Can Firm Competition Explain the Use of Executive Stock Options?

Kuangli Xie*

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Abstract

Stock options are widely used in executive incentive contracts, but the literature fails to provide a satisfactory explanation on why they are so popular. The expected and often researched effect of stock options is that they may make a manager more aggressive. When considering stock options in a competitive environment there is another potentially important but understudied effect on the behavior of rival managers which is that they might react by being less aggressive. We investigate this issue both theoretically and experimentally by examining how executive stock options would affect manager's investment decisions in a two-firm lottery contest. Our theoretical results suggest that owners have little incentive to grant executive stock options if managers are risk neutral, since granting stock options decreases their rival manager's investment by only a very small amount. Our experimental results, however, show that the behavior of the rival manager is impacted much more than theoretically anticipated leading to the use of stock options to be more profitable. Of particular interest is that while individually each firm benefits from their use, it turns out that if both firms use them they are worse off than if neither did.

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*Southern Methodist University, Department of Economics, 3300 Dyer Street, Suite 301 Umphrey Lee Center, Dallas, TX 75275-0496. *kxie@smu.edu*

1 Introduction

The financial crisis of 2007-2008[1] is considered to have been the worst financial crisis since the Great Depression of the 1930s (Temin, 2010). There are a variety of causes for the original crisis. The one of interest here is that the US-government sponsored Financial Crisis Inquiry Commission (FCIC) found that stock options granted to top managers were a significant contributor to the bankruptcy of many firms because they can encourage excessive risk taking. Executive stock options promote such risk taking because they lead to executive compensation that is asymmetric in gains and losses. If the executives of a company engage in behavior that improves the stock price of the firm, then they can execute their options to buy stock in the company at the price when they received the option and enjoy the financial rewards of their efforts. If the executives make poor decisions that leads to a lowering of their stock price, then they do not exercise those stock options and their loss is capped at zero regardless of how far they drive down the price. At this point, one would therefore expect that firms would be discontinuing their use. In 2012, however, more than 90% of the CEOs in S&P 500 firms[2] had stock options in their pay package (Murphy, 2012). The median value of stock options granted to these CEOs was $2.82 million, accounting for approximately one-quarter of their total pay (Murphy, 2012). Moreover, the banking industry, a major contributor to the financial crisis, is still enthusiastic about granting executive stock options. A study conducted by Blanchard Consulting Group found 39% of approximately 200 publicly traded banks granted stock options to their top executives in 2013.

Given the obvious drawbacks to the use of executive stock options, it is a puzzle that they are still in use. There are several commonly proposed reasons such as stock options making managers more aggressive or having accounting and tax benefits. What is often overlooked in the literature is the effect of stock options in a competitive environment. Compensation

[1] The crisis was followed by the failure of key businesses, the unemployment of millions of workers, the foreclosure of four million homes, the loss of a trillion dollars in household wealth, and a downturn in economic activity leading to the Great Recession of 2008-2012.

[2] S&P 500 essentially includes the largest 500 US firms ranked by market value

contracts are important to consider in a competitive setting because the incentive contract a firm signs with a manager will affect not only the behavior of that manager but also of the managers in rival firms. In fact, when a firm chooses to compensate its manager using stock options to make its manager more aggressive, it may push managers of rival firms to be less aggressive. As a result, stock options may become more effective than we would expect had the competitive effect not been considered. On the other hand, it is possible that granting stock options makes the rival firms' managers more aggressive and therefore decreases the firm's profit. The goal for this study is to examine this issue both theoretically and empirically to determine if the effects of stock options under competition might help explain their continued use by firms.

Consider the following example. As of December 31, 2015, the CEO of Pfizer held 6,006,135 stock options and 1,261,099 shares of common stocks. Suppose Pfizer engages in a contest against its major competitor, Merck, to develop the most effective drug to cure a certain disease. In the competition, it is usually firms' CEOs that make the decisions. Here, the CEO of Pfizer has strong incentive to invest heavily in the R&D to win the competition, because he can earn $7.26 million for each dollar increase in their stock price if Pfizer wins the competition while he would lose $1.26 million for each dollar decrease in their stock price if Pfizer loses. His investment decision would be more aggressive than if he had only stocks in the pay package where a $1 loss would lead to losing $7.26 million. Therefore, the asymmetry in gains and losses induces greater risk-taking in firm competition.

There is a secondary effect on the rival firm which are not considered in previous studies. Executive stock options might pull back the investment of the rival manager. In this example, the CEO of Merck might decrease their R&D investment since he would expect the Pfizer's CEO would invest aggressively to win the competition. This, however, depends on what incentive packages Merck's CEO has. Thus the secondary effect might make stock options more useful than if the firm competition is not taken into account. An important precondition to achieve this secondary effect is that managers of the competing firms need to know each other's compensation packages before their competitive decisions. The condition is usually satisfied. After executive incentive contracts are signed, the SEC[3] requires public firms to reveal these pay packages in their annual report. Even for private firms which have no obligation to reveal this information, they are likely to reveal it because they likely expect that granting stock options would affect the behavior of their rival managers in the way that improves their profit.

A related issue that emerges when compensation is considered is that firm owners may employ executive stock options to overcome a competitive disadvantage. For instance, it is possible that Pfizer has a higher marginal cost of R&D than Merck, perhaps because Pfizer has less experienced scientists, or Merck has superior research facilities. Then, Pfizer's CEO is likely to invest less in developing the new drug because of its cost disadvantage. In this situation, Pfizer's owner can make their CEO invest more aggressively to counter the disadvantage. On the other hand, owner of the advantaged firm, Merck in the example, can also grant stock options to secure her advantage. Understanding how these incentives balance out requires a full equilibrium analysis.

We provide a theoretical examination of a two-stage game where firm owners write compensation contracts with the managers in the first stage, and then in the second stage managers decide how much their firms will invest in a competition given incentive packages of their own and their opponents. We model the firm competition as a lottery contest (Tullock, 1980). This setting is particularly useful to examine the impact of stock options, and it is representative of important firm competitions, such as contests for a patent, a license or an indivisible market. With regard to available executive compensation contracts that can be chosen by firm owners, we constrain them to be linear combinations of base salary, restricted stock and restricted stock options where restriction means stock and stock options are not tradable or exercisable until the end of the competition. These three elements usually take up more than 60% of the total value of the compensation (Murphy, 2012). The reason for

[3]U.S. Securities and Exchange Commission

the linear assumptions is that linear contracts are common in practice (Meyer et al., 1992; Bhattacharyya and Lafontaine, 1995), and our goal is to examine how and why stock options are used in practice.

Theoretically, we find that whether firm owners should grant stock options depends on the risk preferences of managers. If we assume managers are risk-neutral, firm owners have little incentive to grant stock option. The reason is that owners granting options cause their rival managers to decrease the investment by a little amount or increase it. When managers are assumed to be loss averse, managers usually invest less in the competition than if they were not. Granting stock options can be a profitable strategy for firm owners since loss aversion enhances not only the aggressiveness of their managers but also the discouragement effect on the aggressiveness of the opponent managers. The impact of risk aversion on this question is ambiguous and depends on the nature of risk aversion. When managers have CRRA[4] utility function, they usually invest less than if they were risk-neutral. Granting stock options can improve owners' profit as it enhances the investment of their own managers significantly to overcome an inherent bias towards risk avoiding behavior managers possess.

Then, we use laboratory experiments to examine how firm owners granting stock options would affect the investment behavior of their own and opponent managers. The data observed in our experiments provide an empirical justification for the extensive use of stock options. When the marginal cost of investment is symmetric between the two competing firms, owners have the incentive to deviate from stock to stock options if the opponent grants stock. Even when their opponent grants stock options, firm owners still have the incentive to deviate from stock to stock options, since by doing so they can lower the opponent's profit significantly at almost no cost. We found the equilibrium empirically occur is that both firm owners grant stock options, even though they are expected to earn significantly less than if they both keep to stock. Therefore, contrary to the theoretical prediction, empirical data show firm owners face a prisoner's dilemma situation in which both firms acting

[4]constant relative risk aversion

rationally leads to a socially suboptimal outcome. When the marginal cost of investment is asymmetric between the two competing firms, empirical data show that owners are actually playing a Hawk-Dove game, where their optimal choice depends on what their opponent is doing. If their opponent grants stock, they should grant options. If their opponent grants options, they should grant stock. In both the symmetric-cost and asymmetric-cost cases, the effectiveness of stock options which is not predicted by the theory is attributable to opposing managers overreacting and becoming less aggressive. Their overreaction is also not consistent with the predictions based on the assumption that managers are loss averse or risk averse.

These results provide a possible justification for the continued use of stock options. While there seems to be little theoretical reason to use them even based on the competitive effects, we found that behaviorally people respond to these option contracts stronger than what theory predicts. In particular, we found that the managers of rival firms over-respond to the use of stock options by their competitor. This leads to a finding that each firm would most prefer that they use stock options while their rivals do not. Sometimes, firms would use stock options even if their rivals use stock options in order to keep down the expected profit of their opponent firms. This explains why firms might be still extensively using stock options despite the fact that it is well known at this point that they lead to overly aggressive behavior that could lead a company to bankruptcy. If a company pulls only its own options back, it puts itself at a competitive disadvantage relative to its competitors, and no firm wants to be the first to do that.

While the effect of competition provides a justification for using options, it is important to note that many others have also been put forward. These alternatives seem deficient in providing a clear justification for current use of stock options. The most fundamental reason is that in some cases, firms might want to encourage such risk-taking behavior in hope of overcoming an inherent bias towards risk avoiding behavior executives might possess. While this is certainly a possibility, the financial crisis suggests that firms went too far in correcting for risk avoiding behavior and again, one would expect that they would now be pulling back. Another set of widely discussed reasons is related to the tax benefits and accounting advantages of using stock options to compensate executives over alternative approaches. For example, before 2004 the value of the option was only required to be disclosed in a footnote to the financial statements allowing companies to essentially underreport executive compensation and make their potential profits look greater. In December 2004, Financial Accounting Standards Board (FASB) announced FAS123R, which required all U.S. firms to recognize an accounting expense when granting stock options, which removed the ability to use stock options for this purpose. These studies do not take into account how the use of stock options might affect how a firms manager will make choices in a competitive environment, and they certainly do not examine how the compensation of a rival manager might impact the behavior of a firm's manager.

There are some previous studies which have explored the strategic impact of precommitment contracts, such as financial contracts or incentive contracts, on competition between firms. Some literature suggests that by choosing the capital structure prior to engaging in product market competition firms can change the intensity of competition (Bolton and Scharfstein, 1990; Rotemberg and Scharfstein, 1990; Kovenock and Phillips, 1997). Another body of literature justifies firm owners granting managers with incentives different from maximizing firm profit (Vickers, 1985; Fershtman and Judd, 1987; Sklivas, 1987; Reitman, 1993; Aggarwal and Samwick, 1999). Most contributions to this second set investigate the strategic effects of managerial incentives in two-stage models, where owners simultaneously choose their managers incentives schemes before a one-shot market interaction between manager-led firms. Fershtman and Judd (1987) found firm owners can precommit to a more aggressive market behavior from their managers by choosing parameters of a managerial contract linear in profits and sales revenue. Aggarwal and Samwick (1999) found the lack of relative performance-based incentives can soften the product market competition. However, the competitive impact of executive stock options is not fully explored by the literature.

