Stock Options Compensation as a Commitment Mechanism in Oligopoly Competition

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Abstract

Stock options have become an important component of contemporary managerial compensation. According to Frydman and Jenter (2010), in 2005 around 37% of CEO compensation was in the form of stock options. It is widely acknowledged that stock options compensation makes managers more willing to take risks. In this paper, I show how a commitment to risk taking through stock options compensation can lead to a strategic advantage in oligopolistic competition. I develop a two period model whereby in the first period shareholders choose a compensation structure for their managers and in the second period managers choose production under Cournot competition with uncertain demand or marginal cost. I show that in equilibrium shareholders will structure managerial compensation and use stock options to make their managers risk-taking. The idea that shareholders could incentivise excessive risk-taking behavior in their managers has important welfare implications. I also investigate a testable implication of my model: that the equilibrium levels of options compensation is positively related to the market power of the firms. Using options compensation data from Capital IQ and industry concentration as a proxy for market power, I show that as predicted the level of options compensation is positively related to the level of industry concentration ($p < 0.001$).
7.4 Regression without fixed effects . . . . . . . . . . . . 47
1 Introduction

Stock options are an important component of contemporary managerial compensation. In 2005, around 37% of CEO compensation was in the form of stock options (Frydman and Jenter, 2010). Since the 1980s, economists primarily understood stock options compensation as an instrument by which risk neutral shareholders (the principals) aligned the incentives of risk averse managers (the agents) in the presence of asymmetric information.

However, the focus on the alignment of incentives misses an important strategic dimension to the principal agent problem. The principal agent problem is characterized by an existence of an agent who has to be incentivized to act in the best interests of the principal. The presence of agents who acts on the principals’ behalf without necessarily conforming to the principals’ interests give the principals an opportunity to credibly commit to a set of strategies that may be different from what the principals would choose themselves.

For example, the shareholders may be expected profit maximizing, but if they incentivise their managers to be risk taking, they can credibly commit to a risk taking set of strategies. If the principals engage in strategic interactions with other players, the ability to make such credible commitments enables the principals to earn a strategic advantage similar to that of the first mover in the Stackelberg competition model (Heinrich von Stackelberg, 1934). As such, my thesis is based on an analysis of principal agent relationships whereby agent compensation setting incorporates the commitment value of various compen-
sation schemes.

Figure 1: A flow chart showing how the agent’s incentives can be a useful commitment device for the principal

My thesis shows how stock options awards can lead to a strategic advantage by allowing shareholders to commit to a risk-taking set of strategies. The awarding of stock options leads to greater management risk taking because stock options enable managers to enjoy the potential upside gain (a rise in stock value) while protected from the downside risk (a fall in stock value) of their decisions. By credibly incentivising managers to take risks through options compensation, firms can commit to a more aggressive management style. With uncertain returns on production due to demand and cost uncertainty, managers incentivised to be risk seeking face incentives to overproduce in or-
der to increase the volatility of the returns of the firm. The public knowledge
that a firm has a credible commitment to overproduce may force the other
firms to scale back their own planned production to avoid flooding the mar-
et. As a result, in equilibrium, all firms adopt stock options compensation
and incentivise their managers to be risk taking in order to avoid ending up
as a disadvantaged Stackelberg follower.

The insight I propose can be demonstrated within a two stage Cournot oligopoly
model. In the first stage, shareholders choose the compensation structure for
managers. In the second stage, managers choose production under Cournot
oligopoly with uncertain demand or cost. This approach differs from the in-
centive alignment model traditionally used to explain stock options compensa-
tion in that it implies that executive compensation will incentivise managers
to be risk taking rather than risk neutral. Dong, Wang, and Xie (2010) gives
empirical evidence that stock options compensation for managers is associ-
ated with financing decisions that leave firms over-leveraged, suggesting that
shareholders do incentivise risk taking (instead of incentive alignment and risk
neutrality) in managers.

My model implies that the equilibrium executive compensation structure is
related to the extent of market power available to the firms in an industry. It
is less relevant when the market approaches perfect competition where indi-
vidual firm decisions do not influence the decisions of other firms. If firms do
not have market power, committing to a certain set of actions can yield no
response from other firms and hence no competitive advantage. This means
that the amount of options compensation awarded should be positively related to market concentration. The risk preference alignment model does not necessarily imply this. As a result, studying the relationship between market power and options compensation offers one way to test the model.

I obtained employee compensation data for manufacturing companies from CapitalIQ and linked them with US Census Bureau data on industry concentration, which is a proxy for market power, in 2002 and 2007. From the data, I found a positive and statistically significant ($p < 0.001$) relationship between the change in options compensation and the change in industry concentration during those five years.

The main insight of my thesis, that options compensation can be used as a commitment device for production by the shareholders, can apply to other situations where such a commitment may be useful. For example, a commitment to higher investment in product innovation through options compensation may also lead to a strategic advantage for the firm. My model is based on a commitment to production under Cournot competition, but the insight of the model could apply whenever a commitment to a set of best response functions could yield accommodation from the other players.

## 2 Literature Review

The use of stock options as executive compensation started in the 1950s. By the 1970s, stock options constituted 11% of total CEO compensation (Frydman and Jenter, 2010). The first models on options compensation focused on
the usefulness of stock options compensation in addressing the principal-agent problem between risk averse managers and risk neutral shareholders. They include Haugen and Senbet (1981), Smith and Stulz (1985), and Greenwald and Stiglitz (1990), and are now recognized as standard explanations for options compensation.

In these models, the managers and the shareholders have conflicting interests regarding risk. While shareholders can eliminate idiosyncratic risk through diversification, managers cannot due to their specific human capital investment that are tied to the firm. As a result, shareholders are more likely to prefer a risk neutral and expected profit maximizing style of decision making than the managers. Given some information asymmetry between managers and shareholders, managers who are risk averse may be able to mask their risk averse managing of the firm. The inclusion of options in the managers’ compensation presumably makes managers more willing to take risks and lead to decisions that are more aligned with shareholder interests. There are many empirical studies linking options compensation with increased risk taking, including Rajgopal and Shevlin (2002), Coles, Naveen, and Lalitha (2006), and Gormley, Matsa, and Milbourn (2012).

A number of extensions has been made to the theory of options compensation since the 1980s. Zhang (1998) expanded on the mainstream principal-agent model to include the observation that shareholder vigilance would lead to shareholder concentration and risk aversion in firm behavior as long as information was costly to obtain. The awarding of risk rewarding compensation
to managers, then, is better able to induce risk-neutral decision making than shareholder vigilance. Other models explore the usefulness of options on employee sorting in terms of the labor economics associated with hiring capable employees. Lazear (2004) derives a model whereby employee skill is assumed to be known to the employees but unknown to the employers (thus leading to asymmetric information in skill levels), and derives a model where pay tied to firm performance would attract able employees to work at the firm. Options compensation for managers, then, would attract capable managers.

Partly due to the success of these models in demonstrating the usefulness of that options compensation, provisions in the Omnibus Budget Reconciliation Act of 1993 (OBRA 1993) encouraged options based compensation by exempting it from the $1 million cap on the deductibility of employment based compensation. Hanlon and Shevlin (2002) noted that the use of employee stock options reduced the amount of taxes owed by the firm by allowing firms to circumvent the cap on the deductibility of employee compensation. Another explanation of options compensation from the accounting perspective comes from Core, Guay, and Larcker (2003). Core, Guay, and Larcker explained that the Generally Accepted Accounting Principles (GAAP) used in financial accounting allow the expenses of awarding options compensation to be hidden from income statements. Options compensation can be valued by the difference between the exercise price and the stock price of the firm under GAAP. Since options are usually awarded with a strike price equal to the current stock price of the firm (ie. with a difference of zero), the expense of options com-
Figure 2: A chart showing the importance of options compensation as a component of CEO compensation in S&P500 firms by Frydman and Jenter (2010).

Options compensation is hidden from income statements. Options compensation increased to 32% of total CEO compensation in the 1990s and to 37% in the early 2000s (Frydman and Jenter, 2010).

