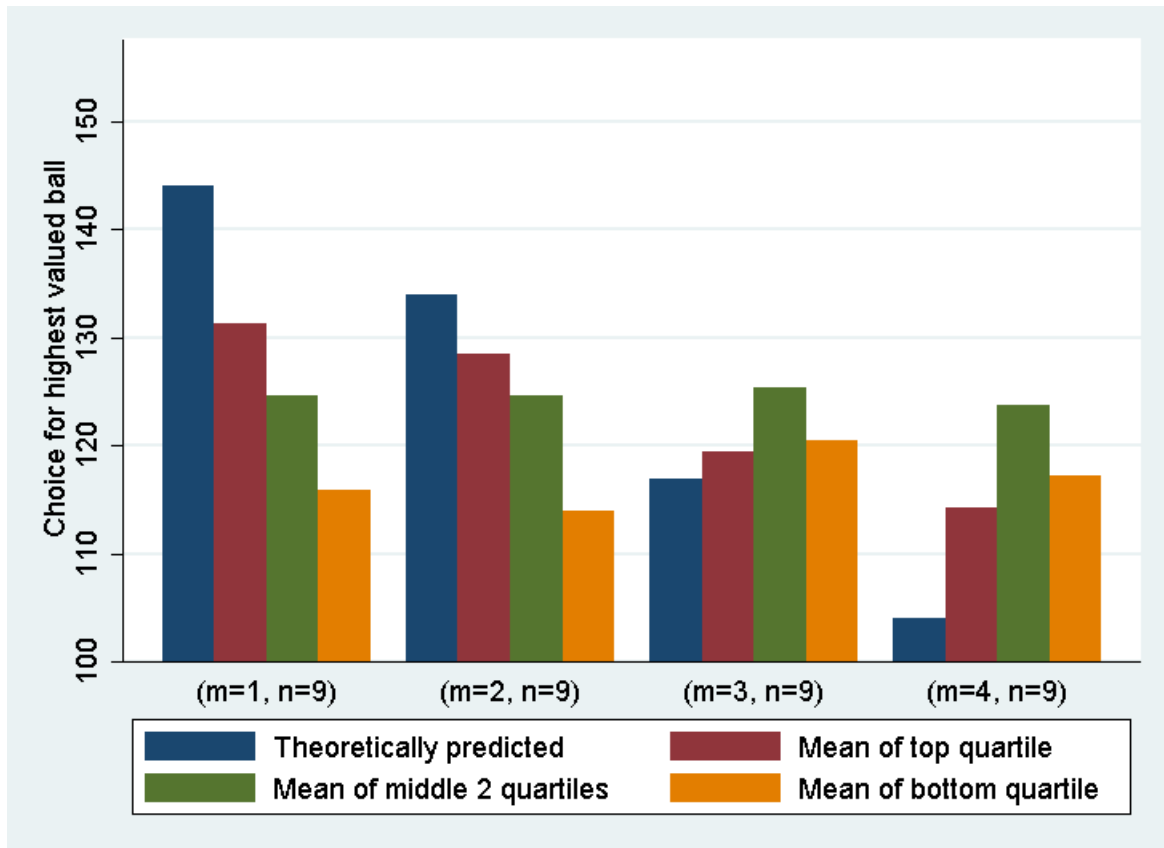


Figure 16: Comparison of theoretically predicted behavior and actual player behavior for when m is increasing, and when broken down by quartiles based on performance