2 Theoretical Model

This paper focuses on how stock options in executive incentive contracts affect managers' behavior in the competitive environment and how owners should design the incentive schemes to maximize firm profit. We use a two-stage game to model this issue. Firm owners write compensation contracts with the managers in the first stage, and then in the second stage managers decide how much their firms invest in a competition given the incentive packages. We focus on the case of two competing firms, firm i and j, but most of our results can be extended to cases with more firms. There is one owner and one manager for each firm, so we call the owner of firm i as owner i and the manager of firm i as manager i, and define owner j and manager j in the same manner.

The competition between firms is modeled as a lottery contest (Tullock, 1980), since such a contest is representative of important firm competitions. Firms i and j compete for an indivisible prize valued at R by simultaneously choosing their effective investment, b_i and b_j. The effective investment is what compared against each other in the competition to determine the winning probability. Firm i's probability of winning is equal to the ratio of its own effective investment to the total effective investment of both firms, or $P_i = b_i/(b_i + b_j)$. Regardless of whether a firm wins the contest or not, it forgos its total investment cost. Firm i's total investment cost would equal the amount of effective investment times the unit cost of its effective investment, $b_i c_i$, as we assume the marginal cost of the effective investment is constant. Therefore, the expected profit from the competition for firm i, $E(\pi_i)$, can be expressed as Eq. 1.

$$E\left[\pi_i\right] = \frac{b_i}{b_i + b_j} R - b_i c_i \tag{1}$$

Let us look at the information structure of this game. We assume that the value of the prize, R, is the common knowledge. The marginal investment cost of both firms is known by the managers but not the owners. For example, manager i can observe both c_i

and c_j before the investment decision. On the other hand, owner i can observe neither c_i nor c_j. The owner could not observe the effective investment chosen by her manager, b_i. Even though the owner can back out the total investment cost, $b_i c_i$, from the competition outcome, they have little information on the effectiveness of the spending which is captured by the marginal cost, c_i. For example, an owner can see her manager has spent $1 million in R&D but not how that cost translates to effective research which is compared in the patent competition. Such unobservability is natural from the owners' perspective. It also gives managers a role in discerning the effectiveness of their own firms as well as that of their rival firms. The unobservability eliminates the feasibility of contracting on the effective investment. Owners can only contract on observable variables, such as firm value and firm profit. This unobservability enables competing owners to strategically manipulate their executive incentive contracts and therefore affect the competition outcome.

We also place some assumptions on the relationship between firm value and competition profit as well as the relationship between executive compensation and competition profit. In order to concentrate on the impact of competition, we assume that the firm value will be changed only by the net profit from the competition. Furthermore, we assume that the compensation paid to the manager is negligible compared to competition profit, as the compensation usually is relatively small compared to firm profit. For example, in 2011 the median CEO compensation of S&P 500 companies was $9.6 million while the median earnings and median market value of these companies were $2.12 billion and $31.7 billion respectively (Murphy, 2012). Thus the firm's value at the end of this game is equal to its value before the competition plus profit from the competition. It can be rewritten as Eq. 2, where V_{i0} is firm value before the competition, π_i is profit from competition and V_{i1} is the value after the competition.

$$V_{i1} = V_{i0} + \pi_i \tag{2}$$

We constrain available incentive contracts to be linear combinations of base salary, shares of stock and stock options as shown by Eq. 3. The reason for the linear assumption is that linear contracts are common in practice (Meyer et al., 1992; Bhattacharyya and Lafontaine, 1995). In the first stage of the game, by writing these contracts, owners make promises [5] on base salary, the quantity of stock, and the quantity of stock options, which are denoted by e_i, x_i and y_i respectively. In the second stage, managers make competitive decisions on the basis of these incentive packages. When the competition result is revealed, managers obtain the base salary, stock and stock options according to their incentive contracts.

$$W_{i1} = e_i + x_i P_{i1}(V_{i1}) + y_i max\{(P_{i1}(V_{i1}) - S_i), 0\} \tag{3}$$

The stock is defined as a share of the firm. Empirical studies (Jones and Litzenberger, 1970; Patell and Wolfson, 1984) have shown that the stock price, P_{it}, positively correlates with the firm value, V_{it}, and the information on firm value is reflected in the stock price very quickly. We assume that P_{it} is a non-decreasing linear function of V_{it}[6]. The stock option is defined as the right to purchase a share of the firm at the strike price, S_i. Holding stock options will generate positive payoff for the manager if the stock price goes above the strike price, and zero payoff otherwise. In practice, the strike price is usually set to be the stock price at the granted date (Murphy, 2012), so here we make the strike price equal to the stock price before the competition, $P_{i0}(V_{i0})$.

Next, we normalize the quantity of stock in the contract using the total stock shares of the firm, which is equal to the ratio of firm value to stock price, $\beta_i = x_i P_{i1}(V_{i1})/V_{i1}$. Similar,

[5] Some firms might grant their managers stocks or stock options at the very beginning, but these equity-related incentives usually have a vesting period where they are not tradable.

[6] Even though the relation between stock price and firm value might take more complex form, our comparative analysis can still provide useful insight for the situations where the linearity assumption does not hold. Furthermore, we let V_{it} be the current firm value without considering any expected profit in the future, so initial firm value, V_{i0} , does not reflect the expected earnings from the coming game. We concede that the expected profit could be accounted into initial firm value since optimal contracts and the resulting expected competition profit can be calculated in advance given certain belief on the behavior of managers and owners. However, even if the firm value is defined in this way, it still changes at the end of the game because the competition outcome is probabilistically determined. And, the dynamics of the value change will be similar regardless of which way the firm value is defined. Since managers' incentives are based on these changes, our model implication can still be proper if expectation is considered. Similarly, we assume the stock price, P_{it}, is only affected by current firm value not future earnings.

we also normalize the quantity of stock options, $\gamma_i = y_i max\{(P_{i1}(V_{i1}) - S_i), 0\}/V_{i1}$. The value of the compensation at the end of the game can be written as Eq. 4.

$$W_{i1} = e_i + \beta_i V_{i1} + \gamma_i max\{(V_{i1} - V_{i0}), 0\} \tag{4}$$

Since neither the base salary, e_i, nor the initial value of stock, $\beta_i V_{i0}$, is affected by the managers' investment decisions or the competition outcome, we can replace the sum of them using $\alpha_i = d_i + \beta_i V_{i0}$. If we plug Eq. 2 into Eq. 4, we will get Eq. 5.

$$W_{i1} = \alpha_i + \beta_i \pi_i + \gamma_i max\{\pi_i, 0\} \tag{5}$$

We can write down the manager i's optimization problem as shown in Eq. 6, where $\underline{U_i}$ refers to the manager's reservation utility. Manager i chooses the effective investment for her firm, b_i, to maximize her utility from the compensation.

$$\begin{gathered} max_{b_i} E[U(\alpha_i + \beta_i \pi_i + \gamma_i max\{\pi_i, 0\})] \\ \text{s.t.} E[U(\alpha_i + \beta_i \pi_i + \gamma_i max\{\pi_i, 0\})] \geqslant \underline{U_i} \end{gathered} \tag{6}$$

By plugging Eq. 1 into Eq. 6, we can rewrite the optimization as Eq. 7. The managers' equilibrium actions (b_i^*, b_j^*) would be functions of $(\alpha_i, \beta_i, \gamma_i)$ and $(\alpha_j, \beta_j, \gamma_j)$, which are determined by their owners' incentive choices, (d_i, f_i, g_i) and (d_j, f_j, g_j), respectively.

$$\begin{gathered} max_{b_i} \frac{b_i}{b_i + b_j} U(\alpha_i + (\beta_i + \gamma_i)(R - b_i c_i)) + \frac{b_j}{b_i + b_j} U(\alpha_i - \beta_i b_i c_i)) \\ \text{s.t.} \frac{b_i}{b_i + b_j} U(\alpha_i + (\beta_i + \gamma_i)(R - b_i c_i)) + \frac{b_j}{b_i + b_j} U(\alpha_i - \beta_i b_i c_i)) \geqslant \underline{U_i} \end{gathered} \tag{7}$$

Based on managers' optimal strategies in the second stage, firm owners choose base salary, the amount of stock and the amount of stock options to maximize the firm's net profit from the competition. We have assumed that the executive compensation is relatively small compared to the firm's competition profit, so owners would conduct their optimization following the steps. First, the firm owner would derive a set of incentive schemes that induce her manager to choose the effective investment level maximizing the firm's competition profit. Within this set, the owner can then select a subset that satisfies her manager's participation constraint. Finally, from this subset, the owner finds out the incentive contract that minimizes the expected cost of the executive compensation. For example, if the optimal effective investment turns out to be high, then the owner would grant the manager more stock options relative to shares of stock. So, in order to take care of the participation constraint and compensation cost, the owner optimally choose the base salary and the total amount of shares of stock and stock options.

Notice that the equilibrium actions of both managers and owners would depend on their risk preferences. We assume that firm owners are risk-neutral, and they treat gains and losses equally. However, managers might have different preferences. Managers' preferences affect how they react to executive stock options, therefore determining whether granting stock options is a profitable strategy for firm owners. In the following subsections, we identify owners' optimal contracts given different assumptions on managers' preference, including risk neutrality, loss aversion and risk aversion.

2.1 Managers are risk-neutral

We start from the simplest case where managers are risk-neutral. Manager i's maximization problem can be written as Eq. 8.

$$\begin{aligned} &max_{b_i}\alpha_i + (\beta_i+\gamma_i)(\frac{b_i}{b_i+b_j}(R-b_ic_i) - \frac{\beta_i}{\beta_i+\gamma_i}\frac{b_j}{b_i+b_j}(b_ic_i)) \\ \text{s.t. } &\alpha_i + (\beta_i+\gamma_i)(\frac{b_i}{b_i+b_j}(R-b_ic_i) - \frac{\beta_i}{\beta_i+\gamma_i}\frac{b_j}{b_i+b_j}(b_ic_i)) \geqslant \underline{U_i} \end{aligned} \tag{8}$$

In Eq. 8, α_i refers to the sum of base salary and initial value of stock in the contract. We refer the sum of normalized amount of stock and normalized amount of stock options, $\beta_i+\gamma_i$, as normalized amount of equity. Since the values of those parameters are decided by the owners rather than managers, we can simplify manager i's objective function as shown in Eq. 9, where θ_i is defined as the ratio of the normalized amount of stock options to the normalized amount of equity, $\theta_i = \frac{\gamma_i}{\beta_i+\gamma_i}$.

$$\begin{aligned} & max_{b_i} \frac{b_i}{b_i+b_j}(R-b_ic_i) - (1-\theta_i)\frac{b_j}{b_i+b_j}(b_ic_i) \\ & \text{s.t. } \alpha_i + (\beta_i+\gamma_i)(\frac{b_i}{b_i+b_j}(R-b_ic_i) - (1-\theta_i)\frac{b_j}{b_i+b_j}(b_ic_i)) \geqslant \underline{U_i} \end{aligned} \tag{9}$$

The simplified objective function indicates that owner i affects both managers' investment decisions through the choice of θ_i. As we have assumed that the executive compensation is negligible compared to competition profit, firm owner i would first choose the value of θ_i to induce managers' behavior that maximizes the competition profit of firm i. Given the optimal choice of θ_i, the owner then determines α_i and $\beta_i+\gamma_i$ that satisfy manager i's participation constraint and minimizing the cost of manager i's compensation. Thus we focus on the owners' choices of the ratios of normalized amount of stock options to the normalized amount of equity, (θ_i, θ_j), and their managers' reactions to these ratios.