The common theme of imperfect information models is that they assume some sort of asymmetric information between the employers (the principals) and the employees (the agents). They introduce options compensation as a way to work around the information constraints by aligning the incentives of managers and shareholders. The theory of asymmetric information is insightful and expansive, and its pioneers are awarded well deserved Nobel Prizes in economics.
in 2001. Nevertheless, asymmetric information may not be necessary to explain options compensation, and the alignment of the shareholder/manager decision making process may not lead to the profit maximizing managerial compensation structure.

My thesis explains how options compensation can be used as a commitment device in oligopoly competition, and proposes an alternative mechanism by which options are awarded. The intuition for my model is similar to that in Allaz and Vila (1993). Allaz and Vila (1993) modeled how firms could use the forward market in stage one to commit to production in stage two, hence gaining a competitive advantage as a first-mover. In a simultaneous game, Allaz and Vila (1993) showed that all firms would participate in forward markets even though by doing so, the firms pre-commit to greater production and drive down prices. As such, the paper explains the existence of forward markets under perfect information by pointing out the strategic element of participating in forward markets. I show that there is a similar strategic element in options compensation: awarding options compensation is a way of pre-committing to risk taking, which in a world of uncertain demand and cost means a pre-commitment to production.

The idea that firms would commit to aggressive strategies through managerial compensation was explored in Fershtman (1985), Fershtman and Judd (1987) and Sklivas (1987), which are sometimes referred to as the FJS models. Similar to my model, the FJS models are two stage models where shareholders set compensation in the first stage and managers set production in the second
stage. Their models showed that shareholders who design a compensation package based on profits and revenue will choose a compensation schedule that leads to managers aggressively setting production beyond the Cournot Nash equilibrium. Instead of depending on a revenue based compensation schedule as a pre-commitment, my model shows how risk based compensation (options compensation) can also be used by shareholders to commit their managers to be aggressive.

Reitman (1993) also explored options compensation as a commitment mechanism under the FJS model. However, he treated options as a discontinuous pay-off schedule based on profits that are revealed immediately when production is set, and as a result did not incorporate the element of risk-taking into his model. In my model, managers set production under demand or cost uncertainty and maximize their expected utility based on the expected payoff of their options. Unlike the Reitman (1993) model, my model incorporates uncertainty and risk-taking behavior. Because one of the most cited rationale for the use of stock options is to make managers more risk-taking, my model uses a more complete characterization of options compensation than the one Reitman (1993) used.

The existence of risk taking firms driven by managerial stock options is empirically examined by Dong, Wang, and Xie (2010). Dong, Wang, and Xie (2010) showed that stock options compensation for managers is associated with financing decisions that leaves the firm over-leveraged, suggesting that stock options compensation can indeed lead to excessive risk taking in firms
(and not simply risk neutrality, as the principal-agent shareholder manager incentive alignment model would suggest).

3 Model

3.1 Model setup

I use a two period model with two sets of players, shareholders and managers, to illustrate the strategic opportunity embedded in options compensation. In this model, shareholders (principals) first choose a type of compensation for the managers (agents), and the managers then act on the shareholders’ behalf given some uncertainty. I will show that through incentivising the managers to be risk taking, shareholders can credibly commit to higher production and behave as a first mover in an otherwise simultaneous Cournot game. Therefore, in equilibrium, shareholders will structure managerial compensation so as to make their managers risk taking.  

I will first prove the result generally, then use a specific example to illustrate the model more concretely. I will use the following notation in both the general model and the specific example:

$(x, y)$, indices for firm x and y

$(q_x, q_y)$, the level of production set by managers in firm x and y

$p$, the price of the goods

$c$, the marginal cost of the goods

1And stock options compensation is a risk-inducing compensation scheme (with some theoretical exceptions outlined in Ross, 2004 that is addressed in the appendix) that shareholders can use to make their managers risk taking.
\( \epsilon \), the uncertainty in either price or cost

\( \sigma_\epsilon \), the standard deviation of the uncertainty in price or cost

\( \pi \), the profit from production

\( \sigma_\pi \), the uncertainty in profit, as a standard deviation

\( f(\pi) \), a function relating the compensation awarded to managers to the profits of the firm

\( E() \), \( var() \), the expected value and the variance

\( U(f) \), the utility function of the manager

\( U^*(E(\pi), \sigma_\pi) \), the expected utility of the manager expressed as a function of the expected value and the variance of the profits

I will assume that there exists either demand or cost uncertainty in the market place, that shareholders are expected profit maximizing, and that the firms engage in Cournot competition with linear demand and constant marginal cost (such that \( p = a - q_x - q_y \), and \( \pi = pq - cq = (p - c)q = (E(p) - E(c) + \epsilon)q = E(p) - E(c))q + \epsilon q \). I will also assume that price or cost uncertainty, \( \epsilon \), follows a distribution that is characterizable by the first two moments (such as the Gaussian distribution). Under these assumptions, shareholders would design executive compensation to induce a positive level of risk taking behavior from the managers.

The manager of firm \( x \) sets the production \( q_x \) to maximize expected utility of the compensation \( f(\pi_x) \):

\[
\max_{q_x} E(U(f(\pi_x)))
\] (1)
Given the assumption that $\epsilon$ follows a distribution that is characterizable by the first two moments, we can express managers’ expected utility in terms of the mean (the first moment) and the variance (the second moment) of the profits (Pennacchi, 2008, Ch. 2, which noted that $E(U(\pi)) = U(E(\pi)) + \frac{1}{2} \text{var}(\pi) U''(E(\pi)) + \frac{1}{8} \text{var}(\pi)^2 U''''(E(\pi) + ...))$. As such, the managers’ incentive function can be written as: $max_q E(U(\pi)) = U^*(E(\pi), \sigma_\pi).

Since shareholders could diversify away idiosyncratic risks, they are assumed to be expected profit maximizing. As a result, shareholder of firm $x$’s incentive is to structure management compensation $f$ such that expected profit is maximized:

$$max_f E(\pi) = E(p)q - E(c)q$$ (2)

I set up the game so that shareholders choose executive compensation $f(\pi)$ with the understanding that managers choose $q_x$ in order to maximize the expected utility from $f(\pi)$. I will solve the game through backward induction: I will first look at the equilibrium quantities and profits of managers playing a Cournot game for a given $f(\pi)$, and then explore how shareholders would set $f(\pi)$ with an understanding of the resulting equilibrium quantities.

### 3.2 General model

In this section I develop the key lemmas underlying my proposed insight on the strategic value of options compensation. As such, I will be as general as possible, and will only assume that managers have monotone increasing
and differentiable utility $U(f)$ and that executive compensation $f(\pi)$ is also monotone increasing and differentiable, in the tradition of Ross (2004).

**Lemma 3.1.** The best response function of the managers can be expressed as
\[ \frac{\partial E(\pi)}{\partial q} + b(q) = 0, \]
where $b(q)$ takes the sign of $\frac{\partial E(U)}{\partial \sigma_\pi}$.

**Proof.** By first order condition for maximization:
\[
\frac{dE(U(\pi))}{dq} \equiv \frac{dU^*}{dq} = \frac{\partial U^*}{\partial E(\pi)} \frac{\partial E(\pi)}{\partial q} + \frac{\partial U^*}{\partial \sigma_\pi} \frac{\partial \sigma_\pi}{\partial q} = 0
\]
Dividing both sides by $\frac{\partial U^*}{\partial E(\pi)}$ yields:
\[
\frac{\partial E(\pi)}{\partial q} + \frac{\partial U^*}{\partial \sigma_\pi} \frac{\partial \sigma_\pi}{\partial q} = 0
\]
This can be expressed as:
\[
\frac{\partial E(\pi)}{\partial q} + b(q) = 0
\]
where $b(q) = \frac{\partial U^*}{\partial \sigma_\pi} \frac{\partial \sigma_\pi}{\partial q}$
\[
\sigma_\pi = q\sigma_e, \quad \text{and therefore } \frac{\partial \sigma_\pi}{\partial q} > 0.
\]
Furthermore, by the monotonic increasing nature of $f(\pi)$ and $U(f)$, $U(f(\pi))$ is monotonically increasing in $\pi$ and hence $\frac{\partial U^*}{\partial E(\pi)} > 0$. As such, $b(q)$ takes the sign of $\frac{\partial U^*}{\partial \sigma_\pi}$, or $\frac{\partial E(U)}{\partial \sigma_\pi}$.

