Search for Optimal CEO Compensation: Theory and Empirical Evidence*

Melanie Cao
Schulich School of Business
York University
4700 Keele St., Toronto, ON M3J 1P3
Email: mcao@schulich.yorku.ca

Rong Wang
Lee Kong Chian School of Business
Singapore Management University
Singapore 178899
Email: rongwang@smu.edu.sg

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Abstract

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Abstract

There are two stylized facts that standard theories on executive compensation are incapable of explaining: 1) there is no definitive empirical relation between pay-to-performance-sensitivity and a firm's total risk; 2) in recent decades, executive compensation and firm size have increased steadily. We propose a dynamic equilibrium agency model to resolve these standing issues. Our theoretical and empirical analyses show that the indeterminate relation between pay-to-performance-sensitivity and total risk is due to the diametrically opposing effects of firm-specific risk and systematic risk on pay-to-performance-sensitivity, and the increases in executive compensation and firm size are mainly driven by a steadily growing economy.

Keywords: principal-agent problem, CEOs' job search, endogenous reservation utility, dynamic equilibrium, optimal compensation policy.

JEL classifications: J33, G13.

1. Introduction

Two facts about the compensations to firms' executive officers deserve particular attention. The first is the relationship between a firm's risk and the executive's pay-to-performance sensitivity, i.e., the part of the executive's pay that is contingent on the firm's performance. Standard principal-agent models (e.g., Holmstrom, 1982) predict that the pay-to-performance sensitivity decreases with the firm's total risk. This relationship is ambiguous in the data. For example, Core and Guay (1999) and Oyer and Shaefer (2005) find a positive relationship while Aggarwal and Samwick (1999a) document a negative relationship.[1]

The second fact is the steadily increasing executive compensation along with the increase in firm size in the past three decades. According to Hall and Murphy (2002, 2003), the base salaries and bonuses of Forbes 800 CEOs, excluding executive stock options, has increased from an average of $700,000 to more than $2.2 million, measured in 2000 constant dollars. Gabaix and Landier (2008) indicate that the average CEO total compensation and firm size have increased six times between 1980 and 2003. This sharp increase in executive compensation has created a strong public sentiment that CEOs are overly compensated for firms' performance that is largely due to economic booms.

In this paper, we develop an equilibrium search model with optimal incentive contracts to explain the above facts and empirically test the model. The model focuses on the intuitive mechanism that the competition among firms for CEOs affects optimal incentive contracts in the equilibrium by affecting a CEO's incentive to participate in a firm. If a CEO is not satisfied with his current compensation, he will quit the firm and search for another firm. In more detail, our model is as follows. There are many firms and many CEOs in the economy. In each period, a firm offers a compensation package, which consists of salary plus a profit-sharing payment. The CEO decides whether to accept the offer, upon seeing the realization of a match-specific risk that is only observable to the CEO. The match-specific risk can be understood as the match

[1] Prendergast (2002) summarizes additional conflicting empirical evidence on this relationship. Please consult other references therein. As argued by Prendergast (2002), the existing literature fails to account for an important effect of uncertainty on incentives through the allocation of responsibility to employees.

quality between the CEO and the firm and it is the firm's specific risk. The CEO quits only if his reservation utility (i.e., the value of search) exceeds the utility that he can derive from the current compensation scheme. After the CEO's acceptance decision, a publicly observable economy-wide shock occurs. If the CEO accepts the contract, he chooses the effort level which is not observable by others. The firm's output depends on the match-specific risk, the aggregate productivity shock, and the CEO's effort. The incentive contract can be contingent on the firm's output and the aggregate productivity shock, but not directly on the unobservable match-specific risk and the CEO's effort.

Since only the CEO observes the match-specific risk, an optimal contract cannot induce the CEO to always participate. If the CEO rejects a contract, he will get a chance to be matched with another firm next period. Thus, the value of search by a CEO is determined by other firms' contracts. Although this reservation utility of a CEO is taken as given by each firm, it is endogenous in the market equilibrium and depends on aggregate economic conditions and other firms' contracts. Because of this link, a market equilibrium must determine all firms' contracts and CEOs' reservation utilities simultaneously. We focus on a stationary and symmetric equilibrium in which all firms offer the same type of contracts. The equilibrium incentive contract exhibits new and important features that can explain the two facts discussed earlier.

First, the equilibrium pay-to-performance sensitivity depends positively on a firm's specific risk, and negatively on the systematic risk. To explain the positive relationship between the pay-to-performance sensitivity and the firm's specific risk, it is important to note that a CEO will only work for the firm if the realized match quality is higher than a cut-off point. Therefore, the profit is analogous to a call option written on the match quality and hence it increases with the volatility of the match risk. The CEO prefers a positive dependence of the pay-to-performance sensitivity on the match-risk volatility since he can receive a higher profit-sharing payment. In contrast to the match-specific risk, a firm's systematic risk affects the pay-to-performance sensitivity negatively. Note that the systematic risk is common to all firms. Given a fixed total compensation, to reduce the downside effect of a large systematic risk, the CEO prefers a contract with a relatively high salary and a relatively low profit-sharing ratio. Because of this distinction between the effects of systematic risks versus match-specific risks, our theory can reconcile the mixed evidence on the empirical relationship between the pay-to-performance sensitivity and a firm's risk.

Second, the equilibrium compensation and firm size increase with the aggregate productivity, and the relative pace of growth in compensation and firm size depends positively on the firm's specific risk and negatively on its systematic risk. The intuition is that the improved aggregate conditions make a firm more profitable, and so the opportunity cost of leaving a CEO position vacant is higher than in normal conditions. To retain the existing CEO or to attract a new CEO, the firm needs to increase the compensation. But the increase in compensation is less than the increase in the firm's profit; therefore, a growing economy will induce both the compensation and firm size to increase. As discussed earlier, a lower systematic risk or a higher firm specific risk leads to a higher pay-to-performance sensitivity, which, in turn, leads to a lower firm value. Therefore, in a growing economy with a lower systematic risk or a higher specific risk, the total compensation, including salary plus the profit-sharing payment, will grow faster than the firm value. These equilibrium results can be used to explain the second stylized fact. Therefore, our model suggests that the recent increase in executive pay and firm size are an efficient equilibrium outcome in response to the growing economy and the increase in the competition for CEOs.

We use these theoretical predictions to guide our empirical tests. Specifically, we test the effects of the aggregate productivity, a firm's systematic risk and specific risk on the compensation contract and firm size. Our proxies for the aggregate economy are the gross domestic product (GDP) and the commercial paper spread. Using the executive compensation data for the period from 1992 to 2005, we show that (1) the pay-to-performance sensitivity negatively depends on the aggregate economy and the firm's systematic risk, and positively on the firm's specific risk; (2) executive compensation and firm size increase with the aggregate economy and the firm's systematic risk, and decrease with the firm's specific risk; the overall effect of these three variables accounts for 88% of the increase in total compensation and almost fully of the increase in firm size; (3) we empirically uncover that the increase in compensation outpaced the increase in firm size from 1992 to 2005 and show that the outpaced growth in compensation is largely due to the increase in the firm's specific risk.

Our paper contributes to the principal-agent literature in three dimensions. First, we explicitly model CEOs' quitting decisions and study the incentive contracts that induce both the optimal effort and optimal retention. Second, we analyze the optimal compensation contract in a dynamic equilibrium setting in which firms interact in the CEO job market. Third, we endogenously determine the effects of the aggregate productivity on a CEO's reservation utility. The dynamic equilibrium structure contrasts a typical principal-agent model that analyzes only the optimal contract for a single firm in a static setting. In addition to these three contributions, this paper also contributes to the labor search literature (e.g., Mortensen and Pissarides, 1994) by integrating incentive contracts into a search model.

This paper shares with Oyer (2004) in recognizing the importance of the fact that an agent may choose not to participate in a contract in certain states of the world. However, our paper differs from Oyer (2004) in two aspects. First, we focus on CEO compensation and study the joint effects of the incentive and participation constraints on the equilibrium incentive contract. Oyer (2004) studies the broad-based stock option plans for lower-ranked employees. Because of the limited incentive effects offered by these contracts, Oyer (2004) abstracts from the effort-inducing mechanism. Second, the reservation utility is endogenous in our model, but exogenous in Oyer (2004). The endogenous reservation utility enables us to analyze how the performance of the macro-economy affects the executive compensation and firm size.