When the marginal investment cost is symmetric between the two firms, $c_i = c_j = 1$, the analytical solution is derived through backward induction. The only symmetric subgame perfect Nash equilibrium is that both owners grant no stock option, that is, $(\theta_i^*, \theta_j^*) = (0,0)$. In the equilibrium, the managers choose the investment level, $\frac{1}{4}R$, which is equal to the Nash equilibrium of the lottery contest with no delegation.

When the marginal investment cost is asymmetric, a closed form solution is not available but it can be computationally approximated. We constrain the available strategies for firm owners to be discrete. In particular, owner i and owner j choose θ_i and θ_j respectively among the values: $0, 0.01, 0.02, \cdots 0.99, 1.00$. We first solve the managers' equilibrium choices of b_i and b_j numerically given any possible combination of θ_i and θ_j, and then we can calculate owners' expected competition profit for each combination. Then, we find the owners' Nash equilibrium in the 101×101 normal form game. When doing the numerical calculation, we need to specify the values of the competition prize and the normalized amount of equity in managers' pay packages. We let $R = 200,000$, and $\beta_i + \gamma_i = \beta_j + \gamma_j = 0.1\%$. The values of these parameters are simply scaling issues, so our results hold if any other value is chosen.

In the asymmetric-cost case, we found in equilibrium the cost-advantaged owner grants stock options while the cost-disadvantaged owner does not. We refer to the owners of high-cost firm and low-cost firm as cost-advantaged owner and cost-disadvantaged owner respectively, and we refer to managers of high-cost firm and low-cost firm as cost-advantaged manager and cost-disadvantaged manager respectively. When high cost is 20% above the low cost, the cost-advantaged firm owner grants only stock options as the performance pay. But we found the incentive for the cost-advantaged owner to grant stock options rather than stock is relatively small, less than 1% of the expected competition profit.

As shown above, when competing managers are risk-neutral, there is little incentive for owners to grant executive stock options in both symmetric-cost and asymmetric-cost cases. These results can be understood through looking the reactions of managers. Firm owners granting stock options increases the aggressiveness of their own managers, because losing the competition would not drive down the value of their managers' incentive packages. The increase in aggressiveness of their own managers does not improve the owners' profits unless the rival manager decreases the investment significantly. In the equilibrium, however, the rival manager either decreases her investment a little or increases it.

2.2 Loss Aversion

We also look at the case where managers are loss-averse. To explore the effect of loss aversion, we adopt the utility function found in Tversky and Kahneman (1992) as shown in Eq. 10, where y represents the income relative to the reference point. In our model, we set managers' reference points as the compensation they can obtain if their firms earns zero profit from the competition. So, manager i's reference compensation is equal to α_i, the sum of base salary and initial value of stock in her contract. We found loss averse managers invest less in the competition compared to risk neutral managers.

$$U(x) = \begin{cases} y^{\delta} & \text{if } y \geqslant 0 \\ -\lambda(-y)^{\delta} & \text{if } y < 0 \end{cases} \tag{10}$$

We compute the Nash equilibria of the two-stage game for different levels of loss aversion ($\lambda = 1.20, 1.50, 2.00, 2.25, 2.50, 3.00$) and different levels of sensitivity ($\delta = 0.60, 0.70, 0.88, 1.00$)[7] by employing the same computation method used in the risk-neutral case. When the marginal investment cost is symmetric, we found there are usually two pure strategy Nash equilibria for each combination of loss aversion level and sensitivity level. In each of these equilibria one firm owner chooses only stock options for performance pay while the other owner chooses performance pay consisting mostly of stock. When the marginal investment cost is asymmetric, there are usually two equilibria like those in the symmetric-cost case[8]. Either the cost-advantaged owner or the cost-disadvantaged owner can be the one that grant stock options. Granting stock options can be a profitable strategy for firm owners since loss aversion enhances not only the aggressiveness of their managers but also the discouragement effect on the aggressiveness of the opponent managers.

2.3 Risk Aversion

Risk aversion also serves as a potential reason for granting stock options, since there exists uncertainty in the competition outcomes. The issue of whether risk aversion can justify

[7]Experimental literature demonstrates that the estimate of δ is above 0.6 (Tversky and Kahneman, 1992; Abdellaoui et al., 2008; Harrison and Rutström, 2009)

[8]When the level of cost asymmetry is high and the level of loss aversion is not high enough, there will be only one equilibrium where the cost-advantaged owner grants stock options while the cost-disadvantaged owner does not.

the use of stock options is not trivial. When mangers become more risk averse, no general conclusions on their equilibrium investment level can be made (Briys and Schlesinger, 1990; Skaperdas and Gan, 1995; Konrad and Schlesinger, 1997; McGuire et al., 1991). Higher level of risk aversion does not necessarily reduce or raise the investment, because increasing investment not only lowers wealth in all states of nature but also makes the better state more likely(Konrad and Schlesinger, 1997). But if we use some specific forms of utility function, managers' equilibrium investment behavior can be predicted. Millner and Pratt (1991) noted that if the third derivative of the utility function is positive, increase in risk aversion will reduce equilibrium investment. They observed such reduction in their experimental results. Thus we use CRRA (constant relative risk aversion) utility function, $u(x) = x^{1-\gamma}/(1-\gamma)$, to model managers' risk preference, since its third derivative is positive.

We found managers invest less as they become more risk averse. Firm owners granting stock options can enhance the investment of their own managers significantly to overcome an inherent bias towards risk avoiding behavior managers possess. On the other hand, granting stock options decreases the opponent managers' investment by a small amount. We compute the Nash equilibria of the two-stage game given different levels of risk aversion ($\gamma = 0, 0.1, 0.2, ..., 0.7$ [9]) by employing the same computation method used in the risk-neutral cases. We found there are usually two pure strategy Nash equilibria for each level of risk aversion[10]. This is true for both the symmetric-cost case and the asymmetric-cost case. In each of these equilibria one firm owner chooses only stock options for performance pay while the other owner chooses only stock for performance pay. For the asymmetric-cost case, either the cost-advantaged owner or the cost-disadvantaged owner can be the one granting stock options.

[9]Experimental literature demonstrates that more than 80% of the population has the level of risk aversion between 0 and 0.7(Holt and Laury, 2002; Cox and Oaxaca, 1996; Goeree et al., 2000).

[10]We do the calculations for different levels of managers' initial wealth. These results hold when we vary their initial wealth from the same as the value of compensation to as ten times as the value of compensation.

3 Experiment

We found that when both managers are following the risk-neutral equilibrium strategies, owners have little incentive to grant stock options. However, if managers' behavior deviates from their risk-neutral equilibrium, the use of stock options by firm owners may be justified. Therefore, we use lab experiments to investigate managers' investment behavior when they are facing different combinations of their own and opponent incentive contracts. We only have the role of managers played in the experiment, and their contracts are assigned by the computer. The experiment is to determine whether managers' behavior can justify the use of stock options by owners, so it is the investment behavior of managers that is relevant for that question.

3.1 The Game

When managers are making investment decisions for their firms in the competition, managers are actually playing a downsized version of the lottery contest because of the stock and stock options in their incentive contracts. The size of manager i's contest is determined by the normalized amount of equity in the contract, $\beta_i + \gamma_i$. When manager i is making the investment decision, $b_i * c_i$, for her firm, she is actually investing $x_i * c_i = b_i * c_i * (\beta_i + \gamma_i)$ in the downsized lottery contest. When her firm wins the prize, R, she actually earns $r_i = R * (\beta_i + \gamma_i)$. If we let the values of these parameters be the same as those in the theoretical section, $R = 200,000$, and $\beta_i + \gamma_i = 0.1\%$, then managers are competing for a prize for which their share would be 200. In the experiments, we have our subjects play a series of the lottery contest. For each round of the contest, each subject is endowed with 100 ECUs, which corresponds to the sum of base salary and initial value of stock in the contract, α_i. They then compete for a 200 ECU prize inside the competition pair through choosing their effective investment, x_i. When we need to calculate the profit for the firm, we can derive the investment decision for firm i based on manager i's decision, $b_i = 1000 * x_i$.

We examine the impact of stock options on managers' investment behavior by varying the ratios of the normalized amount of stock options to the normalized amount of equity in their own and opponent's contracts, (θ_i, θ_j). Even though the incentive contracts are specified by the amount of base salary, the amount of stock and the amount of stock options, we have shown theoretically that (θ_i, θ_j) are crucial parameters affecting managers' competitive behavior. We test four contract configurations which only differ in these ratios. The contract configuration is defined from the perspective of one subject rather than the competition pair. In these four contract configurations manager i has either only stock or only stock options in her performance pay and so does her rival, $(\theta_i, \theta_j) = (0,0),(0,1),(1,0),(1,1)$. We call them Stock v Stock (S v S), Stock v Option (S v O), Option v Stock (O v S) and Option v Option (O v O). We focus on these four contract configurations because owners grant either stocks only or stock options only in a typical theoretical equilibrium. Another reason is to test subjects' reactions to substantial changes in stock options.