k

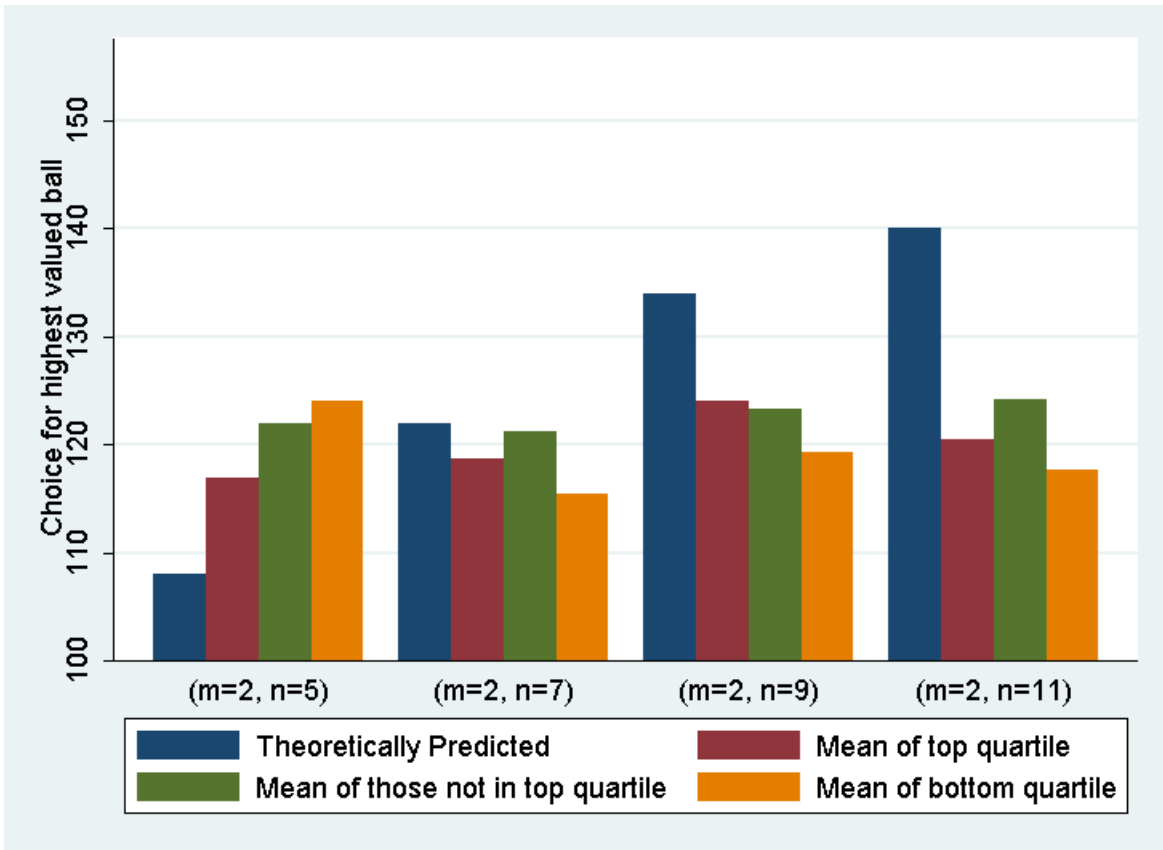


Figure 17: Comparison of theoretically predicted behavior and actual player behavior for the top and bottom quartile of performance when n is increasing

4.6.2 Instructions for the experiment

Consent and instructions

CONSENT TO PARTICIPATE IN RESEARCH

You are invited to participate in a research study conducted by Suzanne Shu, Assistant Professor at Anderson School of Management. To be a participant in this study you must be at least 18 years of age or older. Participation in this study is voluntary. You will be surveyed about choices for decisions under competition and uncertainty.

PURPOSE OF THE STUDY We are investigating decision-making and attitudes towards different choices and scenarios involving hypothetical decisions under competition and uncertainty.

PROCEDURES You will be given hypothetical situations to consider. You will then be asked questions about different choices and preferences related to those situations. You will then play a game where your choices will influence your chances of winning the game.

POTENTIAL RISKS AND DISCOMFORTS There are no foreseeable physical or psychological risks associated with this study.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY There are no immediate benefits to participants. The data we collect from this study will contribute to ongoing research in decision making.

PAYMENT FOR PARTICIPANT Payment for a 45 minute study will be a guaranteed payment of \$5 and a performance dependent payment may be as high as \$20.

CONFIDENTIALITY All responses are anonymous and no information that is obtained through your responses from this study will be identified with you. Only the investigators will have access to your data during and after the study concludes.

CONTACT INFORMATION If you have any questions or concerns about this study; please feel free to contact Suzanne Shu at suzanne.shu@anderson.ucla.edu.

RIGHTS OF RESEARCH SUBJECTS Your participation in this study is voluntary. You may choose to withdraw consent and discontinue participation at any time without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you wish to ask questions about your rights as a research participant or if you wish to voice any problems or concerns you may have about the study to someone other than the researchers, please call the Office of the Human Research Protection Program at (310) 825-7122 or write to Office of the Human Research Protection Program, UCLA, 11000 Kinross Avenue, Suite 102, Box 951694, Los Angeles, CA 90095-1694.

SIGNATURE OF RESEARCH SUBJECT I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. Your voluntary completion of the survey constitutes your consent to participate.

Instructions for the experiment

Welcome to this experiment!

Please read these instructions carefully. Please note the following:

1. All decisions are anonymous. No one will learn the identity of you or any of the other participants.
2. The payment is anonymous too. No one else will get to know how high the payment of each participant is.
3. This study consists of two parts. The first part is an experiment where you will choose your strategy to compete against other individuals in a game, as well as an evaluation of how much you would pay to play the game. The second part consists only of a short questionnaire.
4. In each round of the game you will be competing against other participants and their choices (not a computer). The identity of other players will not be revealed, and will be randomly chosen from the set of

- past participants that have already played a game that matches the conditions of the game/stage you are in.
5. After all rounds of the game are finished the second part of the experiment starts. Please fill out the questionnaire which will appear on the screen.
 6. Payment will only be given to those that finish both the experiment and survey. At the end of this survey you will receive payment both your participation payment as well as a performance based payment based on your performance in randomly selected rounds.
-

Progress of the game

1. In each round you will play a game competing against a set number of competitors, of which there will be a pre-determined number of winners. For example, a game may have 15 competitors, and if the predetermined number of winners is 5, then the top 5 performers will earn the prize for that round.
2. Your score is determined by a random lottery draw. Imagine you have 1,000 balls in a basket each with a number on them. One ball is then selected randomly for you, and the number on the ball is your score for that round. All players' scores will be determined in this way.
3. Before the ball is drawn you get to choose the composition of the numbers on the balls in the basket from predetermined options. For example, you may have two options.
 1. The first option is that all balls have the score of 100 written on them. Then since all balls have the number 100 on them you know your score will be 100.
 2. In the second option you can choose to have 500 of the balls with a score of 95 and 500 with a score of 105. Then half the time your score will be 95 and half the time 105. In this case you have the chance at a higher score, but at the risk of having a lower score.
4. Since choosing the composition of the is the strategic decision you will make each round this step will be explained in detail during a tutorial that will walk you through one round of the game before you start.
5. Once you and your competitor's scores are determined by drawing balls from the chosen baskets, players will be ranked according to their score for that round, and the predetermined number of winners will win the prize.
6. So, if the number of winners is m , then the players with the top m values will win and collect their profits for that round. In the case of a tie, if both players are in the top m then both win. If it is a tie for the last position that will win, the firm that wins will be chosen randomly so every tied firm has an equal chance of being chosen.