This paper is related to Murphy and Zabojnik (2004) and Gabaix and Landier (2008) in the attempt to explain the steady increase in the executive compensation. Murphy and Zabojnik (2004) argue that as the general managerial skills become relatively more important for the CEO jobs, firms are more likely to hire CEOs from outside, hence the pay has to increase. Gabaix and Landier (2008) use the extreme-value theory to show that a CEO's pay depends on the firm size and the aggregate firm size.[2] Both studies provide plausible explanations for the increase in executive pay. However, both studies are silent on the relationship between the firm's risk and

[2]Edmans, Gabaix and Landier (2008) extend the effort-inducing mechanism into Gabaix and Landier's (2008) talent assignment model. They intend to explain the negative relationship between the CEO's effective equity stake and firm size. Also, they show that the dollar change in wealth for a percentage change in firm value, scaled by annual pay, is independent of firm size.

the pay-to-performance sensitivity since they abstract from the effort-inducing mechanism.

A few other related studies focus on the relationship between a firm's risk and the pay-to-performance sensitivity. For example, Prendergast (2002) and Guo and Ou-Yang (2005) provide alternative explanations for the observed positive relation between a firm's risk and pay-to-performance sensitivity. Jin (2002) studies a CEO's portfolio diversification effect on the pay-to-performance sensitivity. Shi (2005) differentiates respondable and non-respondable risk.

The rest of the paper is organized as follows. Section 2 describes the model and analyzes an individual firm's optimal compensation while taking other firms' contracts as given. Section 3 characterizes the market equilibrium, determines the optimal compensation polices and the equilibrium firm size. Section 4 presents the empirical analysis, and Section 5 concludes the paper. Proofs and tables are relegated to the Appendix.

2. Model environment and individual firms' compensation contracts

2.1. Model environment

Consider a discrete-time economy with many firms and many CEOs who are infinitely-lived with a discount factor $\beta \in (0, 1)$. In each period, a CEO is either employed and producing or unemployed and searching, while a firm is either filled with a CEO or has a vacant CEO position. Each CEO is assumed to be effort averse. The utility function is characterized by

$$U(W, e) = W - \frac{c}{2}e^2, \tag{2.1}$$

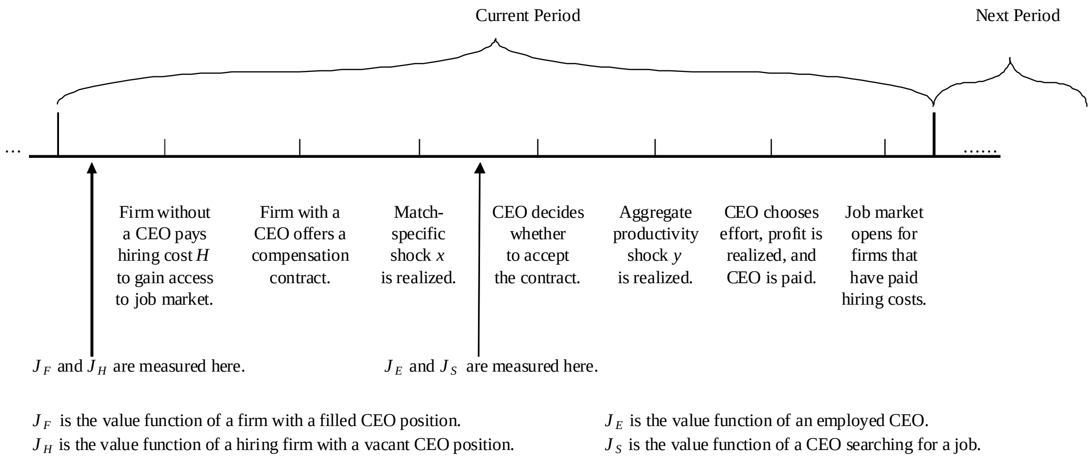
where W is the CEO's total compensation, e is the CEO's effort, and $c > 0$ is a constant. A firm is assumed to be risk-neutral. For a firm with a CEO, its profit depends on the CEO's effort e, the match-specific risk x to be described in detail later, and the aggregate productivity shock y. For tractability, we assume that a firm's profit is given by

$$\pi \equiv \pi(y, e, x) = ye\sqrt{x}. \tag{2.2}$$

Note that profits are correlated among firms through the aggregate productivity shock.

Each firm chooses a contract to maximize its expected residual value, i.e., the value to the firm after paying the CEO. The firm takes other firms' incentive contracts and aggregate conditions of the economy as given. As is standard in the contract literature, we assume that profits and the aggregate productivity of the economy are verifiable and contractable. In contrast, the effort level and the match-specific risks are observable only to the CEO and not verifiable, and so contracts cannot be made directly contingent on $(e,\, x)$. To facilitate the description of the market and the decisions, we depict the timing of events in each period in Fig. 1.

Fig. 1: Timing of Events in Each Period



At the beginning of each period, the firms with vacant CEO positions and searching CEOs enter the search market. To gain access to this market, a firm must pay a hiring cost, $H > 0$. Search is modeled as in Mortensen and Pissarides (1994). Denote v and u as, respectively, the numbers of vacancies and searching CEOs who enter the market at the beginning of the period. The aggregate number of matches in the period is

$$m(v,u) = A\frac{uv}{u+v}, \tag{2.3}$$

where the positive constant A measures the matching efficiency in the economy. Denote the tightness of the job market as $\theta = u/v$. A searching CEO gets a match with probability $\lambda \equiv m\,(v,u)\,/u$, and a vacant position is matched with a CEO with probability $q \equiv m(v,u)/v$. It is easy to verify that $\lambda = A/\,(1+\theta)$ and $q = A\theta/\,(1+\theta)$. These expressions reflect the intuitive property that when there are more searching CEOs per vacancy, the matching probability falls for a searching CEO and increases for a vacancy. Moreover, the two matching probabilities obey the relationship, $q = A - \lambda$, which will simplify the analysis.[3] Each individual CEO or firm takes

[3]The specific matching function has constant returns to scale and is strictly concave in the two arguments, u

the tightness and the matching probabilities as given, because these characteristics depend only on the aggregate numbers of vacancies and searching CEOs. Moreover, the matching outcomes are realized at the end of the period.

For a firm with a filled CEO position, it offers an incentive contract at the beginning of the period. Then, a match-specific risk, x, occurs to the particular firm-CEO pair, which is only observable to the CEO. This risk can be understood as the match quality between the CEO and the firm in this period, rather than a permanent characteristic of the firm or the CEO.[4] After observing the matching quality, the CEO decides whether to accept the contract. We will show that the CEO will choose a cut-off level of the match quality, x_d, and will accept the contract if and only if $x \geq x_d$. After the CEO makes the choice, an aggregate productivity shock, y, occurs. Observing the aggregate shock, the CEO who accepted the contract chooses the effort level to carry out production. He is then paid at the end of the period according to the incentive contract. If the CEO rejects the contract (i.e., when $x < x_d$), he must quit, in which case he derives utility B from all benefits and leisure in the current period and will search for a job next period.

Note that when a CEO quits, the CEO and the corresponding firm cannot immediately enter the search market in the same period; instead, they must wait for the next period to enter the search market. This assumption is intended to capture the idea that search is time-consuming. That is, since it takes an entire period for the matching process to be completed, firms and CEOs who want to be matched must enter the matching process at the beginning of the period.[5]

To simplify the analysis, we assume that the match-specific risk and the aggregate productivity shock are i.i.d. across time, and that the two risks are independent of each other. To simplify further, we assume that the match-specific risk is uniformly distributed in the interval $[\underline{x}, \bar{x}]$, where $\bar{x} > \underline{x} > 0$. This implies that the means of x is $\mu_x = (\underline{x} + \bar{x})/2$ and the standard deviation

and v. The intuition for the main results of our paper should hold for more general matching functions, but the algebra becomes more complicated.

[4]A high match quality means that a CEO's talent, experience, education, and personal objective match well in the particular period with the firm's size, the nature of the business, the strategic direction and the organizational culture, and so on. A CEO who is well matched with a firm at one point of time may not be well matched with the firm at another time if the CEO's feature or the firm's situation has changed.

[5]In continuous time, matching and quitting are Poisson processes, and the probability with which an individual agent experiences both matching and quitting at the same instant is zero. We choose not to use the continuous-time framework because it complicates other parts of the analysis.

is $\sigma_x = (\bar{x} - \underline{x})/(2\sqrt{3})$. Denote the cumulative distribution function of x as $F_1(x)$ and the cumulative distribution function of y as $F_2(y)$. Note that y need not be uniformly distributed.

In this environment, we first analyze a single firm's optimal incentive contract while taking other firms' contracts as given. Later, we will analyze the equilibrium in the market.