We inform managers how their payoff would be calculated under different incentive contracts without mentioning the above parameters. When a manager is assigned to be paid by Stock, we will give her a 100 ECU endowment and let her compete for a 200 ECU prize in the two-player lottery contest. She can spend as much as 300 ECUs to invest. Her payoff can be calculated as shown by Eq. 11, where x_i and x_j stand for the investment chosen by herself and her opponent. When a manager is assigned to be paid by Option, she does not pay the investment cost if she loses the competition. Her payoff is calculated as shown by Eq. 12.

$$\pi_i = \begin{cases} 100 + 200 - c_i x_i & \text{if subject } i \text{ wins} \\ 100 - c_i x_i & \text{if subject } i \text{ loses} \end{cases} \tag{11}$$

$$\pi_i = \begin{cases} 100 + 200 - c_i x_i & \text{if subject } i \text{ wins} \\ 100 & \text{if subject } i \text{ loses or invest more than 200} \end{cases} \tag{12}$$

The winning probability of a manager equals the ratio of her effective investment to the sum of the effective investment by herself and her opponent. In the case that neither of the paired managers invests, the prize will be granted to either of them with equal probability.

$$prob_i = \begin{cases} \frac{x_i}{x_i + x_j} & \text{if } x_i > 0 \text{ either } x_j > 0 \\ \frac{1}{2} & \text{if } x_i = 0 \text{ and } x_j = 0 \end{cases} \tag{13}$$

As you may have noticed, the expected compensation of contract Option would be higher than that of contract Stock if managers choose the same investment level under these two incentive schemes. There are two reasons why we design the contracts in this way rather than make them equivalent in terms of expected payoff. First, in order to make them payoff equivalent, we need to give managers different amounts of endowment when assigning them different contracts. Then, across treatments we vary not only the ratios of normalized amount of stock options to the normalized amount of equity but also the amount of endowment. This would make it hard to isolate managers' reactions to the change of these ratios. Secondly, even if we make these contracts payoff equivalent based on certain assumptions about managers' behavior, it is very likely that their actual payoffs in the experiment will be different from the prediction, because their actions may deviate from our assumptions. Thus, even though it is possible to make these contracts' payoff equivalent in theory, it is hard to make sure that managers with different contracts would earn the same expected payoff in the experiment.

Our theoretical model suggests that the asymmetry of marginal investment cost would affect managers' reactions to executive stock options. Thus, we examine their investment behavior under symmetric-cost and asymmetric-cost settings. In the symmetric-cost setting, rival subjects will have the same unit cost for the effective investment, $c_i = c_j = 1.00$ ECU. In the asymmetric-cost setting, one subject of each competition pair has a unit cost equal to 1.25 ECU while the other has 1.00 ECU. The reason for choosing 1.25 is that it is high enough to induce significant behavioral shift indicated by the theoretical models.

The experiment has a 2×4 design. We test their reactions to four different contract configurations within subjects. In each round of the experiment session, every subject faces any of the four contract configurations with equal probability. On the other hand, we test how cost asymmetry affects their reactions between subjects. We have half of our sessions where the cost is symmetric between the competing subjects while the half where cost is asymmetric. The cost-advantaged players will be randomly selected for each round.

3.2 Procedure

In each session of the experiment, the subjects play the lottery contest for 30 rounds. At the beginning of each round, subjects are paired randomly, and they will compete against each other within the pair. After the pairing, every subject is assigned the contract either Stock or Option with equal probability, so she has a 25% chance of facing each of the four contract configurations. For example, one subject has a 50% chance to get Stock, and her opponent has a 50% chance to get Option, so that subject has a 25% chance to face the contract configuration Stock v Option. Then, the unit cost of effective investment for each subject is determined. In the symmetric-cost sessions, all subjects have the unit cost equal to 1.00 ECU. In the asymmetric-cost sessions, within each pair, we randomly choose one subject to have a unit cost of 1.25 ECU while the other have 1.00 ECU. The pairing, assignment of contracts and determination of unit cost are redone in every round.

The contract assigned to subjects determine how their payoff is going to be calculated as shown by Eq. 11 and Eq. 12. However, during the experiment, we do not mention these words, "stock" or "stock option". Instead, subjects are explained how their payoffs would be calculated under different circumstances corresponding to different contracts. Subjects are told how much endowment they have, how much they can earn if they win the prize, and how much the investment costs. In the experiment, we use the phrase "loss exemption" to help them understand the fundamental incentives of stock options. Subjects are asked to pay attention to how their potential earnings are different due to the loss exemption.

After we finish the pairing subject, assigning contracts and determining unit cost, the subjects is asked to choose the effective investment in the lottery contest. On their decision screens, we show their own contract and their opponent's contract, as well as their own unit cost and that of their opponent. In order to help them understand the consequences of their investment decisions, we provide them a calculator. They can enter a potential number of their own effective investment and a guess about opponent's, and then we show them their probability of winning, your earnings if you win and your earnings if you lose. Once all subjects have made decisions, the computer would determine the winner based on Eq. 13. At the end of each round, we inform subjects whether they win the competition or not, and how much they have earned for this round.

Each session began with an introduction of the games, after which we demonstrated to them the computer interface and the rules through two sample rounds of competition against robot players. The interactive software system is programmed using z-Tree (Fischbacher, 2007). Subjects engage in the lottery contest for thirty rounds, and their final payoff would be a $10 show-up fee plus the sum of earnings in five rounds randomly draw from these thirty rounds. Each session lasted an hour and a half to two hours. Their payments including the show-up fee ranged from a minimum of $10 to a maximum of around $ 45, with an average of $35.

We have run three symmetric-cost sessions with 60 subjects and three asymmetric-cost sessions with 60 subjects. We are expected to have $450 (= 60 \times 30 \times 0.25)$ observations of the investment decision for each contract configuration in either the cost-symmetric or the cost-asymmetric case. Table 1 shows how many observations we actually get in the experiment for each contract configuration. All of our experiment sessions are conducted at Southern Methodist University. Subjects were recruited from a university-wide subject pool comprising undergraduate and graduate students who had indicated a willingness to be paid volunteers in decision-making experiments.

Table 1: Experimental Design and Data Points

	Sessions	Subjects	S v S	S v O	O v S	O v O
Symmetric Cost	3	60	476	453	453	418
Asymmetric Cost	3	60	462	429	429	480

4 Hypotheses

Based on the experiment design, we have the predictions on managers' investment behavior and owners' expected profit based on the assumption that managers are risk neutral as shown in Table 2. The predicted investment is shown in ECUs. The expected profit of firm owners is shown in thousands of ECUs. We treat the configuration where both owners grant Stock as the baseline. If managers follow the risk neutral prediction, there is little incentive for the firm owners to deviate from Stock to Option. When the cost is symmetric, the owners are expected to earn 50.0 thousands of ECUs if they keep to Stock while expected to earn 49.4 thousands of ECUs or less if they deviate. When the cost is asymmetric, Stock is still the dominant strategy for the cost-disadvantaged owner, as 39.5 is bigger than 36.9 and 32.2 is bigger than 23.7. For the cost-advantaged owner, by deviating from Stock to Option she can increase her profit from 61.7 thousands of ECUs to 62.4 thousands of ECUs. We will use the experimental data to test whether managers choose the equilibrium strategies and whether the use of stock option by firm owners can be justified.

Table 2: Predictions on Managers' Investment Behavior and Owners' Expected Profit

	Contract Configuration	Symmetric_Cost	Asymmetric_Cost	
			Cost_Advantaged	Cost_Disadvantaged
Investment chosen by managers (ECUs)	Stock v Stock	50.0	49.4	49.4
	Option v Stock	61.6	57.3	65.6
	Stock v Option	49.4	50.0	48.1
	Option v Option	66.7	63.6	69.6
Expected Profit of firm owners (thousands of ECUs)	Stock v Stock	50.0	61.7	39.5
	Option v Stock	49.4	62.4	36.9
	Stock v Option	39.6	47.6	32.2
	Option v Option	33.3	43.1	23.7

Hypothesis 1. *The investment chosen by managers is equal to the risk neutral equilibrium prediction under every contract configuration.*

We will first test whether the investment chosen by managers is consistent with the prediction investment as shown in the upper section of Table 2. If we fail to reject Hypothesis 1, firm owners have little incentive to grant Option as we have shown in the theoretical section. However, we do not expect managers would choose the investment equal to the risk-neutral equilibrium. For example, previous experimental studies (Baharad and Nitzan, 2008; Ahn et al., 2011; Sheremeta, 2013; Savikhin and Sheremeta, 2013; Chowdhury et al., 2014; Dechenaux et al., 2015) have shown that in the symmetric-cost case when both competing managers are paid by an incentive scheme corresponding to Stock, they invest significantly above the risk neutral prediction. Granting Option is likely to make managers more aggressive on the investment decision, so we believe they may also over-invest when paid by Option.

We will then examine whether a firm owner shifting from Stock to Option would affect the investment behavior of her own and opponent managers in a way that improves the owner's profit. In particular, we will investigate whether a firm owner shifting to Option makes her own manager choose the the owner's optimal investment, the investment that maximizes her expected profit given the empirical distribution of the opponent's investment. Based on the experiment data, we can calculate the owner's optimal investment as shown in the third column of the lower section of Table 5 and Table 6. We also examine whether the change in her opponent manager's investment caused by the shift is significantly different from the prediction. For example, in the symmetric-cost case, if the owner deviates from the baseline to Option, her opponent manager is decreases the investment by 0.6 ECU (=50.0-49.4). What we are going to test whether reaction of her opponent manager is consistent with this prediction. As you may have noticed, the effect of granting Option depends on what contract the opponent owner grants, so we investigate the case when her opponent grants Stock and the case when her opponent grants Option respectively.

Hypothesis 2a. *When a firm owner grants Stock given her opponent granting Stock, her own manager chooses the investment maximizing the owner's expected profit.*

Hypothesis 2b. *When a firm owner grants Option given her opponent granting Stock, her own manager chooses the investment maximizing the owner's expected profit.*

Hypothesis 2c. *When a firm owner grants Stock given her opponent granting Option, her own manager chooses the investment maximizing the owner's expected profit.*

Hypothesis 2d. *When a firm owner grants Option given her opponent granting Option, her own manager chooses the investment maximizing the owner's expected profit.*

Hypothesis 3a. *When a firm owner shifts from Stock to Option given her opponent granting Stock, the change in her opponent manager's investment is equal to the prediction.*

Hypothesis 3b. *When a firm owner shifts from Stock to Option given her opponent granting Option, the change in her opponent manager's investment is equal to the prediction.*

Even though these tests on the empirical investment tell us how stock options would affect manager's investment, we still need to know how investment behavior induced by stock options would affect profit of firm owners. We first test whether the expected profit based on the empirical investment behavior is equal to that based on risk-neutral predictions on managers' investment. If we fail to reject, Hypothesis 4 then firm owners have little incentive to grant Option as we have shown in the theoretical section.

Hypothesis 4. *The expected profit for firm owners given managers' empirical investment is equal to the expected profit given risk neutral equilibrium investment under every contract configuration.*

However, Hypothesis 4 is likely to be rejected because managers are unlikely to follow the risk neutral equilibrium, so it is possible that granting stock options is a profitable strategy for firm owners. Therefore, based on the empirical investment observed in the experiment, we look at whether a firm owner shifting from Stock to Option would increase her profit. We investigate the case when her opponent grants Stock and the case when her opponent grants Option, respectively. In addition, we look at the situation when both of the competing firm owners deviate from Stock to Option to see whether they will end up with a better or worse outcome.

Hypothesis 5a. *When a firm owner shifts from Stock to Option given opponents granting Stock, her profit does not change.*

Hypothesis 5b. *When a firm owner shifts from Stock to Option given opponents granting Option, her profit does not change.*

Hypothesis 5c. *When both firm owners in the competition shift from Stock to Option, their profit does not change.*

As we have mentioned before, cost asymmetry might affect managers' reactions to stock options. Even though we did not mention the cost configuration when stating these hypotheses, we will test all of them for firms in the symmetric-cost case, and cost-advantaged and cost-disadvantaged firms in the asymmetric-cost case respectively.