Given this best response function, we are now able to find the Cournot Nash equilibrium quantities chosen by managers in the second period for a given
utility function $U(\pi)$. We can then determine whether shareholders would incentivise managers to be risk averse or risk taking through backward induction. More specifically, we would investigate whether shareholders would incentivise $\frac{\partial E(U)}{\partial \sigma}$ to be positive or negative. If $\frac{\partial E(U)}{\partial \sigma}$ is greater than zero, the manager can be said to be risk taking. If $\frac{\partial E(U)}{\partial \sigma}$ is negative, the manager can be said to be risk averse. Note that $\frac{\partial E(U)}{\partial \sigma} = \frac{\partial E(U)}{\partial f} \frac{\partial f}{\partial \sigma}$, which takes the sign of $\frac{\partial f}{\partial \sigma}$.

Hence, incentives for managers to be risk taking or risk averse are determined by how their compensation $f$ is affected by the variance of the profits $\frac{\partial f}{\partial \sigma}$.

Since stock options increase in value as the variance in profits increases, stock options can be used to induce a risk taking behavior from the managers by making $\frac{\partial f}{\partial \sigma} > 0$.

**Lemma 3.2.** Under Cournot oligopoly with two symmetric players, shareholders would simultaneously set executive compensation structure such that the managers would be incentivised to be risk taking. That is, both managers will have $\frac{\partial E(U)}{\partial \sigma} > 0$.

**Proof.** First, the best response function for the managers of firm $x$ and firm $y$ can be obtained by solving out the condition in Lemma 3.1:

$$q_x = \frac{1}{2}(a - q_y - E(c) + b_x(q_x))$$

$$q_y = \frac{1}{2}(a - q_x - E(c) + b_y(q_y))$$
Solving these equations leads to the Cournot Nash equilibrium quantities:

\[ q_x = \frac{1}{3}(a - E(c) + 2b_x - b_y) \]  
\[ q_y = \frac{1}{3}(a - E(c) + 2b_y - b_x) \]

(6)  
(7)

Shareholders would choose an executive compensation structure \( f \) so as to maximize firm profits under the equilibrium quantities \( q_x \) and \( q_y \).

\[ \max_f E(\pi) = E(p)q - E(c)q \]  
(8)

For shareholders of firm x, substituting in the previously found \( q_x \) and \( q_y \) into the incentive function yields:

\[ \max_f E(\pi) = \frac{1}{9}(a + 2E(c) - b_x - b_y)(a - E(c) + 2b_x - b_y) - \frac{1}{3}E(c)(a - E(c) + 2b_x - b_y) \]

Shareholders can choose \( b \) through some executive compensation structure \( f \) to either incentivise risk aversion or risk taking in managers. In a simultaneous game, they would choose \( b \) based on each others’ best response functions. We now take the functional first order condition with respect to \( b \) to find the best response function of shareholders of firm x.

\[ \frac{d\pi}{db} = \frac{1}{9}(a - E(c) + 2b_x - b_y) + \frac{2}{9}(a + 2E(c) - b_x - b_y) - \frac{2E(c)}{3} = 0 \]

Similarly, the best response function of shareholders of firm y is:

\[ \frac{d\pi}{db} = \frac{1}{9}(a - E(c) + 2b_y - b_x) + \frac{2}{9}(a + 2E(c) - b_y - b_x) - \frac{2E(c)}{3} = 0 \]

Solving out the Nash equilibrium yields:

\[ b_x = b_y = \frac{a - E(c)}{5} > 0 \]  
(9)
By Lemma 3.1, $b$ takes the sign of $\frac{\partial E(U)}{\partial \sigma}$. Since the shareholders of both firms would set $b > 0$, $\frac{\partial E(U)}{\partial \sigma} > 0$, and managers are incentivised to be risk taking. More specifically, shareholders would choose $f$ such that $U^*(E(\pi), \sigma_p) = E(U(f))$ goes up as the variance of profits goes up. Hence, the managers are incentivised to be risk taking. See appendix for a step-by-step presentation of this proof. 

Lemma 3.2 is based on a two stage perfect information model. However, the principal agent relationship between managers and shareholders are usually characterized as one of imperfect information. Nevertheless, the commitment mechanism can work even if we assume some degree of imperfect information.

**Lemma 3.3.** Suppose that the managers’ assessment of expected marginal cost $E_m(c)$ is private information for the managers. Shareholders only have a probability distribution for $E_m(c)$, $P(E_m(c))$, but will assume that the managers’ assessment of expected marginal cost is correct. Shareholders would still set executive compensation structure such that the managers would be incentivised to be risk taking. That is, managers will have $\frac{\partial E(U)}{\partial \sigma} > 0$.

**Proof.** Given that shareholders assume that the managers’ assessment of expected marginal cost is correct, the incentive function for shareholders in Lemma 3.2 is as follows:

$$\max_{b_x} E(\pi) = E\left(\frac{1}{9}(a + 2E_m(c) - b_x - b_y)(a - E_m(c) + 2b_x - b_y)\right)$$

$$- \frac{1}{3}(E_m(c)(a - E_m(c) + 2b_x - b_y))$$

However, given an uncertain $E_m(c)$, the expected profits should be written in terms of expected values of $E_m(c)$, or $E(E_m(c)) = \int_0^\infty E_m(c)P(E_m(c))dE_m(c)$. 

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Hence, the incentive function under imperfect information should be:

\[
\max_{b_x} E(\pi) = \frac{1}{9} E((a + 2E_m(c) - b_x - b_y)(a - E_m(c) + 2b_x - b_y)) \\
-\frac{1}{3} E(E_m(c)(a - E_m(c) + 2b_x - b_y))
\]

Expanding yields:

\[
\max_{b_x} E(\pi) = \frac{1}{9}(a^2 - aE(E_m(c)) + 2ab_x - ab_y + 2aE(E_m(c))) \\
-2E(E_m(c)^2) + 4E(E_m(c))b_x - 2E(E_m(c))b_y \\
-ab_x + E(E_m(c))b_x - 2b_x^2 + b_xb_y + ab_y \\
-E(E_m(c))b_y - 2b_xb_y + 2b_y^2 - \frac{1}{3}aE(E_m(c)) \\
-E(E_m(c)^2) + 2b_xE(E_m(c)) - b_yE(E_m(c))
\]

Which leads to the following first order condition:

\[
d\pi/db_x = -\frac{1}{9}(a - E(E_m(c)) + 2b_x - b_y) \\
+\frac{2}{9}(a + 2E(E_m(c)) - b_x - b_y) - \frac{2}{3}E(E_m(c)) = 0
\]

This first order condition is exactly the same as the one in the proof if Lemma 3.2, with the sole exception being that \(E(c)\) is replaced by \(E(E_m(c))\). Hence, the Nash equilibrium would simply be:

\[
b_x = b_y = \frac{a - E(E_m(c))}{5} > 0 \tag{10}
\]

\(a - E(E_m(c)) > 0\) because otherwise shareholders would be expecting the firm to lose money regardless of quantity produced (since \(E(\pi) = pq - E(E_m(c))q = (a - E(E_m(c)))q - (q_1 + q_2)q\), if \(a - E(E_m(c)) < 0\), \(E(\pi) < 0\). Such firms would could not operate. Hence, \(b_x = b_y = \frac{a - E(E_m(c))}{5} > 0\). By Lemma 3.1, \(b\) takes the sign of \(\frac{\partial E(U)}{\partial \sigma_x}\). See appendix for a step-by-step derivation. \(\Box\)
3.3 Numerical Illustration

To illustrate the model better, we look at an example with a specific form of managerial utility function, executive compensation structure, and demand function. The rest of the setup will follow our general model: managers choose quantity in Cournot competition, and shareholders choose executive compensation to incentivise managers to be either risk-taking or risk-averse amid price or cost uncertainty. Through this more specific example, we are better able to explore the prisoner’s dilemma intuition of the model by looking at what happens if firms do not follow the optimal executive compensation structure found in Section 3.3.