Bonus Structure

1. Each round you will be given \$100,000, and asked to decide how much of this you would be willing to pay to enter the market described.
2. At the end of this survey one of the markets will be randomly selected, and your performance on this round will determine half of your bonus pay.
3. To determine your bonus pay, a random number generator will choose a price between 0 and 100,000. If the value you entered that you are willing to pay is **less** than the price randomly generated, you will not take the gamble and you will add \$100,000 to your game earnings which will be converted to a bonus payment at the end of the game. However, if the value you entered that you are willing to pay is **more** than the price randomly generated, then you will pay the random price generated, the computer will conduct the gamble, and you will win according to the probabilities listed. The amount of money that you have after this gamble will then be added to your game earnings, which will be converted to a bonus payment at the end of the game.
4. **While this seems complicated, all it really means is that it is in your best interest to enter how much you would be willing to pay truthfully.**
5. The other half of your bonus pay will be determined from decision you make where you choose how much of \$100,000 to allocate to a pure chance gamble.
6. At the end of the game the amount you earned from the two rounds selected will be added up, and you will earn \$1 for every \$100,000 you have accumulated. For example, if your total earnings were \$345,000 you would earn \$3.45 in bonus pay on top of the flat payment you are receiving for taking this survey.

You will now be presented with a walk-through of one round of the game explaining the game in detail before you start.

Thank you for your participation and good luck!

Details around each round and an example

Each round will vary in the number of competitors, number of winners, the size of the prize as well as the choices

you have for the composition of the balls in the basket. In general you will be able to choose the maximum value that is on a ball, and that will then determine the composition of the rest of the balls in the basket. You will be able to choose any number between a minimum and maximum value that you will be provided with in the game.

The first screen you will see each round is the one shown below.

It will tell you the number winners the game will have as well as the number of competitors.

Winners profits are what the winners of this round get.

You can also see the maximum and minimum values and the associated composition of balls that you can choose by clicking on the links in the last column. You will be able to choose any value for your highest value between the minimum and maximum shown.

UCLAAnderson
School of Management

Assume, you have \$100,000 for this round. At the end of this survey if this round is selected to determine your bonus pay, your ending balance will go towards your earnings to be converted to your bonus as described in the instructions at the beginning of this study.

As discussed in the instructions at the beginning of the survey, it is in your best interest to enter how much you would be willing to pay truthfully.

# of Winners	# of Competitors	Winner's Profits	Max/Min Complexity as a Distribution
1	4	\$350,000	Max / Min

For the market described above, please enter the maximum amount you would be willing to pay to enter the market in the input box below.

>>

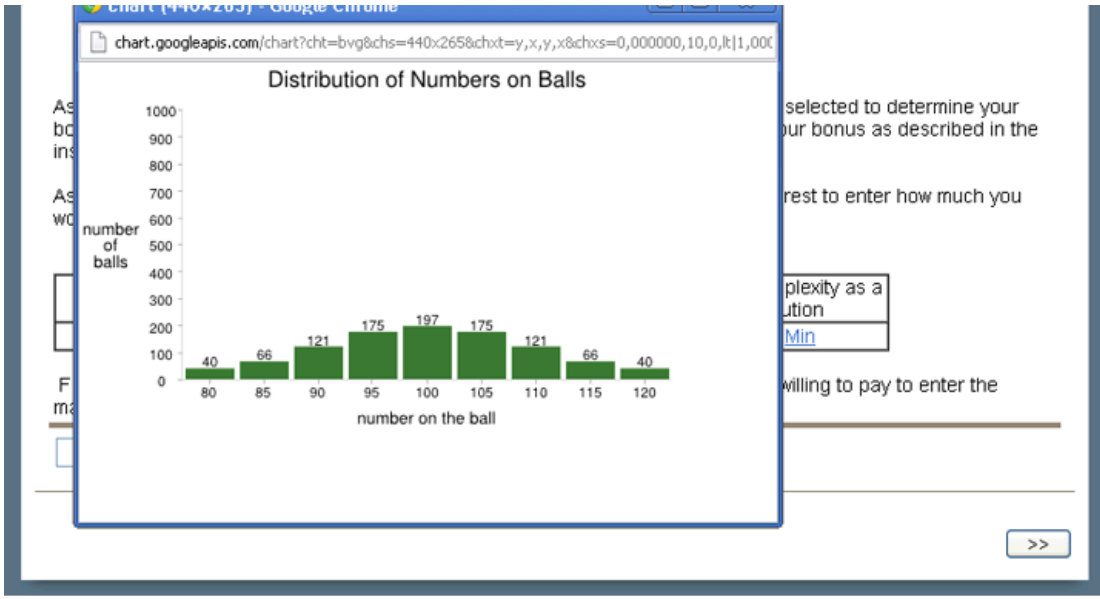
If you click on Max, a pop up window will show you the distribution that is associated with choosing a the maximum value possible for your highest valued ball. In this case the maximum is 120.