5 Experiment Results

5.1 Summary Statistics

The summary statistics of experimental data for symmetric-cost and asymmetric-cost sessions are shown in Table 3 and Table 4 respectively[11]. All numbers in this section are in ECU. We first examine the experiment data by using the Wilcoxon tests. We consider these Wilcoxon tests as preliminary rather than final tests of our hypothesis, as they fail to take into account the lack of independence between the decisions by one subject. Based on the

[11]The expected compensation of a manager and expected profit of her firm are calculated based on the investment by that manager and by her opponent.

Table 3: Summary statistics for symmetric-cost sessions

	Investment (ECUs)		Expected Compensation (ECUs)		Expected Profit (thousands of ECUs)	
	Obs.	Theory	Obs.	Theory	Obs.	Thoery
Stock v Stock	56.0 (5.00)	50.0	41.8*** (3.28)	50.0	41.8*** (3.28)	50.0
Option v Stock	68.0* (3.54)	61.6	77.0 (3.39)	76.8	55.7* (3.54)	49.4
Stock v Option	48.3 (1.55)	49.4	26.5*** (2.67)	39.6	26.5*** (2.67)	39.6
Option v Option	74.2 (5.99)	66.7	55.6*** (2.60)	66.7	25.9*** (2.46)	33.3

Notes: the investment and compensation are in ECUs while the profit is in thousands of ECUs. Standard deviations in parentheses. *s indicate p-value of Wilcoxon test compared to theoretical prediction. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.1$.

Wilcoxon tests, we found their investment is not significantly different from the prediction if they are paid by Stock (Stock v Stock or Stock v Option), while it is significantly above the prediction if paid by Option (Option v Stock or Option v Option). The expected compensation and expected profit are usually significantly below the prediction except for when the manager is paid by Option while her opponent is paid by Stock (Option v Stock). Under Option v Stock, the compensation and profit are usually either significantly above or not significantly different from the prediction.

We can also look at how these variables differ across the four contract configurations. If we treat the configuration when both competing managers are paid by Stock as the baseline (Stock v Stock), a firm owner deviating to Option makes her own manager, whose contract configuration becomes Option v Stock, increase the investment significantly.[12] On the other hand, her opponent manager, whose configuration becomes Stock v Option, would decrease the investment significantly [13]. In the case when both firm owners deviate to Option, the managers invest even more[14]. As for the expected profit for firm owners, we found deviating from Stock to Option would increase owners' profit if they are in the symmetric-cost case or if they are cost-advantaged in the asymmetric-cost case.

[12]Here, we only show the results of Wilcoxon test for the symmetric-cost case. As for the cost-asymmetric sessions, reactions of subjects are evidencing a roughly similar pattern. Wilcoxon test: $z = 3.07, Prob > |z| = 0.0022$.

[13]Wilcoxon test: $z = -2.78, Prob > |z| = 0.0054$.

[14]Wilcoxon test: $z = 4.08, Prob > |z| = 0.000$.

Table 4: Summary statistics for asymmetric-cost sessions

	Investment (ECUs)		Expected Compensation (ECUs)		Expected Profit (thousands of ECUs)	
	Obs.	Theory	Obs.	Theory	Obs.	Theory
Low cost						
Stock v Stock	52.0 (3.39)	49.4	55.0* (4.04)	61.7	55.0* (4.04)	61.7
Option v Stock	73.2*** (4.90)	57.3	82.1 (4.04)	85.4	66.2 (4.09)	62.4
Stock v Option	46.6 (3.98)	50.0	29.6*** (3.88)	47.6	29.6*** (3.88)	47.6
Option v Option	78.7*** (4.68)	63.6	55.5*** (2.93)	72.7	22.3*** (3.61)	43.1
High cost						
Stock v Stock	49.0 (0.70)	49.4	39.4 (0.45)	39.5	39.4 (0.45)	39.5
Option v Stock	83.1*** (5.07)	65.6	62.4* (3.05)	68.8	37.0 (6.67)	36.9
Stock v Option	44.2 (4.49)	48.1	20.2*** (3.06)	32.2	20.2*** (3.06)	32.2
Option v Option	91.5*** (5.94)	69.6	45.5*** (2.83)	60.9	6.5*** (3.39)	23.7

Notes: the investment and compensation are in ECUs while the profit is in thousands of ECUs. Standard deviations in parentheses. *s indicate p-value of Wilcoxon test compared to theoretical prediction. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.1$.

5.2 Investment Behavior

As we have mentioned in the hypothesis section, we want to test whether the investment chosen by managers under different contract configurations is consistent with the risk-neutral equilibrium prediction as well as how firm owners granting Option would affect the investment behavior of their own and opponent managers. We conduct regressions to facilitate the formal tests of our hypotheses on managers' investment behavior. All of our regressions are conducted using a fixed effects panel specification with standard errors clustered at the individual subject level.

We run regressions for the symmetric-cost sessions and asymmetric-cost sessions separately. In the basic regressions, the dependent variable is the investment chosen by a manager in a given period, and the independent variables include a constant and dummy variables indicating manager's contract configuration in that period. For example, Stock v Option denotes the configuration where the manager is paid by Stock while her opponent paid by Option. For asymmetric-cost sessions, we also have a dummy to identify the cost-disadvantaged subjects as well as its interactions with the dummies for contract configurations. Additional regression specifications include extra explanatory variables such as dummies indicating the subject's contract configurations in the prior period, a dummy for

Table 5: Panel regressions for investment (ECUs) for symmetric sessions

	Prediction	Regression Specification 1	Specification 2	Specification 3
Cons. (Stock v Stock)	50.00	56.82^{***}	55.82^{***}	56.49^{**}
		(1.777)	(2.138)	(2.688)
Option v Stock	11.60	11.84	11.19	10.87
		(3.567)	(3.676)	(3.629)
Stock v Option	-0.60	-7.109^{**}	-7.609^{***}	-7.548^{***}
		(2.692)	(2.581)	(2.604)
Option v Option	16.70	17.24	17.61	17.39
		(3.862)	(4.012)	(3.987)
L.Option v Stock				2.332
				(3.198)
L.Stock v Option				-3.463
				(2.275)
L.Option v Option				-2.145
				(1.929)
Last ten periods			$5.357^{\ddagger\ddagger\ddagger}$	$5.423^{\ddagger\ddagger\ddagger}$
			(2.295)	(2.241)
L.Win			-0.745	-0.337
			(1.706)	(1.686)
Observation		1800	1740	1740

	Prediction	Owner's Optimal	Investment under Configurations Specification 1	Specification 2	Specification 3
Stock v Stock	50.00	37.7	$56.82^{***,\dagger\dagger\dagger}$	$55.82^{***,\dagger\dagger\dagger}$	$56.49^{**,\dagger\dagger\dagger}$
			(1.777)	(2.138)	(2.688)
Option v Stock	61.60	34.2	$68.66^{***,\dagger\dagger\dagger}$	$67.01^{*,\dagger\dagger\dagger}$	$67.35^{,\dagger\dagger\dagger}$
			(2.224)	(3.050)	(3.728)
Stock v Option	49.40	41.2	$49.71^{,\dagger\dagger\dagger}$	$48.21^{,\dagger\dagger\dagger}$	$48.94^{,\dagger\dagger\dagger}$
			(2.623)	(2.326)	(2.411)
Option v Option	66.70	38.7	$74.06^{***,\dagger\dagger\dagger}$	$73.43^{**,\dagger\dagger\dagger}$	$73.87^{*,\dagger\dagger\dagger}$
			(2.557)	(3.107)	(3.754)

Note 1: Robust standard errors in parentheses.
Note 2: $*$ means we test the estimators against the predictions listed in the second column. † means we test estimators against owner's optimal investment level listed in the third column. ‡ means we test the estimators against zero. In particular, $*p < 0.01, **p < 0.05, ***p < 0.1$. The same is true for † and ‡ .

whether or not the subject won the prize in the prior period, and a dummy for whether or not the round is one of the last ten periods.

We have shown results of the regressions in the upper section of Table 5 and Table 6. The intercepts of these regressions can be interpreted as the average investment in the baseline treatments where both competing managers are paid by Stock. In the cost-asymmetric case, the baseline refers to the cost-advantaged manager under this contract configuration. The coefficients of these regressions indicate how the investment in the indicated treatment differs from that of the baseline. We test these constant terms and coefficients against the risk-neutral equilibrium predictions listed in the second column.

Based on the regression results, the average investment under different contract and cost

Table 6: Panel regressions for investment (ECUs) for asymmetric sessions

			Regression	
	Prediction		Specification 1	Specification 2
Cons. (Stock v Stock)	49.38		52.35	52.38
			(2.577)	(3.343)
Option v Stock	7.92		21.07***	20.69***
			(4.592)	(4.867)
Stock v Option	0.588		-3.190	-3.321
			(3.225)	(3.467)
Option v Option	14.25		25.73***	24.89**
			(4.485)	(4.834)
Cost_dis	-0.173		-1.309	-1.445
			(3.360)	(3.439)
Cost_dis*Option v Stock	8.281		9.226	10.55
			(4.893)	(5.088)
Cost_dis*Stock v Option	-1.888		-4.537	-4.100
			(5.002)	(5.352)
Cost_dis*Option v Option	5.954		14.20**	16.36**
			(3.856)	(4.233)
L.Cost_dis				1.244
				(1.733)
L.Option v Stock				-1.099
				(2.208)
L.Stock v Option				0.449
				(2.109)
L.Option v Option				-2.248
				(2.472)
Last ten periods				-3.105
				(3.178)
L.Win				2.645
				(1.967)
Observation			1800	1740
			Investment under Configurations	
	Prediction	Owner's Optimal	Specification 1	Specification 2
Cost_adv + Stock v Stock	49.38	37.8	52.35 ,†††	52.38 ,†††
			(2.577)	(3.343)
Cost_adv + Option v Stock	57.30	32.1	73.41***,†††	73.07***,†††
			(2.807)	(3.752)
Cost_adv + Stock v Option	49.97	41.8	49.16 ,††	49.05 ,†
			(3.112)	(4.409)
Cost_adv + Option v Option	63.63	41.6	78.08***,†††	77.26***,†††
			(4.485)	(3.628)
Cost_dis + Stock v Stock	49.40	36.2	51.04 ,†††	50.93 ,†††
			(3.360)	(3.766)
Cost_dis + Option v Stock	65.60	34.4	81.33***,†††	82.17***,†††
			(2.507)	(3.252)
Cost_dis + Stock v Option	48.10	38.3	43.31 ,	43.51 ,
			(3.866)	(4.188)
Cost_dis + Option v Option	69.60	36.2	90.97***,†††	92.17***,†††
			(3.484)	(3.786)

Note 1: Robust standard errors in parentheses.
Note 2: $*$ means we test the estimators against the predictions listed in the second column. † means we test estimators against owner's optimal investment level listed in the third column. ‡ means we test the estimators against zero. In particular, $*p < 0.01, **p < 0.05, ***p < 0.1$. The same is true for † and ‡ .