In this section, I will assume that $E(p) = 100 - q_x - q_y$ and $E(c) = 1$. I will also assume that managers’ utility functions are linear, exhibiting risk neutrality. Finally, I will limit executive compensation to a specific functional form in terms of its expected value: $E(f) = jE(\pi) + k\sigma_\pi$, where $j$, $k$ are constants and $j > 0$. A positive $k$ implies that shareholders incentivise their managers to be risk taking, and a negative $k$ implies that shareholders incentivise their managers to be risk averse. Setting $k = 0$ implies that shareholders would like to keep their managers risk neutral.

We will now explore four cases. In the first case, shareholders of both firms incentivise their managers to be risk neutral, setting $k_x = k_y = 0$, leading to the classical Cournot equilibrium. In the second case, shareholders of both firms set $k$ freely, leading to a risk taking equilibrium where $k_x, k_y > 0$. In the third and fourth cases, shareholders of firms x (and y) set $k = 0$ while
shareholders of firm y (and x) set k to induce risk taking. The payoff matrix is summarized below:

<table>
<thead>
<tr>
<th></th>
<th>$k_y = 0$</th>
<th>$k_y &gt; 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_x = 0$</td>
<td>$q_x = 33, q_y = 33$</td>
<td>$q_x = 22, q_y = 55$</td>
</tr>
<tr>
<td></td>
<td>$E(\pi_x) = 1089, \ E(\pi_y) = 1089$</td>
<td>$E(\pi_x) = 484, \ E(\pi_y) = 1210$</td>
</tr>
<tr>
<td>$k_x &gt; 0$</td>
<td>$q_x = 55, q_y = 22$</td>
<td>$q_x = 39.6, q_y = 39.6$</td>
</tr>
<tr>
<td></td>
<td>$E(\pi_x) = 1210, \ E(\pi_y) = 484$</td>
<td>$E(\pi_x) = 784.08, \ E(\pi_y) = 784.08$</td>
</tr>
</tbody>
</table>

This matrix represents a prisoner’s dilemma game. Starting from a position where the managers of both firms are risk neutral (that is, $k_x = k_y = 0$), both firms have incentives to make their managers risk taking (by setting $k > 0$ in order to gain higher profits by committing to higher production. Indeed, production and profits are higher for the firm that commits to a risk taking manager and are lower for the firm that does not commit. In that sense, the firm that commits to higher production through managerial compensation becomes a Stackelberg leader, while the firm that does not commit become a Stackelberg follower. Because both firms have the incentive to switch, having risk neural managers within all firms is not a stable equilibrium.

In the prisoner’s dilemma Nash equilibrium, both players will choose to incentivise their managers with a positive level of risk taking behavior through $k > 0$. However, this means that production is higher and profits are lower in both firms.
See appendix for a derivation of this matrix.

### 3.4 Graphical Illustration

To illustrate the commitment mechanism at work in the prisoner’s dilemma, consider the best response functions of the managers of firms 1 and 2 when setting production quantities.

Starting from the initial position, it is possible for firm 1 to commit to a best response function with higher levels of production by awarding managers with options compensation as its managers become more willing to take risks and over-produce. This leads to a higher quantities of production for firm 1 and lower quantities of production for firm 2 as firm 2 accommodates firm 1’s aggressive behavior. The accommodation by firm 2 in terms of lower quantities of production leads to a strategic benefit for firm 1. Hence, through commitment, firm 1 became a Stackelberg leader.

In order to avoid being a disadvantaged Stackelberg follower, firm 2 would have to use options compensation to commit to a higher level of production
also. This leads to a new equilibrium with options compensation and higher production within both firms.

## 3.5 Consequences for social welfare

In equilibrium, managers choose more production than they would if they were risk neutral and profit maximizing, which implies lower prices for consumers. As such, risk rewarding compensation may improve social welfare.

More specifically, observe that with risk neutral managers, the Cournot game yields an equilibrium of \( q_x = q_y = \frac{a-E(c)}{3} \).

With shareholders setting managerial compensation to incentivise risk taking, the equilibrium quantities are higher:

\[
q_x = q_y = \frac{a-E(c)}{3} + \frac{a-E(c)}{15} = \frac{2(a-E(c))}{5} > \frac{a-E(c)}{3}
\]

As such, risk rewarding executive compensation leads to higher production, lower price, and improved consumer surplus. In short, it leads to a more competitive market outcome, which can yield benefits to the consumer.

However, there may exist external costs to risk taking in some industries. For example, failures for firms in the finance industry could lead to network effects that extend far beyond the failing firms’ shareholders. In fact, as a series of papers shows, increased competition in the banking sector induces firms to have more default risk, which could lead to network effects throughout the economy.\(^2\) As a result, depending on the sizes of the external costs,

\(^2\)See Keeley (1990), Suarez (1994), Matutes and Vives (2000), and Beck, Demirguc-Kunt,
the greater production due to risk rewarding compensation may not benefit consumers enough to compensate for the external costs of risk taking and firm failing. If that is the case, limiting risk rewarding compensation by law would benefit both consumers and shareholders: consumers, because of a reduction of externality costs, and shareholders, because of less competition and higher oligopoly profits.

4 Empirical Exploration

4.1 Introduction

My theory links options compensation with oligopoly strategy. In the mechanism I proposed, shareholders use options compensation to commit to higher production, which improves profits through a higher market share in an oligopoly market. This mechanism is only relevant when market power is present. Without market power, committing to higher production do not confer similar benefits because it cannot lead to an accommodating response from the other firms. Industry concentration is a proxy for market power: in general, companies in more concentrated industries have greater market power. As such, my model predicts greater options use as industry concentration increases.

To test this prediction, I linked US Census Bureau data on industry concentration to CapitalIQ data on all publicly traded firms in the world with a manufacturing North American Industry Classification System (NAICS) code. The Census data is available for 2002 and 2007. For manufacturing NAICS and Levine (2003) among others
industries, it provides data on the Herfindahl-Hirschman Index (HHI) by value of shipments as a measure of industry concentration. As such, my regression examines the relationship between the change in options awarded between 2002 and 2007 and the change in the HHI of their industries.

$$\Delta \text{ Number of Options Granted } = \beta_0 + \beta_1 \Delta \text{HHI} + \text{controls} + \varepsilon$$  \hfill (11)

Capital IQ provides data on options compensation for employees, as well as data on stock compensation, salary and benefits, stock price volatility, revenue, debt-equity ratios, return on assets, primary geographic location, and market capitalization. With these data, I ran a regression with the change (between 2002 and 2007) in options granted as the dependent variable and the change in HHI, stock compensation, salary and benefits, stock price volatility, revenue, assets, debt-equity ratios, and return on assets as independent variables. Data on stock compensation and salary and benefits are used to control for the phenomenon that higher HHI may lead to higher compensation (salary, stock awards, and options) in general. Stock price volatility is used to control for the sensitivity of the value of the options awarded to changes in volatility. Revenue, assets, and return on assets data are used to control for changes in the size and complexity of the company, which may impact options use. Data on debt-equity ratios are used to control for changes in capital structure which may affect the ability for shareholders to influence executive compensation.

The basic regression model is as follows:
\[
\Delta \text{OptionsGranted} = \beta_0 + \beta_1 \Delta HHI + \beta_2 \Delta \text{StockGranted} + \beta_3 \Delta \text{SalaryBenefits} \\
+ \beta_4 \Delta \text{Revenue} + \beta_5 \Delta \text{Assets} + \beta_6 \Delta \text{ReturnonAssets} \\
+ \beta_7 \Delta \text{StockVolatility} + \beta_8 \Delta \text{DebtEquityRatio} \\
+ \text{industry fixed effects} + \varepsilon, \text{ where } \varepsilon \text{ clusters by industry}
\]

4.2 Identification Method

To get an accurate estimate for the relationship between options compensation and market concentration, I used two econometric strategies in the regression model: 1. first differencing, and 2. fixed effects and clustered standard errors by industry. These makeup my identification strategy.