The way to read this chart is that each bar represents the number of times out of a 1,000, that the value on the ball, and thus your score, will be that value. So, for the example below if you choose a your highest value to be 120, then for you 40 out of 1,000 balls will have the value of 120, 66 out of 1,000 balls will have a score of 115, and so on.

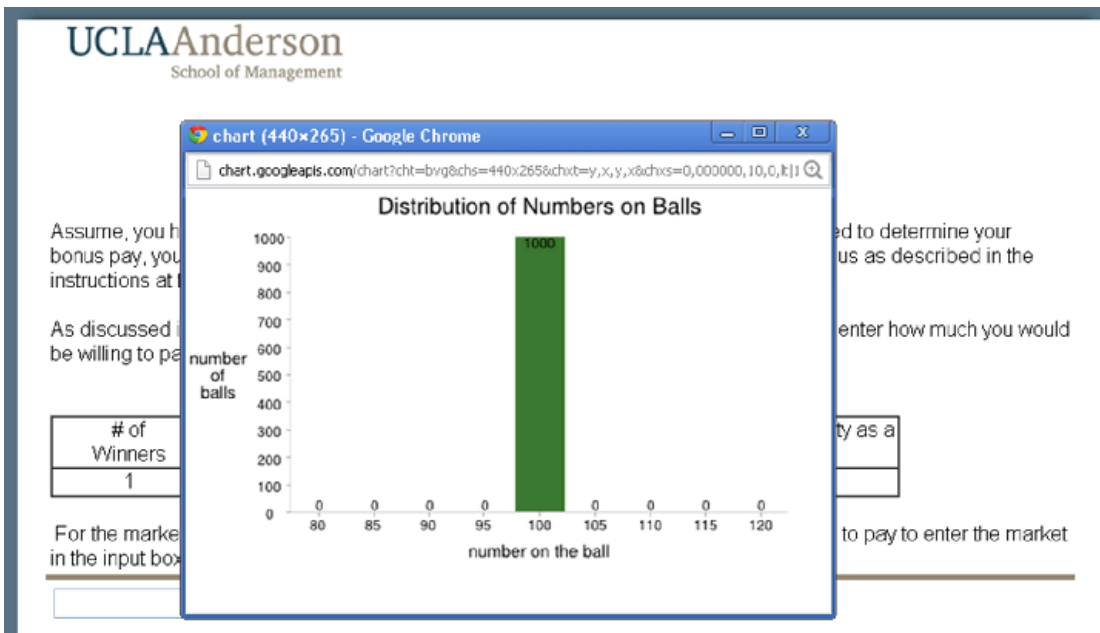
As you can see, as you increase the highest valued ball you also increase the risk of choosing of a lower valued ball.

UCLAAnderson
School of Management

chart (440x265) - Google Chrome



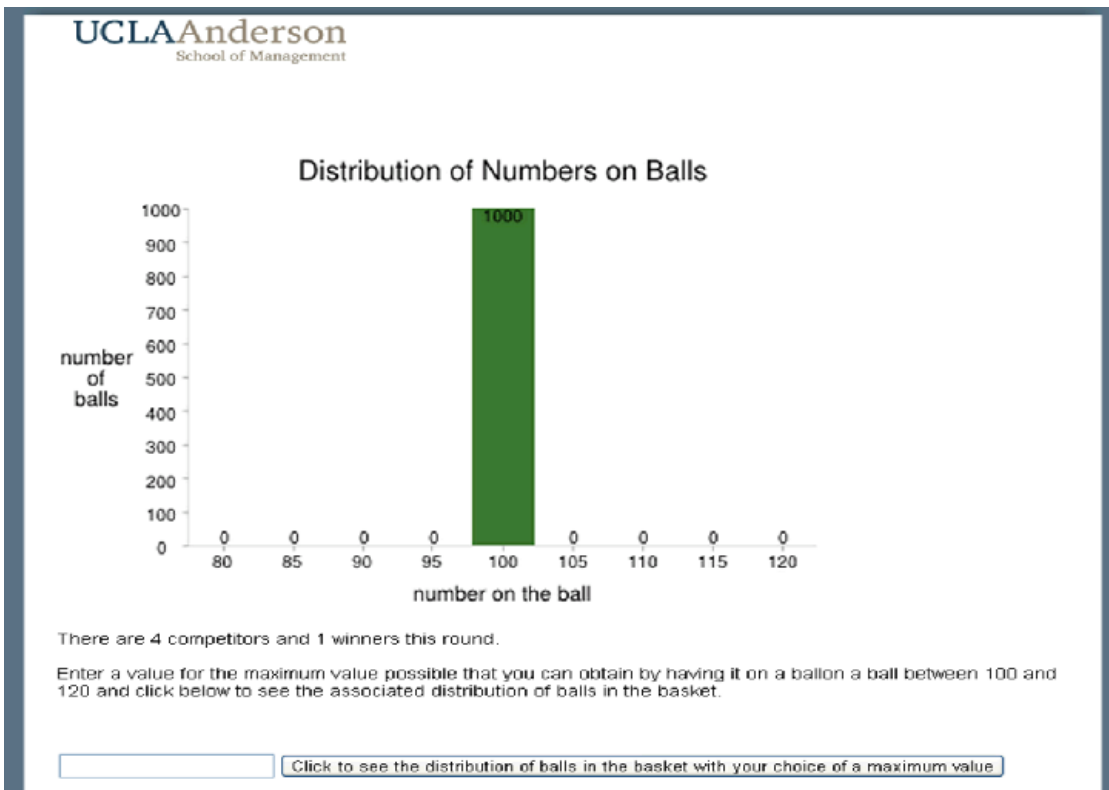
If you click on Min, you will see the distribution that is associated with choosing the minimum value you can choose for your highest value. In this case the minimum is 100, and all 1,000 balls will have the value of 100.