2.2. An individual firm's optimal incentive contract

Consider the optimal contract offer by an arbitrary firm, i. We consider a standard linear contract consisting of a fixed salary and a profit-sharing payment. Denote π_i as firm i's profit, a as the fixed salary, and b as the profit-sharing ratio. Denote firm i's contract as $D \equiv (a, b)$. Firm i's total compensation to the CEO is $W_i = W(D, \pi_i)$ where

$$W_i(D, \pi_i) = a + b\pi_i.$$

Taking other firms' contracts as given, firm i chooses a contract to maximize its expected residual profit, i.e., the profit after paying its CEO. We solve the firm's optimal contracting problem recursively. First, given any contract, we determine the CEO's best response, i.e., the CEO's acceptance decision and, in the case of accepting the contract, the optimal effort. Second, given the CEO's best response to the contract, we solve for the firm's optimal contract.

Let us first examine the CEO's optimal choice of effort under an arbitrary contract, D. Denote the value function of an employed CEO who accepts the contract D as $J_E(x, D)$, which is measured after the CEO observes the match-specific risk x but before observing the aggregate productivity shock y (see Figure 1 for the timing). Denote J_S as the value function of a CEO who does not have a contract and who is not in the matching process in the current period. Then, the value function J_E obeys the following Bellman equation:

$$J_E(x, D) = \int \left\{ \max_e \left[W(D, \pi) - \frac{c}{2}e^2 \right] + \beta \int_{x'} \max \left[J_E(x', D'), J_S' \right] dF_1(x') \right\} dF_2(y). \tag{2.4}$$

Here $'$ indicates the variables in the next period, $\pi = \pi(y, e, x)$ is described by (2.2), and β is the discount factor. The first term in the braces is the CEO's current utility, which is maximized by the choice of effort after observing the aggregate productivity, y. The second term is the CEO's continuation payoff in the next period, in which he will choose whether to accept next period's contract, D', or to reject it. The second maximization problem characterizes this future choice of acceptance. Since J_E is defined as the CEO's expected value before observing y in the current period, the expectation with respect to y is taken on the sum of the current and future utilities.

When choosing the effort level in (2.4), the CEO understands that profit depends on effort in the way described by (2.2). After substituting (2.2) into the first maximization problem in (2.4), we can solve for the optimal level of effort under the given contract (a, b) as

$$e^*(D, x, y) = by\sqrt{x}/c. \tag{2.5}$$

Intuitively, the optimal effort depends positively on the profit-sharing ratio b, the realized match quality x, and the aggregate productivity y, but negatively on the effort-aversion coefficient c.

Substituting the optimal effort into (2.4) and intergrating over y, we can simplify the value function J_E as

$$J_E(x, D) = a + \frac{x}{2c} b^2 \mathbb{E}\left(y^2\right) + \beta \int_{x'} \max[J_E(x', D'), J'_S] dF_1(x').$$

Standard techniques show that the right side of this equation is a continuous, monotone contraction mapping for the function J_E (see Stokey and Lucas with Prescott, 1989). By the contraction mapping theorem, there exists a unique function J_E that solves the above equation. Moreover, since the right-hand side of (**??**) maps functions $J_E\left(., D'\right)$ that are (weakly) increasing in the first argument into functions that are strictly increasing in the first argument, the solution $J_E(x, D)$ is strictly increasing in x. Similarly, the solution $J_E\left(x, D\right)$ is concave in x.

Now we turn to the CEO's acceptance decision, still taking the arbitrary contract D as given. If the CEO rejects the contract, he must wait for the next period to enter the search process. The value function of such a CEO is J_S. Thus, after seeing the match-specific risk, x, a CEO accepts the contract if and only if $J_E(x, D) > J_S$. Because $J_E(x, D)$ is strictly increasing in x and J_S is independent of x, there exists a unique cut-off match quality, denoted as $x_d\left(D\right)$, such that $J_E(x, D) > J_S$ if and only if $x > x_d(D)$. That is, the CEO's optimal acceptance decision obeys a reservation rule: he accepts the contract if the match-specific quality x exceeds the cut-off match quality $x_d(D)$, and quits otherwise. The cut-off match quality $x_d(D)$ is defined as the solution for

x_d to the equation $J_E(x_d, D) = J_S$. To express the cut-off match quality explicitly, let us denote the expected future value for a CEO who accepts the current contract as

$$I \equiv \int_{x'} \max[J_E(x', D'), J_S']dF_1(x').$$

Note that I is taken as given by both the agent and the firm for the contracting problem in the current period, since it depends only on the future contract and future market conditions. Substituting J_E from (**??**) into the defining equation for x_d, we obtain:

$$x_d(D) = \frac{2c}{b^2 \mathbb{E}\left(y^2\right)} \left(J_S - \beta I - a\right). \tag{2.6}$$

If the CEO rejects the contract, he must wait for the next period to enter the matching process. The value function of such a CEO, J_S, is given as:

$$J_S = B + \beta \left[\lambda \int_{x'} \max[J_E(x', D'), J_S']dF_1(x') + (1-\lambda)J_S' \right]. \tag{2.7}$$

The term B is the utility of unemployment benefits and leisure that such a CEO receives, and the sum inside the brackets $[\cdot]$ is the CEO's expected value of entering the next period as a searching CEO. With probability λ, the CEO will get a match in the next period, in which case he will choose whether or not to accept the contract. With probability $(1-\lambda)$, the CEO will fail to get a match in the next period, in which case his value function will be given by J_S'.

We now turn to the firm's optimal choice of a contract. Denote the value function of a firm with a CEO as J_F and the value function of a hiring firm with a vacant CEO position as J_H, both being measured at the beginning of the period (see Fig. 1 for the timing). Given any contract D, the CEO's optimal acceptance decision is $x_d\left(D\right)$, given by (2.6), and the optimal choice of effort is $e^*\left(D, x, y\right)$. Anticipating such best responses to a contract, the firm chooses the contract $D = (a, b)$ as follows:

$$\begin{aligned} J_F = \max\nolimits_{a,b} \int \left\{ \int_{x_d(D)}^{\bar{x}} \left(\hat{\pi} - \hat{W} + \beta J_F' \right) dF_1\left(x\right) + \int_{\underline{x}}^{x_d(D)} \beta J_H' dF_1\left(x\right) \right\} dF_2(y), \\ \text{where} \qquad \hat{\pi}\left(D, x, y\right) \equiv \pi(y, e^*(D, x, y), x) \quad \text{and} \end{aligned} \tag{2.8}$$

$$\hat{W}(D, x, y) \equiv W(D, \hat{\pi}(D, x, y)) = a + b^2 y^2 x / c.$$

The two integrals inside $\{\cdot\}$ give the value of the firm when the contract is accepted and rejected, respectively. The CEO accepts the contracts if and only if $x > x_d\,(D)$, as analyzed above. If the contract is accepted, the firm obtains the residual profit $(\hat{\pi} - \hat{W})$ in the current period plus $\beta J'_F$ which is the firm's continuation value in the future as a firm with a CEO. If the contract is rejected, the firm enters the next period without a CEO, in which case the value is given by $\beta J'_H$. Note that because the firm does not observe the match-specific risk, x, and because the contract is offered before y is realized, J_F is independent of x and y.

When choosing the contract for the current period, $D = (a, b)$, the firm takes J_H and the future values $(J'_H,\, J'_F)$ as given. Also, the firm anticipates that the CEO's effort (e^*) and acceptance rule $x_d(D)$ will depend on the contract. Solving the the maximization problem in (2.8) leads to the following optimal contract:

$$b = \frac{1}{2}\left(1 + \frac{x_d}{\bar{x}}\right) \qquad \text{and} \qquad a = \beta(J'_F - J'_H) - b(1-b)^2\frac{\bar{x}\mathbb{E}(y^2)}{c}. \tag{2.9}$$

Finally, for a firm whose CEO position is vacant at the beginning of the current period, the value function J_H is as follows:

$$J_H = -H + \int \left[q\beta J'_F + (1-q)\beta J'_H\right] dF_2(y). \tag{2.10}$$

The term H is the recruiting cost, and the integral is the expected value of the firm from search. With probability q, the firm will be matched by the end of the period, in which case the firm will enter the next period with a CEO. With probability $(1-q)$, the firm will be unmatched, in which case the firm will enter the next period without a CEO.