In the first differencing process, I ran my regression on the change in options granted and the change in HHI for each firm in my sample between 2002 and 2007. This controls for omitted variables within individual firms that does not change over the short term, such as branding and corporate culture. I also controlled for changes in stock granted, salary and benefits, revenue, assets, return on assets, stock volatility, and debt equity ratio of individual firms to control for the size and the complexity of the firm’s operation.

In addition, I include industry fixed effects and allow for clustered standard errors within industries. The need for estimating industry fixed effects arises because firms in each industry may have clustered changes in options compensation independent of those firms’ change in HHI. Controlling for industry fixed effects allows me to control for time varying omitted variables that may
be common to firms within each industry, such as the nature of the supply chain or changes in regulatory pressures.

Clustered standard errors emerge when options compensation within each industry are correlated (and hence the errors of the regression are correlated) in some unknown way. Firms within each industry may base their compensation on the other firms within their industries, but they each do so to a different extent depending on their corporate culture. Hence, they may have correlated options compensation beyond the fixed effects that are common to all firms in the industry. Using clustered robust standard errors allows me to account for within-industry correlations where the nature of the correlations are unknown.

4.3 Results

The summary statistics for my sample (N=1470) are presented in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆ OptionsGranted (millions)</td>
<td>0.4062</td>
<td>14.77</td>
</tr>
<tr>
<td>∆ StockGranted (millions)</td>
<td>50.19</td>
<td>285.3</td>
</tr>
<tr>
<td>∆ SalaryBenefits (millions)</td>
<td>1410</td>
<td>25980</td>
</tr>
<tr>
<td>∆ Revenue (millions)</td>
<td>6982</td>
<td>121300</td>
</tr>
<tr>
<td>∆ Assets (thousands)</td>
<td>-2213000</td>
<td>85300000</td>
</tr>
<tr>
<td>∆ ReturnonAssets</td>
<td>0.6074</td>
<td>26.14</td>
</tr>
<tr>
<td>∆ StockVolatility (percent)</td>
<td>-15.49</td>
<td>51.58</td>
</tr>
<tr>
<td>∆ DebtEquityRatio</td>
<td>-11.66</td>
<td>317.0</td>
</tr>
</tbody>
</table>

Based on the prediction that higher industry concentration is associated with higher levels of options compensation, the coefficient of interest is the one before HHI. As such, we can safely ignore multicollinearity issues within stock...
compensation and salary compensation, and within revenue, assets, and return on assets as they do not bias the coefficient and standard error estimate for the regressor HHI. However, since stock compensation is likely correlated with salary compensation, and since revenue, assets, and return on assets are likely correlated with each other, the interpretability of the coefficients on non-HHI regressors are limited.

The regression results are summarized in Table 2. Regression (1) is the basic regression as specified. I ran regression (2) with both change and percentage change for revenue, assets, return on assets, volatility, and debt equity ratio, because percentage change may be a better measure of individual company characteristics than change. I ran regression (3) with industry fixed effects on companies whose primary location is the US (instead of another country), which is a way to check for the robustness of my regression because my HHI data also comes from US sources. Doing regressions on US companies only may lead to bias due to the dominance of multinational companies in most markets, so it is useful mainly as a robustness check. Regression (4) is on companies whose primary location is the US and includes both change and percentage change data on revenue, assets, return on assets, volatility, and debt equity ratio.

From the regressions in Table 2, \( \Delta \) Options Granted is positively correlated with \( \Delta \) HHI across all four regressions, controlling for \( \Delta \) Stock Granted, \( \Delta \) Salary and Benefits, and change in company characteristics including \( \Delta \) Revenue, \( \Delta \) Assets, \( \Delta \) Return on Assets, \( \Delta \) Stock Price Volatility, and \( \Delta \) Debt.
Equity Ratio. The coefficient $\beta$ in front of $\Delta$ HHI is statistically significant (at the $p < 0.001$ level) and is stable across all four regressions.

As a further robustness check, I reproduced Table 2 with the dependent variable being the fraction of $\Delta$ Options Granted over $\Delta$ Salary and Benefits. The results are presented in Table 3. This allows me to control for changes in salary and benefits in a different way than putting it in as a linear independent variable. I found a positive and statistically significant (at $p < 0.01$) correlation between $\Delta$ Options Granted over $\Delta$ Salary Benefits and $\Delta$ HHI in all four regressions, and the $\beta$ in front of $\Delta$ HHI is again stable.
Table 2: Regression with ∆ Options Granted as the dependent variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆HHI</td>
<td>.0715*** (.000748)</td>
<td>.0930*** (.00280)</td>
<td>.0225*** (.00113)</td>
<td>.0328*** (.000494)</td>
</tr>
<tr>
<td>∆StockGranted</td>
<td>.000134*** (8.2×10^{-5})</td>
<td>- .807 (.731)</td>
<td>-1.67*** (.416)</td>
<td>-2.08*** (.630)</td>
</tr>
<tr>
<td>∆SalaryBenefits</td>
<td>2.18×10^{-6}*** (9.84×10^{-7})</td>
<td>-2.87×10^{-5} (3.95×10^{-5})</td>
<td>- .000156 (1.07×10^{-4})</td>
<td>- .000113 (1.09×10^{-4})</td>
</tr>
<tr>
<td>∆Revenue</td>
<td>1.12×10^{-6}*** (1.02×10^{-6})</td>
<td>-4.03×10^{-5} (4.15×10^{-5})</td>
<td>-4.08×10^{-6}*** (2.56×10^{-5})</td>
<td>-7.25×10^{-5}*** (1.91×10^{-5})</td>
</tr>
<tr>
<td>% ∆Revenue</td>
<td>.0254* (.0152)</td>
<td>.0922** (.0364)</td>
<td>.00142* (.000757)</td>
<td>.00111*** (.000408)</td>
</tr>
<tr>
<td>∆Assets</td>
<td>-7.25×10^{-10}*** (1.69×10^{-10})</td>
<td>6.91×10^{-6} (8.75×10^{-6})</td>
<td>4.08×10^{-6} (2.62×10^{-6})</td>
<td>3.44×10^{-6} (2.52×10^{-6})</td>
</tr>
<tr>
<td>% ∆Assets</td>
<td>.00142* (.000757)</td>
<td>.00402 (.0108)</td>
<td>.0158*** (.00556)</td>
<td>.0253*** (.00961)</td>
</tr>
<tr>
<td>∆ReturnonAssets</td>
<td>-.00220 (.00697)</td>
<td>.00402 (.0108)</td>
<td>-.0158*** (.00556)</td>
<td>-.0253*** (.00961)</td>
</tr>
<tr>
<td>% ∆ReturnonAssets</td>
<td>-1.77×10^{-8} (5.09×10^{-6})</td>
<td>- .000473 (0.00305)</td>
<td>- .000473 (0.00305)</td>
<td>- .000473 (0.00305)</td>
</tr>
<tr>
<td>∆Volatility</td>
<td>.0308*** (.0115)</td>
<td>5.52×10^{-5} (.00863)</td>
<td>- .000473 (.00305)</td>
<td>- .000473 (.00305)</td>
</tr>
<tr>
<td>% ∆Volatility</td>
<td>5.08*** (.00118)</td>
<td>.440 (.285)</td>
<td>.440 (.285)</td>
<td>.440 (.285)</td>
</tr>
<tr>
<td>∆DebtEquityRatio</td>
<td>4.98×10^{-5} (.000562)</td>
<td>7.24×10^{-5} (.00118)</td>
<td>2.79×10^{-4} (.00305)</td>
<td>3.99×10^{-4} (.00338)</td>
</tr>
<tr>
<td>% ∆DebtEquityRatio</td>
<td>-.00863* (.00508)</td>
<td>-.00130 (.00423)</td>
<td>-.00130 (.00423)</td>
<td>-.00130 (.00423)</td>
</tr>
</tbody>
</table>