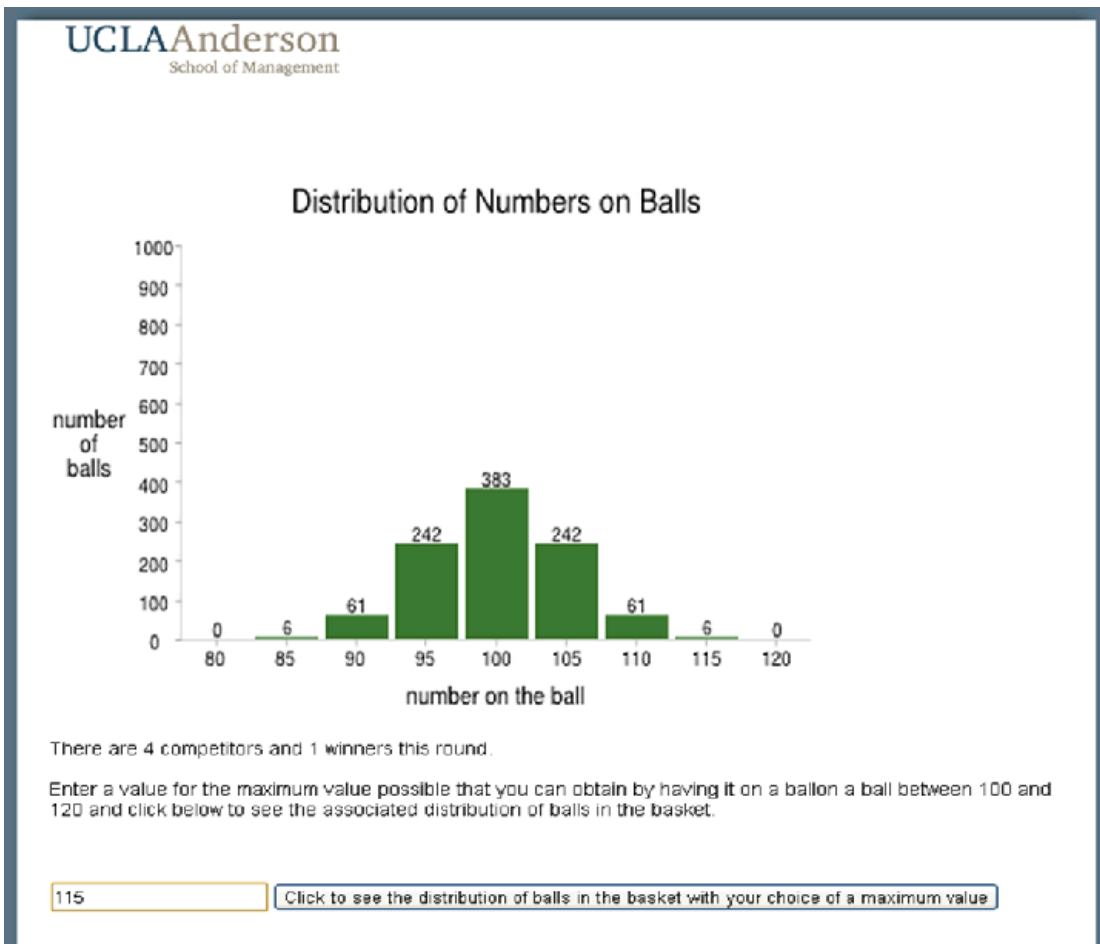
The next screen lets you choose the highest valued ball that you want. You enter in a score between the minimum allowed and the maximum allowed. In this case as shown on the previous screen this means a value between 100 and 120. You then click on the button that says "Click to see the distribution of balls in the basket with your choice of a highest value."

The chart will then update as shown in the following figures.



Click here when the value of sigma you entered above is the value you wish to choose for this round

So if you enter in 115, after clicking on the button you will see the distribution associated with this being the highest valued ball.



Click here when the value of sigma you entered above is the value you wish to choose for this round

Once you are happy with the complexity score you have entered, click on the radio button below your score.

So in this case you would be choosing to have your highest valued ball be 120, and the associated ball frequencies as shown in the chart below.

UCLA Anderson
School of Management

Distribution of Numbers on Balls

number on the ball	number of balls
80	40
85	66
90	121
95	175
100	197
105	175
110	121
115	66
120	40

There are 4 competitors and 1 winners this round.

Enter a value for the maximum value possible that you can obtain by having it on a ball on a ball between 100 and 120 and click below to see the associated distribution of balls in the basket.