2.3. Some properties of a CEO's optimal choices and the optimal contract

We discussed the properties of a CEO's optimal effort, given by (2.5). The CEO's optimal acceptance decision is given by (2.6), which generates the following probability of contract acceptance:

$$prob\,(x > x_d) = 1 - F_1(x_d) = \frac{\bar{x} - x_d}{\bar{x} - \underline{x}}.$$

Thus, a reduction in the cut-off level x_d translates into an increase in the retention probability of the CEO. For any given I and J_S, suppose $J_S - \beta I > a$, so that the cut-off level x_d is positive.

In this case, the optimal cut-off level x_d and the retention probability depend on the contract as follows. First, the cut-off level decreases with the fixed salary a and the profit-sharing ratio b. This is because a higher a or b makes the compensation more generous to the CEO, thus increasing the retention probability. Second, $\partial^2 x_d/\partial b^2 > 0$ and $\partial^2 x_d/\partial a^2 = 0$. The result $\partial^2 x_d/\partial b^2 > 0$ indicates that the marginal benefit of increasing the profit-sharing ratio on retention is diminishing. This result arises because a higher b induces higher effort but the marginal disutility of effort to the CEO is increasing. In contrast, the marginal benefit of increasing the fixed salary on retention is constant, as indicated by the result $\partial^2 x_d/\partial a^2 = 0$, because an increase in a increases the CEO's compensation independently of the effort level. Thus, when b is already high, increasing the fixed salary is more efficient in achieving retention than increasing b. On the other hand, increasing b is the only way to induce effort.

Moreover, the cut-off level x_d and the retention probability depend on the market conditions through J_S and I. If the market is good for CEOs, the value of search, J_S, is high, in which case x_d is high and the retention probability is low. On the other hand, if staying on the job gives the CEO a high payoff in the future, i.e., if I is high, then x_d is low and the CEO is likely to stay with the firm. In the equilibrium analysis later, we will link these market conditions to other firms' contracts and basic parameters of the economy.

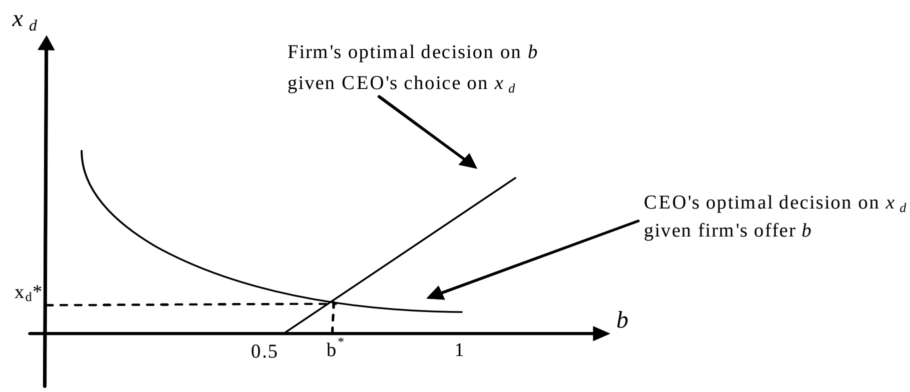
The optimal contract, given by (2.9), has some interesting features. First, b is less than 1 in general and so it is not optimal for a firm to sell the company to the CEO. In a textbook agency model which has only one firm and one agent (e.g., pages 27-28 in Murphy 1999), the optimal contract has $b = 1$ for a risk-neutral agent and $b < 1$ for a risk-averse agent. That is, for an agent who is risk-neutral in income, it is optimal for the firm to sell the firm to the CEO provided that the latter is not liquidity constrained. This standard result for a risk-neutral agent does not hold in our model because of the moral hazard problem associated with quitting.[6] The CEO can unilaterally decide to quit after observing the match quality which is not observable by the firm or contractible. If the firm chose to sell the firm to the CEO, the amount of payment the firm

[6] In the current setting, a CEO is risk-neutral in income and effort averse. We show that b is less than 1 in equilibrium. It is easy to show that b will be even smaller if the CEO is also risk averse in income.

receives (i.e., $-a$) would be too low to be optimal.

Second, the fixed salary increases with the firm's opportunity cost of leaving the CEO position vacant in the next period, which is given by $\beta\left(J'_F - J'_H\right)$. This opportunity cost depends on the market conditions, and hence is linked to other firms' contracts.

Fig. 2: Relationship between b and x_d



Finally, we can put the firm's optimal contract together with the CEO's optimal choices to determine both as functions of the market conditions. Fig. 2 depicts the unique solutions for $x_d\left(D\right)$ and b. The upward sloping curve is the firm's optimal choice of b, given by (2.9), and the downward sloping curve is the CEO's optimal choice x_d, given by (2.6). The intersection of the two curves is the equilibrium pair (b, x_d), as functions of (J_S, J_E, λ).

3. Optimal contracts in a market equilibrium

In the above analysis, market conditions, such as the matching rates and future payoffs, are taken as given and will be determined in a market equilibrium described below.

3.1. Definition and existence of a market equilibrium

To begin with, let us normalize the measure of CEOs to be 1 and let the measure of firms be N. In a period, the measure of searching CEOs is u and the employed CEOs is $1 - u$. Since each searching CEO gets a match with probability λ and accepts the contract with probability $[1 - F_1\left(x_d\right)]$, the flow from searching CEOs to employed CEOs is $u\lambda[1 - F_1(x_d)]$. Since each employed CEO quits with probability $F_1\left(x_d\right)$, the flow from employed CEOs to searching CEOs is $(1-u)F_1(x_d)$. Thus, the measure of searching CEOs at the beginning of the next period is

$$u' = u + (1-u)F_1(x_d) - u\lambda[1 - F_1(x_d)]. \tag{3.1}$$

We focus on a stationary and symmetric market equilibrium, which consists of individual firms' choices (a, b), other firms' choices $(\bar{a}, \bar{b})$, CEOs' choices (e^*, x_d), and value functions (J_E, J_S, J_F, J_H) such that the following requirements are satisfied:

(i) Given the firm's (a, b) and other firms' $(\bar{a}, \bar{b})$, the choices e^* and x_d are optimal for a CEO.

(ii) Given $(\bar{a}, \bar{b})$ and a CEO's best response functions, the firm's choices (a, b) are optimal.

(iii) The value functions satisfy (2.4), (2.7), (2.8) and (2.10).

(iv) The competitive entry of firms requires the benefit of hiring a CEO to be equal to the cost of hiring. That is, $\beta q(J'_F - J'_H) = H$, and hence $J_H = 0$.

(v) Symmetry requires $(a, b) = (\bar{a}, \bar{b})$ and $x_d = \bar{x}_d$.

(vi) Stationarity requires $u' = u$, $J_F{}' = J_F$, $J_H{}' = J_H$, $J_E{}' = J_E$ and $J_S{}' = J_S$.

Based on the above definition, we solve for the equilibrium values of (a, b, x_d), (J_E, J_S, J_F, J_H), and (q, λ) through a set of equations presented in Appendix A. In particular, we show that there exists a unique non-zero solution for b^* if the unemployment benefit satisfies the condition, $B \in [B_1, B_2]$, where B_1 and B_2 (with $B_2 > B_1$) are constants given in Appendix A. We will maintain this condition throughout the analysis.

3.2. Equilibrium incentive contract and firm size

Given the unique solution b^*, we can express the equilibrium salary a^* and firm value J_F^* as

$$a^* = b^*(1-b^*)^2 \frac{\mathbb{E}(y^2)\bar{x}}{c\sqrt{3}\sigma_x}\left(\beta\bar{x} - \sqrt{3}\sigma_x\right) \qquad \text{and} \qquad J_F^* = b^*(1-b^*)^2 \frac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}. \tag{3.2}$$

Since J_F^* is the value of a producing firm with a filled CEO position, we can interpret it as the size of the firm. The following proposition states the effects of the aggregate productivity, the systematic risk and the firm specific risk on the optimal contract $D^* = (a^*, b^*)$ and the equilibrium firm value (please see detailed comparative statics in Appendices B).