N: 1470 973 743 525  
R^2: 0.1170 0.1572 0.2265 0.3164  
# Industry Clusters: 144 144 137 121  
Primary Geography: Worldwide Worldwide United States United States  

Significance levels:  * : 10%  ** : 5%  *** : 1%
Table 3: Regression with $\frac{\Delta \text{Options Granted}}{\Delta \text{Salary and Benefits}}$ as the dependent variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \text{HHI}$</td>
<td>.0176***</td>
<td>.0271***</td>
<td>.0197***</td>
<td>.0316***</td>
</tr>
<tr>
<td></td>
<td>(.00316)</td>
<td>(.000488)</td>
<td>(.000173)</td>
<td>(.00173)</td>
</tr>
<tr>
<td>$\Delta \text{StockGranted}$</td>
<td>.000172</td>
<td>-.017**</td>
<td>-.0416</td>
<td>-.0293</td>
</tr>
<tr>
<td></td>
<td>(.000187)</td>
<td>(.00807)</td>
<td>(.0351)</td>
<td>(.0912)</td>
</tr>
<tr>
<td>$\Delta \text{Revenue}$</td>
<td>$6.28 \times 10^{-8}$</td>
<td>$.29 \times 10^{-7}$</td>
<td>$-6.30 \times 10^{-7}$</td>
<td>$1.50 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>(1.74 $\times 10^{-7}$)</td>
<td>(6.47 $\times 10^{-7}$)</td>
<td>(2.40 $\times 10^{-6}$)</td>
<td>(3.39 $\times 10^{-6}$)</td>
</tr>
<tr>
<td>%$\Delta \text{Revenue}$</td>
<td>.0223</td>
<td>.0085</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.00242)</td>
<td>(.0130)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{Assets}$</td>
<td>$1.43 \times 10^{-10}$</td>
<td>$-6.14 \times 10^{-8}$</td>
<td>$2.39 \times 10^{-7}$</td>
<td>$1.37 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>(1.16 $\times 10^{-10}$)</td>
<td>(5.91 $\times 10^{-8}$)</td>
<td>(5.59 $\times 10^{-7}$)</td>
<td>(1.38 $\times 10^{-6}$)</td>
</tr>
<tr>
<td>%$\Delta \text{Assets}$</td>
<td>.000973</td>
<td>.000125</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0217)</td>
<td>(.00197)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{ReturnonAssets}$</td>
<td>-.00688</td>
<td>.000799</td>
<td>-.000394</td>
<td>-.00408</td>
</tr>
<tr>
<td></td>
<td>(.00956)</td>
<td>(.00619)</td>
<td>(.00743)</td>
<td>(.00607)</td>
</tr>
<tr>
<td>%$\Delta \text{ReturnonAssets}$</td>
<td>.00973</td>
<td>.0322</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0217)</td>
<td>(.0779)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{Volatility}$</td>
<td>-.00356</td>
<td>-.00233</td>
<td>-.00203</td>
<td>-.00300</td>
</tr>
<tr>
<td></td>
<td>(.00454)</td>
<td>(.00165)</td>
<td>(.00294)</td>
<td>(.00512)</td>
</tr>
<tr>
<td>%$\Delta \text{Volatility}$</td>
<td>.0650</td>
<td>.400</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.277)</td>
<td>(.526)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{DebtEquityRatio}$</td>
<td>.00798</td>
<td>$3.01 \times 10^{-5}$</td>
<td>$2.22 \times 10^{-7}$</td>
<td>$-3.65 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>(.00926)</td>
<td>(1.78 $\times 10^{-4}$)</td>
<td>(1.13 $\times 10^{-4}$)</td>
<td>(.000165)</td>
</tr>
<tr>
<td>%$\Delta \text{DebtEquityRatio}$</td>
<td>-.00290</td>
<td>.000726</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.00252)</td>
<td>(.00810)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| N    | 694  | 421  | 310  | 201  |
| R$^2$ | 0.3237 | 0.8766 | 0.2080 | 0.3849 |
| # Industry Clusters | 136 | 114 | 104 | 83 |
| Primary Geography  | Worldwide | Worldwide | United States | United States |

Significance levels:  * : 10%  ** : 5%  *** : 1%
The regression results suggest that there is indeed a positive relationship between market concentration (proxying for market power) and the amount of options that are granted to employees, consistent with the prediction of my model.

5 Comment on innovation

Managerial risk taking is commonly associated with innovation. Options compensation leads to greater managerial risk taking, and as a result it leads to greater incentives to invest in innovation. While it is difficult to model innovation due to the large number of competing models available, the theory of options compensation as a commitment mechanism could be expanded to comment on product innovation. In this section I will show that options compensation can lead to a strategic advantage using a particular model for product innovation: the Loury (1979) model.

Under the Loury (1979) model, firms compete for a reward from product innovation $V$ that is available only to the first firm that introduces the product. Investment in innovation $i$ purchases a random variable $\tau(i)$ that represents the uncertain time $t$ at which the R&D project will be completed. $\tau(i)$ is expected to have a distribution $P(\tau(i) \leq t) = 1 - e^{-h(i)t}$, such that $E(\tau(i)) = h(i)^{-1}$. The discount rate is assumed to be $r$.

With the above setup for two symmetric firms $x$ and $y$, Loury (1979) showed that for firm $x$, the present discounted profits is given by:
Using the above incentive function, Loury concluded that, at any equilibrium,
\( \frac{\partial i_x}{\partial y} < 0 \). Hence, greater investment in innovation by one firm leads to less
investment in innovation by another firm.

Given this relationship, a commitment to over-investment in innovation by one
firm would reduce the level of investment in innovation by the other firm. Such
a reduction would be beneficial to the firm that committed to over-investment,
because it increases the chances of that firm being first to market with the
product. It is therefore possible that options compensation, as a commitment
to over-investment in product innovation, could confer a strategic advantage.

6 Conclusion

Stock options compensation has traditionally been explained via three mech-
anisms: the incentive alignment mechanism, the tax benefits mechanism, and
employee sorting. I propose an alternative mechanism. My mechanism makes
use of the commitment opportunity that exists in the principal agent relation-
ship between shareholders and managers. By incentivising the managers to be
risk-taking through options compensation, shareholders can commit their firms
to an aggressive management style, which might lead to a strategic advantage
by forcing accommodation from the other firms both in terms of production
quantities and in terms of product innovation.
In addition, my model makes two predictions that fit real world observations. First, my model predicts that, in equilibrium, shareholders should award options compensation such that the managers are risk-taking rather than risk-neutral. Such a prediction fits observations by Dong, Wang, and Xie (2010). Second, my model predicts that the amount of options awarded to managers should positively depend on the market power of the firm. Using industry concentration as a proxy for market power, I tested this prediction using a regression, and found that indeed a change in the Herfindahl Index (HHI) of manufacturing companies is positively correlated with a change in options awarded (at the p<0.001 level).

Options compensation awards can affect the perception of firms in terms of their aggressiveness. Companies that use options compensation heavily, such as Goldman Sachs and Google, are perceived as aggressive and innovative. Such a perception may well benefit them by stifling competition and innovation from firms that do not incentivise their employees to be as aggressive and innovative. The idea that options compensation can be used as a commitment mechanism to risk taking deserve further attention from the field.
References


Greenwald, B. C., & Stiglitz, J. E. (1990). Asymmetric information and the


7 Appendix

7.1 Detailed derivation for the basic model

Starting from the incentive function in Lemma 3.1, managers’ best response functions can be expressed as:

\[
\frac{\delta E(\pi)}{\delta q} + b(q) = 0, \text{ where } b(q) = \frac{\partial U^*}{\partial q} \frac{\partial \sigma_c}{\partial E(\pi)}
\]

Shareholders can set \( b \) through managerial compensation structures as long as they know the shape of their managers’ utility curve and the relationship between expected profits and uncertainty through the existence property of ODEs.\(^3\)

The best response function for the managers of firm \( x \) can then be obtained by taking the first order condition:

\[
(a - q_x - q_y) - q_x - E(c) + b_x = 0
\]

\[
a - q_y - 2q_x - E(c) + b_x = 0
\]

\[
q_x = \frac{1}{2}(a - q_y - E(c) + b_x)
\]