Click here when the value of sigma you entered above is the value you wish to choose for this round

You will then get a screen that tells you how you performed that round.

UCLAAnderson
School of Management

Here is how you performed :

Your Score	Your rank out of 4 competitors	Your profits for this round
105	1	\$ 350,000

Here is the quality scores and rank of you and your competitors.

Quality Rank	1	2	3	4
Profits	\$350,000	\$0	\$0	\$0
Quality Measure	105	90	85	85

At this point you will repeat the above steps for a new market.

You will now begin. You will play 20 rounds of the game, followed by a quick survey.

Game questions

Assume, you have \$100,000 for this round. At the end of this survey if this round is selected to determine your bonus pay, your ending balance will go towards your earnings to be converted to your bonus as described in the instructions at the beginning of this study.

As discussed in the instructions at the beginning of the survey, it is in your best interest to enter how much you would be willing to pay truthfully.

# of	# of	Winner's	Mean/Std. Dev./Skewness

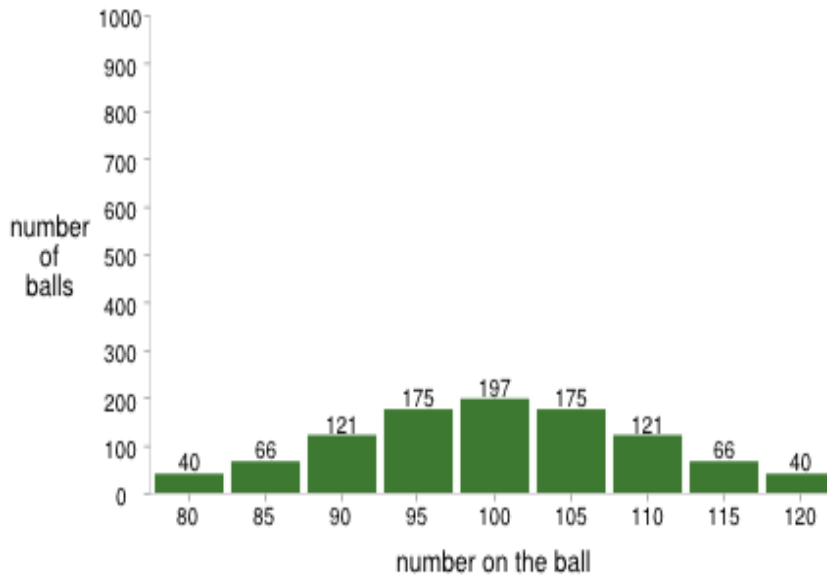
5/1/13

Qualtrics Survey Software
Max/Min Complexity as a Distribution

Winners	Competitors	Profits	
1	4	\$350,000	Max / Min

For the game conditions described above, please enter the maximum amount you would be willing to pay to enter the market in the input box below.

Distribution of Numbers on Balls



There are 4 competitors and 1 winners this round.

Enter a value for the maximum value possible that you can obtain by having it on a ballon a ball between 100 and 120 and click below to see the associated distribution of balls in the basket.

[Click to see the distribution of balls in the basket with your choice of a maximum value](#)

Click here when the value of sigma you entered above is the value you wish to choose for this round

Here is how you performed :

Your Score	Your rank out of $\{e://Field/tempN\}$ competitors	Your profits for this round

<https://ucla.qualtrics.com/ControlPanel/Ajax.php?action=GetSurveyPrintPreview&T=d0F6h>

9/13

\${e://Field/ppq} |
 \${e://Field/ppos} |
 \$ \${e://Field/realizedprofit}

Here is the quality scores and rank of you and your competitors.

You are now done with the game portion of this survey. Before you move on to the next part which consists of a short questionnaire, can you please describe below you decision making process in the previous games.

Please include any information such as why/when you chose to have a high or low maximum value, how market conditions impacted the decisions you made etc.

Risk profile and demographics etc

People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is the possibility of negative consequences. However, riskiness is a very personal and intuitive notion, and we are interested in your gut level assessment of how risky each situation or behavior is.

For each of the following statements, please indicate how risky you perceive each situation to be. Please provide a rating from *Not at all Risky (1)* to *Extremely Risky (7)*, using the scale below:

	Not at all Risky	Slightly Risky	Somewhat Risky	Moderately Risky	Risky	Very Risky	Extremely Risky
Start your own company using your savings.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Starting a new career in your mid-thirties.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Start a company using money invested by friends and family.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Revealing a friend's secret to someone else.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sunbathing without sunscreen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Choosing a career that you truly enjoy over a more secure one.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Investing 5% of your annual income in a very speculative stock.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Driving a car without wearing a seat belt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Not at all Risky	Slightly Risky	Somewhat Risky	Moderately Risky	Risky	Very Risky	Extremely Risky

Not returning a wallet you found that contains \$200.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Investing 10% of your annual income in a new business venture.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Going whitewater rafting at high water in the spring.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Going down a ski run that is beyond your ability.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For each of the following statements, please indicate the likelihood that you would engage in the described activity or behavior if you were to find yourself in that situation.