Proposition 3.1. *In equilibrium, the optimal incentive contract possesses the following features:*

1) The profit-sharing ratio, b, decreases with the expected aggregate productivity $\mathbb{E}(y)$ *and the systematic risk* σ_y*. It increases with the match-specific risk* σ_x *under* $b < 2/3$*.*

2) The salary, a, increases with the expected aggregate productivity $\mathbb{E}(y)$ *and the systematic risk* σ_y*. It decreases with the match-specific risk* σ_x *under* $b < 2/3$*.*

3) The equilibrium firm value, J_F^**, increases with the expected aggregate productivity* $\mathbb{E}(y)$ *and the systematic risk* σ_y*. It decreases with the match-specific risk* σ_x *under* $b < 2/3$*.*

Below we provide some intuitions for the equilibrium results in Proposition 3.1 are as follows:

1) The effects of the expected aggregate productivity, $\mathbb{E}(y)$. With a high expected aggregate productivity, a firm has strong incentive to fill the CEO position since its expected profit from production is high. Thus, the opportunity cost of leaving a vacant CEO position is high. To reduce the chance for a vacant position, the firm needs to offer a higher retention-inducing payment, i.e., the fixed salary. Also, the aggregate productivity y and the CEO's effort are complementary to each other in the firm's profit function. When the aggregate productivity is higher, the CEO has stronger incentive to exert effort for a given profit-sharing ratio. Put differently, a higher aggregate productivity reduces the firm's implicit cost of inducing effort. As a result, the firm can reduce the profit-sharing ratio and still induce the CEO to exert effort. Consequently, a higher aggregate productivity, accompanied by a lower profit-sharing ratio, still leads to a higher firm value.

2) The effects of the firm's systematic risk, σ_y*, and specific risk,* σ_x*.* There are two risks faced by a firm: the firm-specific risk, σ_x, and the aggregate risk, σ_y. The profit-sharing ratio (e.g., the pay-to-performance sensitivity) increases with the firm's specific risk but decreases with the systematic risk.[7] To explain why b increases with σ_x, recall that a CEO works for a firm only if the match quality is higher than a reservation value. That is, the firm's profit is analogous to a call option written on the match quality with a strike price being the reservation value, and hence it increases with the volatility of the match-specific risk. Naturally, a CEO prefers a

[7] Bhattacharyya and Lafontaine (1995) show similar results in a franchising setting. Zabojnik (1996) also shows a possible positive relationship between the risk embedded in a firm's production function and the pay-to-performance sensitivity if the agent's disutility of effort satisfies certain conditions. However, the risk there is understood as the total risk.

positive dependence of the profit-sharing ratio on the specific risk since he can receive more profit sharing payment. Also, when the specific risk is higher, the firm has incentive to provide a higher profit-sharing ratio because a higher profit-sharing ratio induces higher effort from CEO which leads a better profit. However, the increase in profit due to the increased effort is smaller than the increased profit sharing payment due to the higher pay-to-performance ratio. Therefore, the firm value decreases with the volatility of the match-specific risk.

As for the systematic risk, it is common to all firms and taken as given by all CEOs. In order for firms to induce effort and at the same time to provide partial insurance to the effort-averse CEO, the firm offers a higher salary and a lower pay ratio when the aggregate risk is higher. The lower pay ratio leads a higher firm value.[8]

It is important to note that a traditional principal-agent model is unable to distinguish the opposite effects of the systematic risk and the firm-specific risk on the profit-sharing ratio. Instead, it only predicts a negative effect of the firm's total risk on the profit-sharing ratio.

3.3. Relative size of total compensation to firm value

While Proposition 3.1 postulates how the equilibrium compensation and firm value increase with the overall size of the economy, we now discuss their relative growth. To this end, we express the equilibrium salary in terms of the equilibrium firm value as follows: $a^* = J_F^* \left(\beta - \frac{\sqrt{3}\sigma_x}{\bar{x}}\right)$. Unlike Gabaix and Landier (2007) who take firm size as given and show that an increase in firm size can lead to the rise in the executive pay, we show that a growing economy can simultaneously increase the equilibrium salary and firm size, which is consistent with the empirical observation. Our theory provides an alternative explanation to the second stylized fact. From the expression of a^*, we can obtain the expected total compensation as

$$W^* = a^* + b^* \mathbb{E}(\pi) = J_F^* \left[\frac{b^2}{1-b} + \left(\beta - \frac{\sqrt{3}\sigma_x}{\bar{x}} \right) \right],$$

[8] Jin (2002) introduces portfolio diversification into a standard principal-agent model to study the relation between a CEO incentive level and the firm's risk characteristics. He concludes that, when a CEO cannot trade the market portfolio, the optimal incentive level decreases with the firm's nonsystematic risk but is ambiguously affected by the firm's systematic risk. When a CEO can trade the market portfolio, the optimal incentive level decreases with nonsystematic risk but is unaffected by systematic risk. Our results do not necessarily contradict Jin's since we do not study the effects of portfolio diversification.

which is a decreasing function of b. To further investigate the size of total compensation, relative to the firm's value, J_F^*, we denote the ratio between the expected total pay and the firm's value as $R_{pay/size}$. It is easy to show that

$$R_{pay/size} = \frac{a^*+b^*\mathbb{E}(\pi)}{J_F^*} = \frac{b^2}{1-b} + \left(\beta - \frac{\sqrt{3}\sigma_x}{\bar{x}}\right) \qquad \text{and} \qquad \frac{\partial R_{pay/size}}{\partial b} = \frac{b(2-b)}{(1-b)^2} > 0.$$

Thus, a higher profit-sharing ratio leads to a higher ratio between the expected total pay and the firm size. Given the dependence of the expected total compensation W^* and the ratio $R_{pay/size}$ on the profit-sharing ratio, we can derive the following corollary (please see detailed comparative statics in Appendix B).

Corollary 3.2. *1) The equilibrium expected total compensation, W^*, increases with the expected aggregate productivity $\mathbb{E}(y)$ and the systematic risk σ_y, and decreases with the match-specific risk σ_x under $b < 2/3$.*

2) The equilibrium ratio between the total expected pay and firm size, $R_{pay/size}$, decreases with the expected aggregate productivity $\mathbb{E}(y)$ and the systematic risk σ_y. The effect of the match-specific risk σ_x on $R_{pay/size}$ is positive when $\partial b/\partial\sigma_x > \mu_x/\left[\sqrt{3}(\mu_x + \sqrt{3}\sigma_x)^2\right]$.

The intuition for the above results can be obtained based on the intuition provided for the optimal contract presented in Proposition 3.1. For example, when the expected aggregate productivity, $\mathbb{E}(y)$, is high, a firm has strong motivation to fill the CEO position since its expected profit from production is high. Consequently, the firm offers a higher salary and a lower profit-sharing ratio. This lower profit-sharing ratio will increase the value of the firm and, at the same time, reduce the total pay to the CEO. As a result, the ratio between the expected total pay and the firm's value is lower. Also, when the match-specific risk is high, it is optimal for a firm to offer a higher profit-sharing ratio, as explained earlier. This higher profit-sharing ratio will increase the total expected pay to the CEO and meanwhile reduce the value of this operating firm. Hence, the ratio $R_{pay/size}$ will be lower.

4. Empirical analysis

The objective of our empirical analysis is three-fold: 1) to verify our theoretical predictions on the pay-to-performance, annual compensation and firm size; 2) to clarify the mixed evidence presented in the existing literature; 3) to provide new evidence on the relative growth between the executive compensation and firm size. Specifically, we test the following three predictions based on Proposition 3.1 and Corollary 3.2.

Prediction 1: The pay-to-performance sensitivity, b, decreases with the expected aggregate productivity and the firm's systematic risk, and increases with the firm's idiosyncratic risk.

Prediction 2: Annual compensation and firm size increase with the expected aggregate productivity and the firm's systematic risk, and decrease with the firm's idiosyncratic risk.

Prediction 3: The relative growth of the total pay to firm size increases with the firm's idiosyncratic risk and decrease in the firm's systematic risk and the aggregate productivity.

4.1. Data and empirical variable definitions

The executive compensation data are retrieved from the ExecuComp for the period from 1992 to 2005. Firm characteristics and returns are obtained from the COMPUSTAT and CRSP. We exclude financial and utility firms. Our final sample consists of 10,837 firm-year for 2,432 firms and 4,010 executives.

As discussed by Murphy (1999), a typical compensation package includes salary, bonus, and restricted stock and option grants. To empirically examine the two stylized facts based on the theoretical results, we first identify the empirical measures for the pay-to-performance sensitivity ratio (b), salary (a), the total compensation, and the ratio between total pay and firm size ($R_{pay/size}$). Following Jensen and Murphy (1990), we define b as the change in the value of CEO compensation with respect to the $1000 change in shareholders' wealth. Since most incentive payments are related to a firm's equity, we therefore focus on the pay-to-performance sensitivity for stock and option grants.[9] That is, we calculate the value of CEO compensation either based

[9]This interpretation is consistent with the current model because the equilibrium profit π is proportional to J_F

on the stock and option grants in the current year or the accumulated stock and stock option grants up to the current year. Salary, a, is set to be the annual salary paid to executives. Total compensation is the sum of salary, bonus, and equity-related pay. $R_{pay/size}$ is calculated as the ratio between annual total compensation and firm size, where firm size is proxied by either the firm's total assets or market capitalization.