Same goes for player \( y \)

\[
q_y = \frac{1}{2}(a - q_x - E(c) + b_y)
\]

\(^3\)Even if they do not, they can still nudge \( b \) in the direction of their choice through what they expect to be their managers’ utility functions and what they expect to be the relationship between profits and uncertainty. The substance of this argument would not be changed.
Solving the equations simultaneously:

\[ q_x = \frac{1}{2}[a - \frac{1}{2}(a - q_x - E(c) + b_y) - E(c) + b_x] \]

\[ q_x = \frac{1}{3}[a - E(c) + 2b_x - b_y] \]

\[ q_y = \frac{1}{3}[a - E(c) + 2b_y - b_x] \]

Looking at the shareholders’ incentive function and substituting in \( q_x \) and \( q_y \):

\[ \max_{b_x} E(\pi) = \frac{1}{3}E((a + 2E(c) - b_x - b_y)(a - E(c) + 2b_x - b_y)) - E(\frac{E(c)}{3})(a - E(c) + 2b_x - b_y)) \]

Taking the first order condition to find the functional form for \( b \), we have, for the first order condition:

\[ \frac{d\pi}{db_x} = -\frac{1}{9}(a - E(c) + 2b_x - b_y) + \frac{2}{9}(a + 2E(c) - b_x - b_y) - \frac{2}{3}E(c) = 0 \]

Similarly, for firm \( y \), we have the first order condition:

\[ \frac{d\pi}{db_y} = -\frac{1}{9}(a - E(c) + 2b_y - b_x) + \frac{2}{9}(a + 2E(c) - b_y - b_x) - \frac{2}{3}E(c) = 0 \]

Solving out the equation for firm \( x \):

\[ (-\frac{1}{9})(a - E(c) + 2b_x - b_y) + (\frac{2}{9})(a + 2E(c) - b_x - b_y) - \frac{2}{3}E(c) = 0 \]

\[ -\frac{1}{9}a + \frac{1}{9}E(c) - \frac{2}{9}b_x + \frac{1}{9}b_y + \frac{2}{9}a + \frac{4}{9}E(c) - \frac{2}{9}b_x - \frac{2}{9}b_y - \frac{2}{3}E(c) = 0 \]

\[ \frac{1}{9}(a - E(c) - 4b_x - b_y) = 0 \]
\[ \frac{4}{9} b_x = \frac{1}{9} (a - E(c) - b_y) \]
\[ b_x = \frac{1}{4} (a - E(c) - b_y) \]

Similarly.

\[ b_y = \frac{1}{4} (a - E(c) - b_x) \]

Substituting,

\[ b_x = \frac{1}{4} (a - E(c)) - \frac{1}{16} [a - E(c) - b_x] \]
\[ b_x = \frac{3}{16} (a - E(c)) + \frac{1}{16} b_x \]
\[ \frac{15}{16} b_x = \frac{3}{16} (a - E(c)) \]
\[ b_x = \frac{a - E(c)}{5} > 0 \]

And by symmetry,

\[ b_x = b_y = \frac{a - E(c)}{5} > 0 \]

As a result, all shareholders should structure executive compensation so as to induce risk taking behavior from their managers.

In the imperfect information case, we start from the following incentive function for shareholders:

\[ \max_{b_x} E(\pi) = \frac{1}{9} E((a + 2E_m(c) - b_x - b_y)(a - E_m(c) + 2b_x - b_y)) - \frac{1}{3} E(E_m(c)(a-} \]
Expanding yields:

\[
\max_{b_x} E(\pi) = \frac{1}{9}(a^2 - aE(E_m(c)) + 2ab_x - ab_y + 2aE(E_m(c)) - 2E(E_m(c))^2) + \\
4E(E_m(c))b_x - 2E(E_m(c))b_y - ab_x + E(E_m(c))b_x - 2b_x^2 + b_xb_y + ab_y - E(E_m(c))b_y - \\
2b_xb_y + 2b_y^2 - \frac{1}{3}(aE(E_m(c)) - E(E_m(c))^2) + 2b_xE(E_m(c)) - b_yE(E_m(c))
\]

Note that the \(E(E_m(c)^2)\) terms goes away if we take the first order condition with respect to \(b_x\). The rest of the terms are the same as the perfect information case, with \(E(c)\) replaced by \(E(E_m(c))\). Hence, the first order condition is:

\[
d\pi/db_x = \frac{1}{9}(a - E(E_m(c)) + 2b_x - b_y) + \frac{2}{9}(a + 2E(E_m(c)) - b_x - b_y) - \\
\frac{2}{3}E(E_m(c)) = 0
\]

Which leads to the standard equilibrium, with \(E(c)\) replaced by \(E(E_m(c))\).

\[
b_x = b_y = \frac{a - E(E_m(c))}{5} > 0
\]

### 7.2 Numerical Example

First, suppose the managers are risk neutral, such that \(b = 0\). The best response functions can then be written as:

\[
(a - q_x - q_y) - q_x - E(c) = 0
\]

Or: \(a - q_y - 2q_x - E(c) = 0\)
Similarly, for firm y, we also have:

\[ a - q_x - 2q_y - E(c) = 0 \]

Solving the equations simultaneously yields the traditional Cournot equilibrium:

\[ q_x = q_y = \frac{a - E(c)}{3} = 33 \]

Substituting back into the price function yields:

\[ p = a - \frac{2(a - E(c))}{3} = \frac{a + 2E(c)}{3} \]

Which means that:

\[ \pi_x = \pi_y = (\frac{a + 2E(c)}{3} - E(c)) \frac{a - E(c)}{3} = \frac{a^2 + aE(c) - 2E(c)^2 - 3aE(c) + 3E(c)^2}{9} = \frac{a^2 - 2aE(c) + E(c)^2}{9} = \frac{(a - E(c))^2}{9} = 1089 \]

In the second case, with both managers able to set \( k \) freely, we see the following. With this setup, \( E(U(f)) = E(f) = jE(\pi) + k\sigma_\pi \), and managers who maximize their expected utility when setting quantity in a Cournot game have the following first order condition:

\[ j \frac{\partial E(\pi)}{\partial q} + k \frac{\partial \sigma_\pi}{\partial q} = 0 \]

which transforms to:

\[ \frac{\partial E(\pi)}{\partial q} + \frac{k}{j} \sigma_\epsilon = 0. \]

Solving out the best response functions yields:

\[ q_x = \frac{1}{2}(a - q_y - E(c) + \frac{k_x}{j_x} \sigma_\epsilon), \text{ and } q_y = \frac{1}{2}(a - q_x - E(c) + \frac{k_y}{j_y} \sigma_\epsilon) \]
Which means that the Cournot Nash equilibrium is:

\[ q_x = \frac{1}{3}[a - E(c) + 2k_x \sigma_\epsilon - \frac{k_x}{j_x} \sigma_\epsilon] \]

\[ q_y = \frac{1}{3}[a - E(c) + 2k_y \sigma_\epsilon - \frac{k_y}{j_y} \sigma_\epsilon] \]

Shareholders want to maximize expected profits:

\[ \max_k E(\pi) = \frac{E(p) - E(c)}{q} \]

For shareholders of firm x:

\[ \max_{k_x} E(\pi) = (\frac{1}{3}[a + 2E(c) - \frac{k_x}{j_x} \sigma_\epsilon - \frac{k_y}{j_y} \sigma_\epsilon])(\frac{1}{3}[a - E(c) + 2 \frac{k_x}{j_x} \sigma_\epsilon - \frac{k_y}{j_y} \sigma_\epsilon]) - E(c)(\frac{1}{3}[a - E(c) + 2 \frac{k_x}{j_x} \sigma_\epsilon - \frac{k_y}{j_y} \sigma_\epsilon]) \]

And by symmetry for shareholders of firm y. This is equivalent to the form found in the general example, only with \( \frac{k_x}{j_x} \sigma_\epsilon \) replacing \( b(q_x) \). As such, shareholders will set \( \frac{k_x}{j_x} \sigma_\epsilon = \frac{a - E(c)}{5} \), or \( k_x = \frac{j_x(a - E(c))\sigma_\epsilon}{5} = \frac{99j_x\sigma_\epsilon}{5} \).