Please provide a rating from *Extremely Unlikely (1)* to *Extremely Likely (7)*, using the scale below:

	Extremely Unlikely	Moderately Unlikely	Somewhat Unlikely	Not Sure	Somewhat Likely	Moderately Likely	Extremely Likely
Going whitewater rafting at high water in the spring.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Start your own company using your savings.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Investing 5% of your annual income in a very speculative stock.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Going down a ski run that is beyond your ability.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Driving a car without wearing a seat belt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Start your own company using money invested by friends and family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Choosing a career that you truly enjoy over a more secure one.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Not returning a wallet you found that contains \$200.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Extremely Unlikely	Moderately Unlikely	Somewhat Unlikely	Not Sure	Somewhat Likely	Moderately Likely	Extremely Likely
Investing 10% of your annual income in a new business venture.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sunbathing without sunscreen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Starting a new career in your mid-thirties.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Revealing a friend's secret to someone else.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Below are several statements that may apply to you. There are no right or wrong answers, or trick questions.

Based on your understanding of the statement, select answer that you believe is most accurate. **Please provide a rating from *Never(1)* to *Always (7)*, using the scale below:**

	Never	Rarely	Occasionally	Sometimes	Often	Very Often	Always
Achievement is important to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Before making a difficult decision I like to gather as much information as possible.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Having power is important to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I fear losing control.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would rather fail on my own that succeed due to others help/influence.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please indicate the highest level of education completed.

- Grammar School
- High School or equivalent
- Vocational/Technical School (2 year)
- Some College
- College Graduate (4 year)
- Master's Degree (MS)
- Doctoral Degree (PhD)
- Professional Degree (MD, JD, etc.)
- Other

What is your gender?

- Female
- Male

What year were you born? (ie 1964, 2001)

Have you ever started a company?

- Yes
- No

Do you expect to start your own company within the next 5 years?

- Yes

No

Do you expect to ever start your own company ?

Yes

No

Strict gamble preferences

Assume that you have \$100,000. Please enter how much you would be willing to pay for each of the gambles listed below. At the end of this survey one of the gambles will be randomly selected. A random number generator will then choose a price between 0 and \$100,000. If the value you entered that you are willing to pay is *less* than the price randomly generated, you will not take the gamble and you will add \$100,000 to your game earnings which will be converted to a bonus payment at the end of the game. However, if the value you entered that you are willing to pay is *more* than the price randomly generated, then you will pay the random price generated, the computer will conduct the gamble, and you will win according to the probabilities listed. The amount of money that you have after this gamble will then be added to your game earnings, which will be converted to a bonus payment at the end of the game.

While this seems complicated, as discussed in the instructions at the beginning of the survey, all it really means is that it is in your best interest to enter how much you would be willing to pay truthfully.

	Enter how much you would pay to make the following gambles
Win \$50,000 with a probability of 50%	<input type="text"/>
Win \$90,000 with the odds of winning being 3/7	<input type="text"/>
Win \$250,000 with a probability of 10%	<input type="text"/>
Win \$450,000 with a probability of 5%	<input type="text"/>
Win \$850,000 with a probability of 12%	<input type="text"/>

References

- Zoltan J. Acs and David B. Audretsch. Innovation in large and small firms: An empirical analysis. *The American Economic Review*, 78(4):678–690, September 1988.
- Barry C. Arnold, N. Balakrishnan, and H. N. Nagaraja. *A First Course in Order Statistics*. SIAM, September 2008. ISBN 9780898716481.
- David B. Audretsch. New-firm survival and the technological regime. *The Review of Economics and Statistics*, 73(3):441–450, August 1991.
- Albert Banal-Estañol and Inés Macho-Stadler. Scientific and commercial incentives in R&D: research versus development? *Journal of Economics & Management Strategy*, 19(1):185–221, 2010.
- W. J. Baumol. *The Microtheory of Innovative Entrepreneurship*. Princeton Univ Pr, 2010.
- Victor Bennett, Lamar Pierce, Jason Snyder, and Michael Toffel. Customer-driven misconduct: How competition corrupts business practices. *Management Science*, 2013.
- A. V. Bhide. *The origin and evolution of new businesses*. Oxford University Press New York, 2003.
- Timothy F. Bresnahan and Peter C. Reiss. Entry and competition in concentrated markets. *Journal of Political Economy*, pages 977–1009, 1991.
- L. M. B. Cabral. R&D competition when firms choose variance. *Journal of Economics & Management Strategy*, 12(1):139–150, 2003.
- Hongbin Cai and Qiao Liu. Competition and corporate tax avoidance: Evidence from chinese industrial firms*. *The Economic Journal*, 119(537):764–795, 2009.
- C. Camerer and D. Lovo. Overconfidence and excess entry: An experimental approach. *American Economic Review*, pages 306–318, 1999.
- Judith Chevalier and Glenn Ellison. Risk taking by mutual funds as a response to incentives. *Journal of Political Economy*, 105(6):1167–1200, December 1997.
- P. A Diamond and J. E Stiglitz. *Increases in risk and in risk aversion*. MIT, 1973.
- Anil Gaba, Ilia Tsetlin, and Robert L. Winkler. Modifying variability and correlations in Winner-Take-All contests. *Operations Research*, 52(3):384–395, June 2004.
- Judith R. Gelman and Steven C. Salop. Judo economics: capacity limitation and coupon competition. *The Bell Journal of Economics*, pages 315–325, 1983.
- Paul A. Geroski. What do we know about entry? *International Journal of Industrial Organization*, 13(4):421–440, 1995.
- S. M Gilpatric. Risk taking in contests and the role of carrots and sticks. *Economic Inquiry*, 47(2): 266–277, 2009.