We then formulate three major explanatory variables: the aggregate productivity, a firm's systematic risk and non-systematic risk. We use GDP, as well as the commercial paper spread, to proxy for the aggregate productivity.[10] The commercial paper spread is defined as the difference between the annualized rate on three-month commercial paper and the three-month T-bill rate. As expected, a high GDP indicates a good economy while a high commercial paper spread suggests a bad economy. As stated in Bernanke and Blinder (1992), a high commercial paper spread at the beginning of the year signals a bad economy since the commercial paper spread tends to rise sharply during credit crunches. Therefore, in the regression analysis, we use the negative lagged commercial paper spread as a proxy for the aggregate productivity. The annual GDP growth data are retrieved from the website of the Bureau of Economic Analysis while the commercial paper spreads are obtained from the website of the Federal Reserve Board.[11]

Our major proxy for a firm's risk is the volatility of stock returns as in Core and Guay (1999).[12] A firm's total risk is the volatility of stock returns over the 60 months prior to the fiscal year. Its beta is obtained from the market model using the same set of monthly return data. A firm's systematic risk is equal to the firm's beta multiplied by the stock market risk, while the firm's

(the value of an operating firm) and hence the payment $b\pi$ in the model is proportional to bJ_F (which is equivalent to an ownership sharing payment).

[10] Please refer to Friedman and Kuttner (1993) and Korajczyk and Levy (2003) for a thorough discussion on why the commercial paper spread performs well in predicting the economic activity.

[11] Please refer to www.bea.gov/beahome.html for the GDP growth data and www.federalreserve.gov/ for commerial paper rates. Prior to August 1997, the commercial paper rate is the rate based on short-term negotiable promissory notes issued by financial and non-financial companies with AA bond ratings. After September 1997, the rate is based on commercial papers issued by non-financial companies only.

[12] We also consider an alternative measure, the volatility of dollar returns, to proxy for a firm's risk. This measure is proposed by Aggarwal and Samwick (1999b) to ensure that the risks are expressed in dollars since they assume that a firm's profit is the sum of the executive's effort and the noise term. However, in our model, a firm's profit is the product of the aggregate variable, the firm's specific shock variable, and the executive's effort. If the executive's effort has the same measure as the profit, then the aggregate variable and the match-specific shock variable do not have to be measured in dollars. Therefore, stock return volatilities are proper measures for our test. Moreover, the correlations among the firm's total dollar risk, its systematic risk and specific risks are higher than 0.92. Such high correlations will lead to multicollinearity problem for all regressions.

specific risk is the difference between a firm's total risk and the firm's systematic risk.

In addition, we include other control variables such as the executive's age and tenure, the firm size, and the firm growth. The tenure is defined as the number of years a person has been an executive in the firm. A firm's growth is proxied by its sales growth while the size is proxied by either the asset value or the market capitalization.

It is well known that there exist outliers in the executive compensation data. To reduce the effect of outliers on the empirical results, we winsorize the executive compensation data and firm characteristics data at the 1% and 99% levels. Table 1 provides the summary statistics for compensations and characteristics of the executives, characteristics of firms, and the macroeconomic variables representing the aggregate productivity. Panel A of Table 1 shows that the average annual salary for a CEO is about $627,000, which is almost equal to the average annual bonus $640,000. However, the median annual salary $572,000 is much higher than that of the bonus $375,000, indicating that bonus payments are more skewed toward the high end. Similar patterns are observed for the total pay. In particular, the average total compensation is $3,991,000, which is about twice of the median total pay but about one-tenth of the maximum total pay. It is worth noting that the average total pay is more than six times of the average annual salary, indicating that the main income for an executive is from equity-related compensation. The average new equity incentives granted for a fiscal year is $2.10 with respect to the $1000 change in shareholders' wealth, compared to the average accumulated equity incentives $27.56. An average executive is almost 56 years old and stays with a firm for slightly more than eight years. The youngest executive is 29 years old while the oldest is 90. The longest tenure is 38 years, in contrast to the shortest job duration of five months.

The summary statistics of firms' characteristics suggest that the firms in the sample are skewed toward large sizes. In particular, the average market capitalization is $5,947 million, almost six times as large as the corresponding median value, $1,196 million. The average asset value is $4,283 million, almost four times as large as the median sales, $1,074 million. The average firm's total risk represented by the return volatility is 45%, which is slightly higher than the median 39%. The average firm's systematic risk is 15%, which is one-third of the average total risk.

During the sample period of 1992 to 2005, the average GDP in the United States is \$9.09 trillion, compared to the minimum \$6.34 trillion and maximum \$12.49 trillion. The standard deviation is \$1.93 trillion, indicating a small fluctuations in GDP during the sample period. On the other hand, the commercial paper spread is much more volatile. The commercial paper spread is averaged at 23 basis points with a standard deviation of 12 basis points.

Table 2 presents the correlations among the explanatory variables. Clearly, the commercial paper spread is negatively correlated with GDP, where the correlation is -0.544. Also the correlation between the asset value and market capitalization is 0.799, suggesting that the empirical results using the asset value as a proxy for firm size should be very similar to those when the market capitalization is used. Note that most correlations among the explanatory variables are very small, which ensures the absence of the multicollinearity problem for all regressions.

4.2. Test of Prediction 1: Effects of firm's specific and systematic risks on pay-to-performance sensitivity

In this section, we empirically verify our model prediction on the diametrically opposing effects of firm specific and systematic risks. In so doing, we will reconcile the mixed evidence from the existing studies. To this end, we test that the pay-to-performance sensitivity decreases with the expected aggregate productivity and the firm's systematic risk, and increases with the firm's idiosyncratic risk, as stated in *Prediction 1.* Our empirical specification is as follows:

$$\begin{aligned} b = a_1 + a_2(\text{GDP \% / NCP spread}) + a_3\text{Firm-specific risk} + a_4\text{Firm-systematic} \\ \text{risk} + a_5\text{Age} + a_6\text{Tenure} + a_7\text{Firm size} + a_8\text{Firm growth} + \varepsilon, \end{aligned} \tag{4.1}$$

where the aggregate productivity is proxied by the GDP growth (hereafter GDP %), or the negative lagged commercial paper (hereafter NCP) spread.[13] The executive's age and tenure, the firm size, and the firm growth are used as control variables. The regression in (4.1) is performed with the OLS and median regressions. The reason to use the median regression is to reduce the impact of outliers given the skewed compensation data. As indicated in the previous subsection, a firm's growth is proxied by its sales growth while the size is proxied by either the asset value or

[13]To simplify the language, the phrase "commercial paper spread" from this point on refers to the "negative lagged commercial paper spread".

the market capitalization. Since the empirical results are qualitatively the same. To save space, we only report the results in Table 3 for the case in which the asset value is used as the size proxy. Panel A presents the results of the OLS and median regression using the current equity grants to compute b, while Panel B presents the corresponding results using the cumulative equity grants to compute b. The main findings are as follows.

1. Regardless of whether the GDP growth or NCP is used to represent the aggregate productivity, the value of R^2 of the regression is similar. This suggests that the GDP growth and the commercial paper spread are equally good proxies for the aggregate productivity.

2. Whether we use the current or cumulative equity grant to compute b, the regressions confirm a negative relationship between b and the aggregate productivity. The coefficients are all significant at 1% level (see Panels A and B). The impact of the aggregate productivity on the pay-to-performance sensitivity is significant. For example, an increase of one standard deviation (or 1%) in GDP will reduce the current equity incentive by $\$74,800$ ($= 0.073 * \$5,947$million$*17.23\%/1000$)[14] under OLS or $\$39,962$ ($= 0.039 * \$5,947$million$*17.23\%/1000$) under median regression, and will reduce the total equity incentive by $\$935,522$ ($= 0.913 * \$5,947$million$*17.23\%/1000$) under OLS and $\$240,797$ ($= 0.235 * \$5,947$million$*17.23\%/1000$) under median regression. A decrease of one standard deviation (or 12 basis points) in commercial spread will reduce the current equity incentive by $\$245,920$ ($= 0.02*12*\$5,947$million$*17.23\%/1000$) under OLS or $\$73,776$ ($= 0.006 * 12 * \$5,947$million$*17.23\%/1000$) under median regression, and will reduce the total equity incentive by $\$2,028,842$ ($= 0.165 * 12 * \$5,947$million$*17.23\%/1000$) under OLS and $\$430,360$ ($= 0.035 * 12 * \$5,947$million$*17.23\%/1000$) under median regression. The estimated coefficients are generally larger in the OLS regression than in the median regression due to the effect of outliers.