Table 7: Summary of Hypothesis Testing Results on Investment Behavior

Hypothesis	Contract Configuration	Symmetric_Cost	Asymmetric_Cost	
			Cost_Advantaged	Cost_Disadvantaged
H1: Empirical Investment = Risk Neutral Prediction ?	Stock v Stock	>	=	=
	Option v Stock	>	>	>
	Stock v Option	=	=	=
	Option v Option	>	>	>
H2: Empirical Investment = Owner's Optimal ?	Stock v Stock	>	>	>
	Option v Stock	>	>	>
	Stock v Option	>	>	=
	Option v Option	>	>	>
H3: Decreases Opponent's Empirical Investment More than Prediction ?	Stock v Stock → Option v Stock	*Yes*	*Yes*	*No*
	Stock v Option → Option v Option	*No*	*No*	*No*

Note 1: When we test Hypothesis 1, "=" means we cannot reject that empirical investment is equal to the risk neutral prediction in the given contract and cost configuration, and ">" means that the empirical investment is significantly above the risk neutral prediction.
Note 2: When we test Hypothesis 2, "=" means that we cannot reject that empirical investment is equal to the owner' optimal investment, and ">" means that the empirical investment is significantly above the owners' optimal investment.
Note 3: For Hypothesis 3, we actually increase
When we test Hypothesis 2, "=" means that we cannot reject that empirical investment is equal to the owner' optimal investment, and ">" means that the empirical investment is significantly above the owners' optimal investment.

configurations can be calculated as the linear combinations of intercept and coefficients, and the results are presented in the lower section of Table 5 and Table 6. We test them against the prediction listed in the second column in order to see whether managers choose the investment equal to the risk-neutral equilibrium strategy. Moreover, we test the observed investment against the owner's optimal investment listed in the third column to examine whether managers choose the investment that maximizes the profit of their owners given the empirical distribution of their opponents' investment. We also test the difference in investment between contract configurations to see how a firm owner granting Option changes the investment of her opponent manager. Therefore, we actually test Hypothesis 1, Hypothesis 2 and Hypothesis 3. The results of these tests are summarized in Table 7.

We found the empirical investment is not always equal to the risk-neutral equilibrium prediction. When both competing managers are paid by Stock, we found their investment is significantly above the prediction in the symmetric-cost case. This is consistent with previous experimental papers (Baharad and Nitzan, 2008; Ahn et al., 2011; Sheremeta, 2013; Savikhin and Sheremeta, 2013; Chowdhury et al., 2014; Dechenaux et al., 2015). But, in asymmetric-cost case these managers' investment does not differ significantly from the prediction. When a manager is paid by Stock while her opponent is paid by Option, her investment is not significantly different from the prediction, in either symmetric-cost or asymmetric-cost sessions. When a manager is paid by Option, she invests significantly above the prediction in both symmetric-cost and asymmetric-cost cases, regardless of what contract her opponent has.

Since the investment chosen by managers does not always follow the risk neutral predictions, it is possible that granting Option is a profitable strategy for firm owners. We examined whether a firm owner granting Option makes her manager choose the investment maximizing owners expected profit. We found managers usually invest significantly more than the owner's optimal regardless of what contracts they have and what contracts their opponents have. The only case where managers choose the investment not significantly different from the owner's optimal is where they are cost-disadvantaged and under contract configuration Stock v Option. In that case, firm owners granting Option actually push their own managers away from owners' optimal.

Even though a firm owner granting Option fails to make her own manager choose the owner's optimal investment, it is possible that Option would decrease the investment of her opponent manager and therefore increase the owner's profit. We found that the reaction of the opponent manager depends on the cost configuration and contract configuration. When the firm owner is in the symmetric-cost case or she is cost-advantaged in the asymmetric-cost case, the owner deviating to Option decreases her opponent's investment more than the prediction if her opponent grants Stock[15] . If the opponent manager is paid by Option, the firm owner granting Option usually increases the opponent's investment[16]. In addition,

[15] In the symmetric-cost case, firm owner granting Option would decrease the opponent's investment more than the prediction, $F(1,59) = 5.85, Prob > F = 0.0187$. In the asymmetric-cost case, cost-advantaged firm owner granting Option would decrease the opponent's investment more than the prediction, $F(1,59) = 3.48, Prob > F = 0.067$. In the asymmetric-cost case, cost-disadvantaged firm owner granting Option would decrease the opponent's investment not significantly different from the prediction, $F(1,59) = 1.37, Prob > F = 0.2462$.

[16] In the symmetric-cost case, firm owner granting Option would increase the opponent's investment not significantly different from the prediction,$F(1,59) = 0.01, Prob > F = 0.9182$. In the asymmetric-cost case, cost-advantaged firm owner granting Option would increase the opponent's investment not significantly different from the prediction, $F(1,59) = 0.19, Prob > F = 0.6604$. In the asymmetric-cost case, cost-disadvantaged firm owner granting Option would increase the opponent's investment not significantly different from the prediction, $F(1,59) = 2.38, Prob > F = 0.1286$.

the overreaction of managers' investment is inconsistent with the prediction based on the assumption of loss averse managers.

We have shown that risk neutral equilibrium prediction is not consistent with managers' investment behavior. We also examine whether alternative preference settings, including risk aversion and loss aversion, can explain their behavior. As shown in the theoretical section, when managers are risk averse or loss averse, they invest less than if they are risk-neutral. The prevalent over-investment observed in the experiments indicates that neither risk aversion nor loss aversion can explain managers' investment levels under different contract configurations. We then investigate whether these alternative preference settings can justify managers' overreactions when they are paid by stock, and their opponent owners shift from stock to options. The reaction predicted by the risk aversion model is significantly smaller than then observation. For the loss aversion model, even though it suggests managers in that scenario would drop their investment significantly, its predictions[17] still contradict the empirical results which are shown in Table 7.

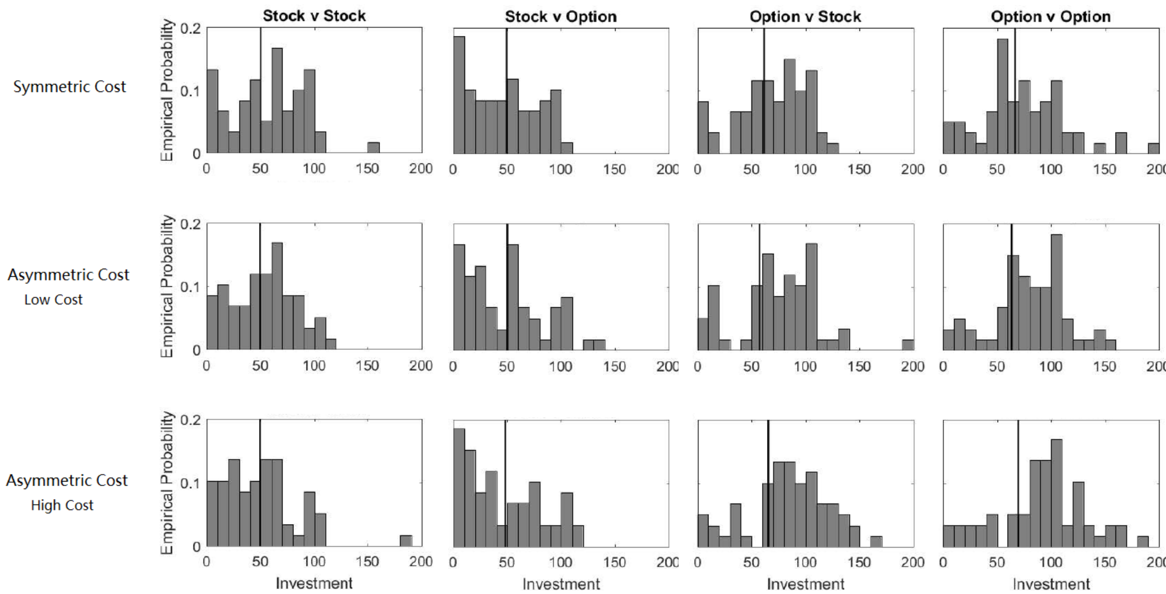
5.3 Heterogeneous Investment Behavior

We have shown how the population as a whole behaves under various contract configurations, but remarkable heterogeneity exists in investment behavior as shown by Fig 1. Since managers of different types make investment decisions differently under these contract configurations, firm owners may need to design their executive incentive contracts accordingly. In this section, we will focus on separating these managers into different types and then examining their reactions to those four contract configurations.

To investigate the heterogeneity in their investment behavior, we apply the finite mixture model (El-Gamal and Grether, 1995; Anderson and Putterman, 2006), which can be used to analyze data where observations originate from various groups and the group affiliations

[17] The loss aversion model indicates that cost-disadvantaged firm owner granting options decreases her manager's investment by an amount significantly larger than then risk-neutral prediction, while cost-advantaged firm owner decreases her manager's investment not significantly different from risk-neutral prediction.

Figure 1: The Empirical Distribution of Investment (ECUs)



Notes:The vertical line in each subplot is the risk neutral equilibrium prediction under the indicated contract and cost configuration.

are not known (Titterington et al., 1985; McLachlan and Peel, 2004). To separate subjects into groups, we adopt an expectation-maximization (EM) algorithm within a maximum likelihood framework (Dempster et al., 1977; McLachlan and Peel, 2004; Leisch, 2004).[18] We then run regressions for each group using a fixed effect panel specification with standard errors clustered at the individual levels.

We report the results for the symmetric-cost sessions in Table 8. It contains a two-segment grouping and a three-segment grouping, which generate the highest AIC/BIC when we vary the number of segments. Each column of the table reports the proportion of the sample in the group, summary statistics, the estimated coefficients of the regressions, and

[18]The estimation-classification algorithm assumes choices of each person in the sample are described by function F(theta), where theta is a vector of unknown model parameters. Heterogeneity is introduced by allowing that population contains K segments, or types of person, with each type described by one of K different thetas. The thetas which describe each type and which subjects are which type are estimated simultaneously. In estimation, person i's contribution to the likelihood function, given theta is the maximum of the joint likelihood of all i's observations across the K types. Conventional maximization algorithms can be used to identify the theta which maximize the likelihood of the observed data, with care taken to ensure the global maximum is identified in a likelihood function which often has many local maxima.