- Christine Harbring, Bernd Irlenbusch, Matthias Kräkel, and Reinhard Selten. Sabotage in asymmetric contests—An experimental analysis. *International Journal of the Economics of Business*, forthcoming, 2004.
- Joachim Henkel, Thomas Ronde, and Marcus Wagner. And the winner is – acquired: Entrepreneurship as a contest with acquisition as the prize. *SSRN eLibrary*, December 2010.
- Teck-Hua Ho, Colin Camerer, and Keith Weigelt. Iterated dominance and iterated best response in experimental "p-beauty contests". *The American Economic Review*, 88(4):947–969, 1998.
- H. A. Hopenhayn. Entry, exit, and firm dynamics in long run equilibrium. *Econometrica: Journal of the Econometric Society*, 60(5):1127–1150, 1992.
- Nguyen M. Hung and Nicolas Schmitt. Quality competition and threat of entry in duopoly. *Economics Letters*, 27(3):287–292, 1988.
- Hans K. Hvide and Eirik G. Kristiansen. Risk taking in selection contests. *Games and Economic Behavior*, 42(1):172–179, January 2003.
- B. Jovanovic. Selection and the evolution of industry. *Econometrica: Journal of the Econometric Society*, pages 649–670, 1982.
- Daniel Kahneman and Dan Lovallo. Timid choices and bold forecasts: A cognitive perspective on risk taking. *Management Science*, 39(1):17–31, January 1993.
- Olga M. Khessina and Glenn R. Carroll. Product demography of de novo and de alio firms in the optical disk drive industry, 1983–1999. *Organization Science*, 19(1):25–38, January 2008.
- Matthias Kräkel. Optimal risk taking in an uneven tournament game with risk averse players. *Journal of Mathematical Economics*, 44(11):1219–1231, December 2008.
- Matthias Kräkel and Dirk Sliwka. Risk taking in asymmetric tournaments. *German Economic Review*, 5(1):103–116, 2004.
- E. P. Lazear and S. Rosen. Rank-order tournaments as optimum labor contracts. *The Journal of Political Economy*, 89(5), 1981.
- Gwendolyn K. Lee and Marvin B. Lieberman. Acquisition vs. internal development as modes of market entry. *Strategic Management Journal*, 31(2):140–158, 2010.
- Marvin B. Lieberman. The learning curve and pricing in the chemical processing industries. *The RAND Journal of Economics*, 15(2):213–228, 1984.
- Marvin B. Lieberman. The learning curve, diffusion, and competitive strategy. *Strategic management journal*, 8(5):441–452, 1987.
- S. A. Lippman and R. P. Rumelt. Uncertain imitability: An analysis of interfirm differences in efficiency under competition. *The Bell Journal of Economics*, pages 418–438, 1982.
- James G. March. Exploration and exploitation in organizational learning. *Organization Science*, 2(1):71–87, January 1991.

- Claire Cain Miller. Venture firm's 'Green' funds top \$1 billion. *The New York Times*, September 2009. ISSN 0362-4331.
- H. Minc and M. Marcus. *Permanents*. Cambridge Univ Pr, 1984. ISBN 0521302269.
- Johannes Münster. Selection tournaments, sabotage, and participation. *Journal of Economics & Management Strategy*, 16(4):943–970, 2007.
- Petra Nieken. On the choice of risk and effort in tournaments-experimental evidence. *Journal of Economics & Management Strategy*, 19(3):811–840, September 2010.
- Petra Nieken and Dirk Sliwka. Risk-taking tournaments - theory and experimental evidence. *Journal of Economic Psychology*, 31(3):254–268, June 2010.
- J. A. Schumpeter. *Capitalism, socialism and democracy*. Routledge, 1994.
- Christiane Schwieren and Doris Weichselbaumer. Does competition enhance performance or cheating? a laboratory experiment. *Journal of Economic Psychology*, 31(3):241–253, 2010.
- Beth Seidenberg. A VC perspective on the life sciences, 2008.
- Andrei Shleifer. Does competition destroy ethical behavior? Technical report, National Bureau of Economic Research, 2004.
- Jason Snyder. Gaming the liver transplant market. *Journal of Law, Economics, and Organization*, 26(3):546–568, December 2010.
- D. F. Spulber. Competition among entrepreneurs. *Industrial and Corporate Change*, 19:25–50, July 2009. ISSN 0960-6491, 1464-3650.
- Barry M. Staw and Eugene Sz wajkowski. The scarcity-munificence component of organizational environments and the commission of illegal acts. *Administrative Science Quarterly*, pages 345–354, 1975.
- John Sutton. *Sunk costs and market structure: Price competition, advertising, and the evolution of concentration*. The MIT press, 1991. ISBN 0262193051.
- David J. Teece. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, 15:285–305, 1986.
- R. J. Vaughan and W. N. Venables. Permanent expressions for order statistic densities. *Journal of the Royal Statistical Society. Series B (Methodological)*, 34(2):308–310, 1972. ISSN 00359246.
- Brian Wu and Anne Marie Knott. Entrepreneurial risk and market entry. *Management Science*, 52(9):1315–1330, September 2006.