3. Consistent with the model's predictions, b is positively related with firm-specific risk and negatively related with firm-systematic risk in almost all regressions and with all of the measurements of b. Most coefficients are statistically significant. Given that in our model, b is

[14] $\$5,947$ million is the average market value of equity, and 17.23% is the average stock return in our sample period. Therefore, $\$5,947$ million$*17.23\%$ is the average change in shareholder wealth during a year.

determined in each period, the tests on the pay-to-performance sensitivity of new equity grant are more direct. Thus, we use the results in Panel A to discuss the impact of a firm's risks on pay-to-performance sensitivity. A rise of one standard deviation (or 19%) in firms' specific risk increases the current equity grant by $\$548,433$ ($= 2.817 * 19\% * \$5,947$million$*17.23\%/1000$) or $\$626,503$ ($\$421,886$ or $\$478,735$) under OLS (median) regression, depending on whether the GDP growth or commercial paper spread is used to represent the aggregate productivity. On the other hand, a rise of one standard deviation (10%) in firms' systematic risk decreases the current equity incentive by $\$119,476$ ($= 1.166 * 10\% * \$5,947$million$*17.23\%/1000$) or $\$77,772$ ($\$62,300$ or $\$56,450$) under OLS (median) regression. The above numbers show that the impacts of firms' specific risk and systematic risk on pay-to-performance sensitivity are economically significant.

4. The pay-to-performance sensitivity of the current or the cumulative equity grant decreases with firm size, consistent with prior work (e.g., Baker and Hall, 2000). The results on tenure are interesting. Similar to Gibbons and Murphy (1992), and Milbourn (2003), we obtain a positive relation between CEO tenure and pay-to-performance sensitivity when the pay-to-performance sensitivity is measured with the cumulative equity grants. However, the relation becomes negative when pay-to-performance sensitivity is measued by the current equity grants. This negative relationship may be consistent with argument of CEO entrenchment which is not addressed in the current model.

5. To contrast our predictions with those of a standard principal-agent model, we run the regression (4.1) by replacing the firm's "specific risk" and "systematic risk" with the firm's "total risk". For brevity, we only report the coefficient and t-value for the firm's "total risk", as well as the corresponding R^2. In general, the R^2 with the firm's total risk as an explanatory variable is smaller than that obtained from regression in (4.1), indicating that b is better explained by separating the firm's systematic risk from its specific risk. More importantly, the relationship between b and firms' total risks is positive and significant at 1% level for all regressions in Panel A and median regressions in Panel B. This positive relationship is opposite to the predicted negative relationship from the standard principal-agent model.

To summarize, our results suggest that the model predictions are generally supported by our empirical analysis, in particular, the pay-to-performance sensitivity b is negatively (positively) affected by the firm's systematic (specific) risks.

4.3. Test of Prediction 2 on annual compensation and firm size

The second stylized fact concerns the steady increases in annual executive compensation and firm size in the past three decades. To gain a better understanding about the changes in annual compensation and firm size over time, we report the median annual compensation and firm size in Table 4.[15] It is easy to see that there is an upward trend in annual compensation, which is confirmed by Fig. 3. In particular, the median salary, salary plus bonus and total compensation increased from \$469,00, \$726,000 and \$1,315,000 in 1993 to \$677,000, \$1,304,000 and \$3,107,000 in 2005 respectively. The corresponding percentage increases are 44.35%, 79.61% and 136.27%. Table 4 also shows a positive growth in the median firm size during the sample period, which is illustrated by Fig. 4. The percentage increase in the asset value and the market capitalization are 54.5% and 105.05% from 1993 to 2005, respectively. Since our theory attributes the increase in compensation and firm size to the growing performance of the macro-economy, we also plot the two aggregate proxies in Fig 4. Clearly, the GDP has increased steadily while the commercial paper spread has decreased from 1993 to 2005.

Table 4 suggests that the percentage increases in the median salary plus bonus and the total compensation are bigger than those in firm size. Therefore, we further document the ratio between total compensation and firm size in Table 4. It is clear that the median ratio exhibits a positive time trend (please see Fig. 5). In particular, the median ratio has increased from 0.073% to 0.208% based on the asset value, and increased from 0.056% to 0.174% based on the market capitalization, although the median ratio based on the asset value is more stable than the ratio based on the market capitalization. Given the important influence of the firm-systematic and firm-specific risks on compensation, firm size and the ratio between compensation and firm size, we also present median statistics for the firm risks in Table 4. The median firm-specific risk shows a positive time trend while the median firm-systematic risk presents a slightly downward trend

[15] In Table 5, we omit the median statistics for 1992 because there are only 27 observations for 1992 and the statistics are biased toward large firms.

(see Fig. 6). Specifically, the median firm-specific risk changed from 0.317 in 1993 to 0.406 in 2005, and the median firm-systematic risk dropped from 0.161 in 1993 to 0.151 in 2005.

To summarize, the median statistics during 1993 to 2005 exhibit two important features: (1) different components of the executive compensation and firm sizes have increased; (2) the increase in total compensation has outpaced the increase in firm size.

Below we empirically examine the first feature by testing *Prediction 2*. Specifically, we test that the annual compensation and firm size increase with the aggregate productivity and the firm's systematic risk, and decrease with the firm's specific risk. The regression is specified below.

$$\begin{aligned}\log(\text{Compensation/firm size}) = a_1 + a_2(\log(\text{GDP})/\text{NCP spread}) + a_3\text{Firm-specific}\\ \text{risk} + a_4\text{Firm-systematic risk} + a_5\text{Age} + a_6\text{Tenure} + a_7\text{Firm growth} + \varepsilon.\end{aligned} \tag{4.2}$$

Since the OLS results have the same qualitative features as those of the median regression, to save space, we only report the median regression results in Table 5. Panel A presents the results for annual compensations which are measured by salary, salary plus bonus and total compensation while Panel B reports the results for firm size which is measured by either the firm's asset value or its market capitalization. The following patterns emerge from Table 5.

First, Table 5 indicates that the executive pay (salary, salary plus bonus or total compensation), as well as firm size, increases with the aggregate productivity. In other words, the growing macro-economy during the past decade has a positive and significant effect on the firm size and the executive pay. This is evident since all coefficients for GDP and NCP spread are positive and significant at 1% level. For example, a 1% increase in GDP leads to 1.982% increase in total compensation and 2.224% in the firm's market capitalization.

Second, the regressions confirm a negative impact of the firm's specific risk, as well as a positive effect of the firm's systematic risk, on compensation and firm size. All coefficients are significant at 1%. For example, when GDP represents the aggregate economy, a 1% increase in the firm's specific risk leads to a 2.341% reduction in total compensation and a 5.606% reduction in the firm's market capitalization. On the other hand, a 1% increase in the firm's specific risk yields a 2.13% rise in total compensation and a 4.676% rise in the firm's market capitalization.

Table 5 shows that the aggregate economy, the firm's specific risk and systematic risk all have significant impact on annual compensations and firm size. To determine the order of importance of these three factors, we first calculate the changes in these variables from 1993 to 2005. Based on Table 4, the percentage increase in GDP is 72.56% ($= 12.487/6.657 - 1$). There is an increase of 8.9% ($= 0.406 - 0.317$) in the firm's specific risk while there is a decrease of 1% ($= 0.151 - 0.161$) in the firm's systematic risk. Also we calculate the percentage changes in total compensation and firm size. From 1993 to 2005, total compensation has increased by 136.27% ($= 3.107/1.315 - 1$) while firm size measured by market capitalization has increased by 105.05% ($= 1.786/0.871 - 1$).

Now we examine the overall effect of these three variables on total compensation and firm size. To do so, we take full derivatives to equation (4.2) and use the coefficients for the three variables in Table 5 to compute the predicted percentage changes for total compensation as

$$\begin{aligned}&1.982 * 72.56\%(\text{GDP}) - 2.341 * 8.9\%(\text{specific risk}) + 2.13 * (-1\%)(\text{systematic risk})\\ &= 143.81\%(\text{GDP}) - 20.835(\text{specific risk}) - 2.13\%(\text{systematic risk}) = 120.85\%.\end{aligned}$$

Clearly, the increase in the firm's specific risk and the decrease in the firm's systematic risk create negative effects on the total pay by 20.835% and 2.13%, respectively. However, the 72.56% increase in GDP is the main positive force which lifted up the total compensation by 143.81%. The overall impact of these three variables on total compensation leads to a 120.85% increase, which accounts for 88.68% of the 136.27% increase in total pay. The remaining 11.32% may be explained by other control variables such as the CEO's tenure, age and the firm's sales growth. Similar exercise shows that these three variables can almost fully explain the 105.05% increase in firm size measured by market capitalization.