Solving out the quantity by substituting \( \frac{k_x}{j_x} \sigma_\epsilon \) and \( \frac{k_y}{j_y} \sigma_\epsilon \) into the Cournot equilibrium yields:

\[ q_x = q_y = \frac{a - E(c)}{3} + \frac{a - E(c)}{15} = \frac{2(a - E(c))}{5} = \frac{198}{5} = 39.6 \]

Hence, \( p = 100 - q_x - q_y = 20.8 \), and \( \pi_x = \pi_y = (20.8 - 1)39.6 = 784.08 \).

In the third and fourth case, one of the firms choose risk rewarding compensation while the other choose to keep the manager risk neutral. Let us first look at the case when shareholders of firm x choose risk rewarding compensation.
Managers of firm $x$ have the first order condition:

$$j_x \frac{\partial E(\pi_x)}{\partial q_x} + k_x \frac{\partial \sigma_x}{\partial q_x} = 0,$$

which transforms to:

$$\frac{\partial E(\pi_x)}{\partial q_x} + \frac{k_x}{j_x} \sigma_x = 0.$$

Solving out the best response functions yields:

$$q_x = \frac{1}{2} (a - q_y - E(c) + \frac{k_x}{j_x} \sigma_x), \text{ and } q_y = \frac{1}{2} (a - q_x - E(c))$$

Which means that the Cournot Nash equilibrium is:

$$q_x = \frac{1}{3} [a - E(c) + 2 \frac{k_x}{j_x} \sigma_x], \text{ and } q_y = \frac{1}{3} [a - E(c) - \frac{k_x}{j_x} \sigma_x]$$

Shareholders want to maximize expected profits:

$$\max_k E(\pi) = \frac{E(p) - E(c)}{q}$$

Shareholders of firm $y$ cannot change $k$. For shareholders of firm $x$:

$$\max_{k_x} E(\pi) = (\frac{1}{3} [a + 2E(c) - \frac{k_x}{j_x} \sigma_x]) (\frac{1}{3} [a - E(c) + 2 \frac{k_x}{j_x} \sigma_x] - \frac{E(c)}{3} [a - E(c) + 2 \frac{k_x}{j_x} \sigma_x])$$

Taking the first order condition yields:

$$\frac{d\pi}{dk_x} = (-\frac{1}{3})(a - E(c) + \frac{k_x}{j_x} \sigma_x) + (\frac{2}{3})(a + 2E(c) - \frac{k_x}{j_x} \sigma_x) - \frac{2}{3} E(c) = 0$$

Simplifying:

$$\frac{d\pi}{dk_x} = (\frac{1}{3})(a + 5E(c) - 3 \frac{k_x}{j_x} \sigma_x - 6E(c)) = 0,$$

so $a - E(c) - 3 \frac{k_x}{j_x} \sigma_x = 0$, and

$$\frac{k_x}{j_x} \sigma_x = \frac{a - E(c)}{3}$$
As such, shareholders will set $k_x \sigma_x = \frac{a - E(c)}{3}$, or $k_x = \frac{j_x(a - E(c)) \sigma_x}{3} = \frac{99j_x \sigma_x}{3}$.

Solving out the quantity by substituting $k_x \sigma_x$ into the Cournot equilibrium yields:

\[ q_x = \frac{1}{3} [a - E(c) + 2k_x \sigma_x] = \frac{1}{3} [a - E(c) + 2 \frac{a - E(c)}{3}] = \frac{a - E(c)}{3} + \frac{2(a - E(c))}{9} = \frac{5(a - E(c))}{9} = 55 \]

and

\[ q_y = \frac{1}{3} [a - E(c) - k_x \sigma_x] = \frac{1}{3} [a - E(c) - \frac{a - E(c)}{3}] = \frac{a - E(c)}{3} - \frac{a - E(c)}{9} = \frac{2(a - E(c))}{9} = 22. \]

Hence, $p = 100 - q_x - q_y = 23$, and $\pi_x = (23 - 1)55 = 1210$, while $\pi_y = (23 - 1)22 = 484$.

By symmetry, in the reverse situation where shareholders of firm x cannot incentivise managers to be risk taking, the reverse is true.

### 7.3 Welfare implications

First, suppose the managers are risk neutral, such that $b = 0$. The best response functions can then be written as:

\[ (a - q_x - q_y) - q_x - E(c) = 0 \]

Or:

\[ a - q_y - 2q_x - E(c) = 0 \]

Similarly, for firm y, we also have:

\[ a - q_x - 2q_y - E(c) = 0 \]

Solving the equations simultaneously yields the traditional Cournot equilib-
rium:

\[ q_x = q_y = \frac{a - E(c)}{3} \]

Solving out the quantity from Appendix 7.1 by substituting \( b_x \) and \( b_y \) into the Cournot equilibrium yields:

\[ q_x = q_y = \frac{a - E(c)}{3} + \frac{a - E(c)}{15} = \frac{2(a - E(c))}{5} > \frac{a - E(c)}{3} \]
## 7.4 Regression without fixed effects

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\Delta$ Options Granted</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$HHI</td>
<td>.00173** (.000801)</td>
</tr>
<tr>
<td>$\Delta$StockGranted</td>
<td>-.805 (.674)</td>
</tr>
<tr>
<td>$\Delta$SalaryBenefits</td>
<td>$-4.95 \times 10^{-7}$ $(3.58 \times 10^{-5})$</td>
</tr>
<tr>
<td>$\Delta$Revenue</td>
<td>$-3.26 \times 10^{-5}$ $(3.55 \times 10^{-5})$</td>
</tr>
<tr>
<td>$%\Delta$Revenue</td>
<td>.0269** (.0129)</td>
</tr>
<tr>
<td>$\Delta$Assets</td>
<td>$4.76 \times 10^{-7}$ $(1.69 \times 10^{-10})$</td>
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<tr>
<td>$%\Delta$Assets</td>
<td>.000381 (.000757)</td>
</tr>
<tr>
<td>$\Delta$ReturnonAssets</td>
<td>.00244 (.00244)</td>
</tr>
<tr>
<td>$%\Delta$ReturnonAssets</td>
<td>$5.41 \times 10^{-7*}$ $(5.79 \times 10^{-6})$</td>
</tr>
<tr>
<td>$\Delta$Volatility</td>
<td>-.0130 (.0115)</td>
</tr>
<tr>
<td>$%\Delta$Volatility</td>
<td>4.53*** (1.38)</td>
</tr>
<tr>
<td>$\Delta$DebtEquityRatio</td>
<td>$-8.45 \times 10^{-6}$ (.000738)</td>
</tr>
<tr>
<td>$%\Delta$DebtEquityRatio</td>
<td>-.00533* (.00288)</td>
</tr>
</tbody>
</table>

| N | 973 |
| R$^2$ | 0.1572 |
| # Industry Clusters | 144 |
| Primary Geography | Worldwide |

Significance levels: * : 10%  ** : 5%  *** : 1%
Corrections

When originally submitted, this honors thesis contained some errors which have been corrected in the current version. Here is a list of the errors that were corrected.

**Corrections:**

**p. 7.** “Executive compensation” was changed to “CEO compensation in S&P500 firms”.

**p. 9.** “discontinuous” was changed to “discontinuous”

**p. 14.**

\[ q_x = \frac{1}{2}(a - q_y - E(c) + b_x) \]
\[ q_y = \frac{1}{2}(a - q_x - E(c) + b_y) \]

Was changed to:

\[ q_x = \frac{1}{2}(a - q_y - E(c) + b_x(q_x)) \]
\[ q_y = \frac{1}{2}(a - q_x - E(c) + b_y(q_y)) \]

**p. 15.** \( \frac{2c}{3} \) was changed to \( \frac{2E(c)}{3} \).

**p. 19.** \( \pi_x, \pi_y \) was changed to \( E(\pi_x), E(\pi_y) \).