Table 8: Heterogeneous estimates of determinants on investment for symmetric-cost sessions

		Two-segment		Three-segment		
		I	II	I	II	III
Summary Statistics						
Proportion of subjects		30.0%	70.0%	30.0%	63.33%	6.67%
Average investment		26.04	77.43	26.04	73.85	111.45
Median investment		10.00	80.00	10.00	80.00	100
Overinvestment frequency		15.00%	72.70%	15.00%	72.72%	72.50%
Frequency of investment = 0		10.37%	1.59%	10.37%	1.75%	0%
Frequency of investment < 10		43.15%	3.89%	43.15%	3.42%	8.33%
Frequency of investment = 100		6.11%	22.86%	6.11%	24.47%	7.50%
Frequency of investment >= 100		6.66%	31.11%	6.66%	28.77%	53.33%
	Prediction	*Regression*				
Constant	50.00	17.83***	73.50***	17.83***	71.77***	89.96**
		(3.180)	(2.118)	(3.180)	(1.966)	(8.167)
Stock v Option	-0.60	-3.354	-8.702**	-3.354	-9.052**	-4.762
		(2.540)	(3.713)	(2.540)	(3.323)	(24.01)
Option v Stock	11.60	19.12	8.928	19.12	8.210	13.53
		(7.485)	(3.938)	(7.485)	(3.928)	(21.73)
Option v Option	16.70	19.10	16.50	19.10	9.560*	74.50*
		(5.495)	(5.055)	(5.495)	(3.784)	(19.15)
Log Likelihood		-9012.58		-8802.89		
AIC/BIC		18047.16/18107.62		17639.77/17733.19		
Observations		540	1260	540	1140	120
	Prediction	*Investment under Different Configurations*				
Stock v Stock	50.00	17.83***	73.50***	17.83***	71.77***	89.96**
		(3.180)	(2.118)	(3.180)	(1.966)	(8.167)
Stock v Option	49.40	14.47***	64.80***	14.47***	62.71***	85.19**
		(3.129)	(3.559)	(3.129)	(3.114)	(23.14)
Option v Stock	61.60	36.94***	82.42***	36.94***	79.98***	103.48
		(4.530)	(2.526)	(4.530)	(2.275)	(18.89)
Option v Option	66.70	36.93***	90.00***	36.93***	81.33***	164.45***
		(2.873)	(3.502)	(2.873)	(2.466)	(13.27)

Note 1: Robust standard errors in parentheses
Note 2: + means we test the estimators against the predictions in the first column.
means we test the estimators against zero.
Note 3: The stars on the left of these coefficients indicate whether they are significantly different from the predictions or zero.
In particular, *** p<0.01, **p<0.05, * p<0.1

estimated investment under different configurations. The two-segment grouping divides the population into under-investors (segment I) and over-investors (segment II). The investment chosen by under-investors is significantly below the risk neutral equilibrium prediction given all contract configurations; that chosen by over-investors is significantly above. Since the over investors take up 70.0% of the sample, we observe pervasive overinvestment in the aggregate data. And, the over-investors decrease their investment by significantly more than the prediction if the contract configuration shifts from Stock v Stock to Stock v Option. In addition, adding another segment separates the extensively aggressive subjects out from the over-investors. There are only 4 out of 60 subjects placed in this aggressive group.

The grouping results for the asymmetric-cost sessions are presented by Table 9. The two-segment grouping also divides the population into under-investors (segment I) and over-investors (segment II). As for the three-segment grouping, there still exist a group for under-investors (segment I) and a group for over-investors (segment III). These subjects either overinvest or underinvest in the baseline treatment (cost-advantaged subjects under Stock v

Table 9: Heterogeneous estimates of determinants on investment for asymmetric-cost sessions

		Two-segment		Three-segment		
		I	II	I	II	III
Summary Statistics						
Proportion of subjects		43.33%	56.67%	28.33%	56.67%	28.33%
Average investment		42.37	83.07	33.61	65.49	97.16
Median investment		39.50	97.75	25.00	68.75	100.00
Overinvestment frequency		35.00%	77.25%	23.53%	62.43%	89.02%
Frequency of investment = 0		6.67%	4.31%	7.84%	6.79%	0.59%
Frequency of investment < 10		22.69%	7.55%	30.00%	11.28%	2.54%
Frequency of investment = 100		5.51%	28.82%	3.53%	19.10%	33.33%
Frequency of investment >= 100		8.33%	48.43%	4.12%	31.15%	57.84%
	Prediction			*Regression*		
Cons. (Stock v Stock)	49.38	35.42***	64.91***	32.98***	44.83	83.37***
		(3.882)	(3.202)	(4.148)	(3.283)	(4.607)
Stock v Option	0.588	-5.345	-1.773	-5.209	-10.46***	5.208
		(4.581)	(4.416)	(6.127)	(3.601)	(7.020)
Option v Stock	7.92	10.62	28.85***	1.208	34.18***	20.09
		(7.000)	(5.593)	(7.114)	(5.939)	(9.264)
Option v Option	14.25	14.32	34.86***	6.332	43.60***	16.30
		(4.902)	(6.593)	(5.158)	(6.385)	(7.922)
Cost_dis	0.0173	-0.912	-1.538	-4.797	-0.865	1.174
		(4.956)	(4.655)	(6.535)	(4.205)	(6.887)
Cost_dis*Stock v Option	-1.888	-0.963	-6.280	-2.111	-0.490	-5.006
		(5.783)	(7.309)	(8.341)	(6.077)	(12.62)
Cost_dis*Option v Stock	8.281	10.18	8.758	13.03	11.40	4.135
		(8.399)	(6.018)	(11.18)	(6.346)	(8.478)
Cost_dis*Option v Option	5.954	12.66	14.31	8.168	16.09**	15.09*
		(5.863)	(5.144)	(8.746)	(4.744)	(7.158)
Log Likelihood		-8864.18			-8725.76	
AIC/BIC		17766.35/17870.76			17509.52/17668.89	
Observations		780	1020	510	780	510
	Prediction			*Investment under Different Configurations*		
Cost_adv + Stock v Stock	49.38	35.42***	64.91***	32.98***	44.83	83.37***
		(3.882)	(3.202)	(4.148)	(3.283)	(4.607)
Cost_adv + Stock v Option	49.97	30.07***	63.13***	27.77***	34.37***	88.57***
		(3.999)	(4.638)	(4.088)	(4.514)	(5.776)
Cost_adv + Option v Stock	57.30	46.04***	93.76***	34.19***	79.01***	103.45***
		(3.741)	(3.778)	(3.859)	(4.072)	(6.077)
Cost_adv + Option v Option	63.63	49.74***	99.77***	39.31***	88.43***	99.67***
		(2.758)	(4.397)	(3.628)	(4.094)	(5.346)
Cost_dis + Stock v Stock	49.40	34.51***	63.37***	28.18***	43.97	84.54***
		(2.543)	(4.373)	(3.202)	(3.349)	(7.070)
Cost_dis + Stock v Option	48.1	28.19***	55.32	20.86***	33.02***	84.74***
		(3.340)	(5.983)	(4.159)	(5.233)	(8.944)
Cost_dis + Option v Stock	65.6	55.30***	100.98***	42.42***	89.54***	108.77***
		(3.375)	(3.534)	(4.358)	(4.264)	(3.741)
Cost_dis + Option v Option	69.6	61.49*	112.54***	42.68***	103.65***	115.93***
		(4.490)	(4.886)	(5.065)	(4.115)	(6.796)

Note 1: Robust standard errors in parentheses
Note 2: + means we test the estimators against the predictions in the first column.
means we test the estimators against zero.
Note 3: The stars on the left of these coefficients indicate whether they are significantly different from the predictions or zero.
In particular, *** p<0.01, **p<0.05, * p<0.1

Stock), and their reaction to any shift of configuration is not significantly different from the prediction. In contrast, the investment by subjects in segment II is not significantly different from the prediction under the baseline treatment, but they overreact to the shift of contract configuration. The proportion of subjects in segment II is 56.67%.

5.4 Expected Profit of Firm Owners

In this section, we examine how granting Option would affect the profit of firm owners given managers' investment behavior. We calculate the empirically expected profit of firm owners

Table 10: Panel regressions on expected profit (thousands of ECUs) for symmetric sessions

	Prediction	Regression
Cons. (Stock v Stock)	50.00	41.98***
		(0.918)
Option v Stock	-0.60	12.57***
		(1.532)
Stock v Option	-10.39	-14.74***
		(1.302)
Option v Option	-16.67	-15.50
		(2.000)
	Prediction	Expected Profit
Stock v Stock	50.00	41.86***
		(0.906)
Option v Stock	49.40	54.55***
		(1.036)
Stock v Option	39.61	27.24***
		(1.020)
Option v Option	33.33	26.48***
		(1.222)

Note 1: The profit in this table are in thousands of ECUs.
Note 2: Robust standard errors in parentheses.
Note 3: $*$ means we test the estimators against the predictions listed in the second column. † means we test estimators against owner's optimal investment level listed in the third column. ‡ means we test the estimators against zero. In particular, $*p < 0.01, **p < 0.05, ***p < 0.1$. The same is true for † and ‡.

based on the investment behavior observed in our experiments. For comparison, we also calculate the theoretically expected profit based on the risk-neutral equilibrium investment. When calculating the expected profit, we let the values of the parameters be the same as those used in the theoretical model and experiment design.

We conduct panel regressions to facilitate the formal tests of our hypotheses on the expected profit for firm owners. The dependent variable is the empirically expected profit, and independent variables include dummy variables indicating contract configurations and cost configurations. Based on the regression results, the average empirically expected profit under different contract and cost configurations can be calculated as linear combinations of intercept and coefficients. We test the empirically expected profit against the theoretical prediction (Hypothesis 4). We found that firm owners are usually expected to earn lower profit than the prediction due to the overinvestment by their own and opponent managers. But if the firm owner grants Option while her opponent grants Stock, then her expected profit would be either higher than or not different from the prediction. The results for the

Table 11: Payoff matrices for firm owners based on theoretical prediction and empirical data

Prediction for symmetric-cost sessions

		$c_2 = 1.00$ Stock	Option
$c_1 = 1.00$	Stock	**50.0, 50.0**	**39.6**, 49.4
	Option	49.4, **39.6**	33.3, 33.3

Empirical data for symmetric-cost sessions

		$c_2 = 1.00$ Stock	Option
$c_1 = 1.00$	Stock	41.9, 41.9	**27.2, 54.6*** **
	Option	**54.6*** , 27.2**	**26.5, 26.5**

Prediction for asymmetric-cost sessions

		$c_2 = 1.25$ Stock	Option
$c_1 = 1.00$	Stock	61.7, **39.5**	**47.6**, 32.3
	Option	**62.4, 36.9**	43.1, 23.8

Empirical data for asymmetric-cost sessions

		$c_2 = 1.25$ Stock	Option
$c_1 = 1.00$	Stock	56.1, **39.4**	**29.5** **, **39.0**
	Option	**66.1*** , 17.9*** **	23.9, 6.6

Note 1: The profit in this table are in thousands of ECUs.
Note 2: We make the best response in bold. The best response refers the strategy(s) which produces the most favorable outcome for a firm owner, taking other owner's strategy as given.
Note 3: For matrices based on the empirical data, we test firm owner's empirical expected profit of one strategy against that of the other strategy while fixing opponent's strategy. If we found one strategy will generate significantly higher expected profit, we would mark it with $*$, and $*p < 0.01, **p < 0.05, ***p < 0.1$.

symmetric-cost sessions are contained in Table 10. For the asymmetric-cost sessions, we found similar results.

We then examine whether firm owners have an incentive to grant Option (Hypothesis 5). Given managers' investment behavior under different contract configurations, owners of the two competing firms are actually playing a 2×2 normal form game where they choose either Stock or Option as shown in Table 11. On the left side, the payoff matrices indicate what firm owners are expected to earn if their managers choose the risk-neutral equilibrium investment level. On the right side of Table 11, the payoff matrices are based on managers' empirical investment behavior observed in our experiment.

We first look at the symmetric-cost case. Theoretically, we found that granting Stock is the dominant strategy. Therefore, if managers are following the risk-neutral equilibrium, the use of Option cannot be justified in the symmetric-cost case. Our experiment data, however, show that managers deviate from the equilibrium leading to a justification of Option. In the empirical payoff matrix, given the opponent grants Stock, the firm owner is expected to earn significantly higher profit granting Option instead of Stock. When the opponent grants Option, the expected profit for the firm owner is not significantly different between Stock and Option. We believe, however, the firm owner is more likely to grant Option, because doing so lowers the opponent's profit significantly at almost no cost. There are three Nash equilibria based on the empirical data: (Stock, Option), (Option, Stock), and (Option, Option). The equilibrium most likely to be chosen by owners is (Option, Option), where they are expected to earn significantly less than if both keep to Stock. Therefore, contrary to the theoretical prediction, empirical data suggest firm owners are faced with a prisoner's dilemma situation. Either owner would most prefer that she uses Option while her rival does not. The owner would also use Option even if her rival uses Option to keep down the opponent's expected profit. This creates a prisoner's dilemma setting in which both firms acting rationally leads to a socially suboptimal outcome.

For the asymmetric-cost case, we run a similar analysis. Theoretically, Stock is the dominant strategy for the cost-disadvantaged firm owner, while the best response for the cost-advantaged firm owner depends on her opponent's action. If the opponent grants Stock, the cost-advantaged owner may grant Option even though the incentive to grant Stock rather than Option is very small. On the other hand, if the opponent grants Option, the cost-advantaged owner is expected to earn significantly more by granting Stock. Thus if managers are following the risk-neutral equilibrium strategies, the Nash equilibrium is that the cost-advantaged firm owner grants Option while the cost-disadvantaged firm owner chooses Stock. Based on the empirical data, however, we found that the cost-disadvantaged firm owner has the incentive to grant Option if her opponent chooses Stock. The cost-advantaged firm owner still has the same best response, but she has a stronger incentive to grant Option if her opponent grants Stock. Therefore, the empirical data show that firm owners are playing a Hawk-Dove game, where their optimal choice depends on what their opponents are doing. If their opponents grant Stock, they should grant Option. If their opponents grant Option, they should grant Stock.

We also examine firm owners' optimal choices if managers are of different types. The results are shown in Table 12. When managers are under-investors, granting Option is the dominant strategy for firm owners even for the cost-disadvantaged owner in the cost-asymmetric cases. When managers are over-investors, firm owners in the cost-symmetric

Table 12: Payoff matrices for firm owners given managers' types

Under investors & Symmetric-cost

$c_1 = 1.00$		Stock	Option
$c_2 = 1.00$	Stock	$(82.6, 82.6)$	$(41.8, 106.8^{***})$
	Option	$(106.8^{***}, 41.8)$	$(63.1^{***}, 63.1^{***})$

Over investors & Symmetric-cost

$c_1 = 1.00$		Stock	Option
$c_2 = 1.00$	Stock	$(26.5, 26.5)$	$(23.2^{***}, 29.6)$
	Option	$(29.6, 23.2^{***})$	$(10.0, 10.0)$

Under investors & Asymmetric-cost

$c_1 = 1.00$		Stock	Option
$c_2 = 1.25$	Stock	$(77.0, 53.1)$	$(50.1, 63.8^{***})$
	Option	$(88.2^{***}, 37.6)$	$(50.8, 38.0)$

Over investors & Asymmetric-cost

$c_1 = 1.00$		Stock	Option
$c_2 = 1.25$	Stock	$(47.4^{***}, 24.3^{***})$	$(24.1^{***}, 11.3)$
	Option	$(42.1, 8.8^{***})$	$(5.4, -17.7)$

Note 1: The profit in this table are in thousands of ECUs.
Note 2: For matrices based on the empirical data, we test firm owner's empirical expected profit of one strategy against that of the other strategy while fixing opponent's strategy. If we found one strategy will generate significantly higher expected profit, we would mark it with $*$, and $*p < 0.01, **p < 0.05, ***p < 0.1$.

cases still have an incentive to deviate from Stock to Option, while both cost-advantaged and cost-disadvantaged firm owners in the asymmetric-cost case have no incentive to deviate from the Nash equilibrium, Stock v Stock.

6 Conclusion

Executive stock options are widely used in practice, but previous literature fails to provide a compelling justification for their extensive use. One important element left out of previous work is how stock options might affect the nature of competition between firms. The competitive setting is important because executive stock options granted to a manager would affect not only the behavior of that manager but also of the managers in rival firms. If rival managers are pushed to be less aggressive, we would expect that stock options are more effective than had the competitive effect not been considered. This paper investigated this issue both theoretically and experimentally, and provided a justification for the use of stock options.

We theoretically examine a two-stage game where firm owners write compensation contracts with the managers in the first stage, and then in the second stage managers decide how much firms will invest in a competition given both their own and opponents' incentive packages. If managers are following risk neutral equilibrium, the theoretical model suggests firm owners have little incentive to grant stock options. But if managers deviate from the risk neutral equilibrium, then the optimal contract for firm owners should be based on the empirical investment chosen by managers.

We use laboratory experiments to investigate how executive stock options would affect managers' investment decisions in the competition, and then based managers' empirical investment behavior we examine whether granting stock options is a profitable strategy for firm owners. When the marginal cost of investment is symmetric between the competing firms, owners have the incentive to deviate from stock to stock options given their opponents granting stock. Even when the opponents grant stock options, they still have the incentive to deviate from stock to stock options, as by doing so they can lower opponents' profit significantly at almost no cost. When the marginal investment cost is asymmetric between firms, there are usually two equilbria, in either of which one owner grants options while the other grants stock. Either the cost-advantaged firm owner or the cost-disadvantaged firm owner can be the one granting options. Therefore, the empirical data actually provide strong support for the extensive use of stock options. The divergence between the empirical data and the theoretical model is attributable to managers' overreaction compared to the risk-neutral equilibrium prediction. The theory suggests that a firm owner granting stock options decreases the investment of the opponent manager by a very small amount or increases it. The empirical data, however, show the owner deviating to options decreases her opponent's investment more than the prediction if her opponent grants Stock.

These experimental results provide a possible justification for the continued use of stock options despite their problematic nature. This leads to a finding that each firm would most prefer that they use stock options while their rivals do not. Sometimes, firms would use stock options even if their rivals use stock options in order to keep down the expected profit of their opponent firms. Of particular interest is that while individually each firm benefits from their use, it turns out that if both firms use them they are worse off than if neither did.

The managers' overly aggressive investment behavior induced by the executive stock option has negative impact on the society. When the investment of the contestants does not add any social value, such as advertisement, firm owners granting stock options waste social resources. Even when the investment benefits the society, such as R&D expenditure, the excessive investment might push the marginal cost of the investment above its the marginal benefit, and therefore lead to socially suboptimal outcome. Furthermore, managers' overly aggressive actions increase the bankruptcy risk of their firms. Sometimes, it is the whole society that bear the cost of their bankruptcy. For example, in the 2008 financial crisis, several major financial institutions[19] either failed, or were subject to government takeover. US government had to sink trillions of dollars to prevent the world bank system collapsing. The ramifications of the banking collapse of 2008 will be felt for years if not decades to come[20].

Since the extensive use of stock options decreases the social welfare, so the government policies should discourage encourage the use of stock options by either removing the advantage of stock options or making other forms of compensation more preferable. Some government policies do remove the advantage of stock options. For example, before 2004 the value of the option was only required to be disclosed in a footnote to the financial statements allowing companies to essentially underreport executive compensation and make their potential profits look greater. In December 2004, Financial Accounting Standards Board (FASB) announced FAS123R, which required all U.S. firms to recognize an accounting expense when granting stock options. In addition, the Obama administration's proposal to cut the corporate-tax rate to 28% by ending some deductions also could threaten a long-standing tax benefit that made stock options attractive[21]. On the other hand, some other

[19] These financial institutions included Lehman Brothers, Merrill Lynch, Fannie Mae, Freddie Mac, Washington Mutual, Wachovia, Citigroup, and AIG.

[20] Total home equity in the United States, which was valued at $13 trillion at its peak in 2006, had dropped to $8.8 trillion by mid-2008 and was still falling in late 2008. Total retirement assets, Americans' second-largest household asset, dropped by 22%, from $10.3 trillion in 2006 to $8 trillion in mid-2008. During the same period, savings and investment assets (apart from retirement savings) lost $1.2 trillion and pension assets lost $1.3 trillion. Taken together, these losses total a staggering $8.3 trillion. Since peaking in the second quarter of 2007, household wealth is down $14 trillion. Source: https://en.wikipedia.org/wiki/Financial_crisis_of_2007%E2%80%932008.

[21] https://blogs.wsj.com/cfo/2013/08/26/last-gasp-for-stock-options/

policies move in the opposite direction. For example, the Trump administration proposes to eliminate the alternative minimum tax (AMT). This will make stock options more preferable as currently the income spread at exercise of executive stock options can trigger the AMT and complicate tax planning[22].

Moreover, our results also show that it is hard to replace stock options once they are widely used. If a company pulls only its own options back, it puts itself at a competitive disadvantage relative to its competitors, and no firm wants to be the first to do that. By 2000, stock options accounted for more than half of the total compensation for a typical S&P 500 CEO. There are several factors fueling the explosion of stock options, such as SEC option disclosure rules and tax and accounting rules for options. In the late 2000s, tax and accounting rule changes removed the advantage for stock options. Executive stock options proved to be a significantly contributor to the financial crisis due to the fact that they can encourage excessive risk taking. Despite this, stock options still comprise around one-quarter of the total value of executive pay packages. The reason why firm owners are reluctant to give up stock options can be explained by our empirical data. In the symmetric-cost case, we found neither firm owners has an incentive to shift from options to stock if both firm owners granting options. The firm owner shifting to stock will not significantly increase profit while increasing the profit of her opponent significantly. In the asymmetric-cost case, either of the firm owners would grant option in the equilibrium. Therefore, the government should be cautious when they issue policies that would affect the executive stock options. Once they issue the policies that increase the use of stock options, it is hard to wipe out its impact in the future even if we abandon those policies.

[22] https://www.mystockoptions.com/articles/index.cfm/ObjectID/22615723-D31E-CCDF-68284D3C456C3E3A

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