Therefore, our empirical evidence shows that the main driving force behind the increases in total compensation and firm size is the rapid growth of the macro-economy. The increase in the firm's specific risk and the decrease in its systematic risk actually dampened the growth in total compensation and firm size.

4.4. Test of Prediction 3 on relative magnitude of total compensation to firm size

The above empirical analysis only shows that the annual compensation and firm size increase with the growing economy. It does not answer the question how the total compensation evolves relative to the firm size over time. As shown in Table 4, the total compensation increases faster than the firm size in the sense that the ratio between total compensation and firm size exhibits a positive time trend. We intend to explain this positive time trend by testing *Prediction 3* which is based on Corollary 3.2. Precisely, we test that the ratio between total pay and firm size decreases with the aggregate productivity and the firm's systematic risk, and increases with the firm's idiosyncratic risk. We run the following regression:

$$\begin{aligned} R_{pay/size} = a_1 + a_2(\text{GDP \% /NCP spread}) + a_3\text{Firm-specific risk} + a_4\text{Firm-} \\ \text{systematic risk} + a_5\text{Age} + a_6\text{Tenure} + a_7\text{Firm growth} + a_8\text{Year} + \varepsilon. \end{aligned} \tag{4.3}$$

The dependent variable and most explanatory variables in (4.3) have been defined in the previous sections. The variable "Year" is a time variable equal to the calendar year of the observation and is used as a dummy variable to capture the possible time trend in the ratio of total pay and firm size. Table 6 reports the results.

Clearly, the ratio $R_{pay/size}$ is affected positively by the firm's specific risk and negatively by the firm's systematic risk, confirming the theoretical prediction. All coefficients are significant at 1% level. For example, when the negative commercial paper spread is used to proxy the aggregate economy and when firm size is measured by asset value, a 1% increase in the firm's specific risk leads to a $7.526\% \times 10^{-3}$ increase in the ratio between total pay and market capitalization while a 1% reduction in the firm's systematic risk yields a $4.355\% \times 10^{-3}$ rise in the same ratio.

However, the effects of the aggregate proxies are mixed. The negative impact of the aggregate economy is confirmed when the negative commercial paper spread is used as the proxy but is somewhat rejected when the GDP growth is used. To be conservative when determining the order of importance among the firm's specific risk, its systematic risk and the aggregate economy, we use the estimated coefficients corresponding to the case where the negative commercial paper is involved. Based on Table 4, we know that the commercial paper spread has decreased by 23 basis points from 1993 to 2005. The change in the ratio between total pay and the firm's asset value is $72\% \times 10^{-3}$. Recall there is an 8.9% increase in the firm's specific risk and an 1% decrease in the firm's systematic risk. Using the coefficients estimated from (4.3), the change in the ratio can be explained by these three factors as

$$[-0.01 \times 23(\text{NCP}) + 7.526 \times 8.9\%(\text{specific risk}) - 4.355 \times (-1\%)(\text{systematic risk})] \times 10^{-3}$$
$$= [-23\%(\text{NCP}) + 66.98\%(\text{specific risk}) + 4.355\%(\text{systematic risk})] \times 10^{-3} = 48.34\% \times 10^{-3}.$$

That is, the increase in the firm's specific risk and the decrease in its systematic risk create positive effects on the ratio total pay by $66.98\% \times 10^{-3}$ and $4.355\% \times 10^{-3}$, respectively. However, the 23 basis point reduce in the commercial paper spread reduces the ratio by $23\% \times 10^{-3}$. The overall impact of these three variables on the ratio is a $48.34\% \times 10^{-3}$ increase, which accounts for about 67.13% of the $72\% \times 10^{-3}$ increase in the ratio. The remaining 32.87% may be explained by other control variables such as the CEO's tenure and age, the Year dummy, and the firm's sales growth. Hence, our empirical evidence shows that the increase in the firm's specific risk is the main contributing factor to the increase in the ratio between total compensation and firm size.

5. Conclusion

Managerial compensation theory suggests that the proper mechanism to compensate CEOs is to base the reward on CEOs' performance. As such, academic researchers (such as Jensen and Murphy, 1990) and public activists (such as Crystal, 1991) have advocated the reliance on performance-based reward system for CEOs. However, the rapid increase in executive compensation in the past three decades has created a sentiment that CEOs are overly compensated for firms' performance that is largely due to economic booms. Also, economic theory on managerial compensation indicates that the pay-to-performance sensitivity should negatively depend on the total risk of a firm. This prediction is not fully supported by empirical observations.

This paper provides an explanation for these two stylized facts by developing a dynamic equilibrium model which explicitly addresses the role of incentive for CEOs to participate in the optimal contracts. In particular, a CEO is allowed to search for outside options while working for a firm. The CEO can quit if his outside options exceed the utility derived from the existing incentive contract. In our multi-firm and multi-agent setup, the value of a job that a CEO can find in the marketplace is determined by other firms' compensation schemes. In other words, the contract offered by one firm depends on other firms' contracts through the CEO's outside options. Because of this link among different firms' contracts, all firms' contracts and CEOs' reservation utilities are determined simultaneously in a market equilibrium. The equilibrium compensation contract induces both the optimal effort and the optimal participation, as opposed to the traditional model where the optimal effort is induced in a context with a binding participation constraint.

Our equilibrium analysis yields new and important results. First, the equilibrium pay-to-performance sensitivity depends positively on the firm's specific risk, and negatively on a firm's systematic risk. The separate effects of firms' specific and systematic risks on the pay-to-performance sensitivity offer a possible theory to reconcile with the mixed empirical evidence on the relationship between the pay-to-performance sensitivity and firms' total risk. Second, the equilibrium analysis shows that a growing economy can simultaneously induce the growth in executive compensation and firm size. The relative pace of growth in compensation and size depends positively on the firm's specific risk and negatively on the firm's systematic risk. These results provide a consistent explanation to the steady increase in executives' salaries and firm size during the past three decades.

We use these theoretical predictions as the guiding lights to formulate our empirical tests and show that the two stylized facts are consistent with our dynamic equilibrium agency model. Our theoretical and empirical results suggest that the role of incentive for CEOs to participate in optimal contracts is very important in the design of executive compensation policy, in addition to the role of incentive to induce effort.

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Appendix

A. Solution to the market equilibrium

Given the equilibrium definition presented in Section 3, we solve for the equilibrium values of (a, b, x_d), $(J_E, J_S, J_F,\ J_H)$, and (q, λ) through the following equations:

$$a = \beta(J_F - J_H) - b(1-b)^2 \tfrac{\bar{x}\mathbb{E}(y^2)}{c}, \tag{1}$$

$$b = \tfrac{1}{2}\left(1 + \tfrac{x_d}{\bar{x}}\right), \tag{2}$$

$$x_d(D) = \tfrac{2c[B - a + \beta(1-\lambda)(J_S' - I)]}{b^2\mathbb{E}(y^2)}, \tag{3}$$

$$J_F = \beta J_H + b(1-b)^2 \tfrac{\mathbb{E}(y^2)\bar{x}^2}{\sqrt{3}c\sigma_x}, \tag{4}$$

$$J_H = q\beta J_F + (1-q)\beta J_H - H, \tag{5}$$

$$J_S = B + \beta\lambda I + (1-\lambda)\beta J_S, \tag{6}$$

$$J_E(x) = a + \tfrac{b^2}{2c} x\mathbb{E}(y^2) + \beta I, \tag{7}$$

$$(1-u)F(x_d) = u\lambda[1 - F(x_d)], \tag{8}$$

$$\beta q(J_F - J_H) = H, \tag{9}$$

$$q = A - \lambda, \tag{10}$$

$$\text{with} \quad I \equiv \textstyle\int_{x'} \max[J_E(x'), J_S]dF(x').$$

First, we find the expressions for I and J_S based on J_E. To do so, we work with (6), (7) and $I \equiv \int_{x'} \max[J_E(x'), J_S]dF(x')$. Putting (7) into the expression for I, together with (6), we solve for J_S and I and further compute

$$J_S - I = -[1 - F(x_d)]\frac{b^2(1-b)}{2c}\mathbb{E}(y^2)\bar{x}^2.$$

After simplifying (3), we obtain

$$B - \beta(J_F - J_H) = \beta(1-\lambda)\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c(\bar{x} - \underline{x})} b^2(1-b)^2 + (3b^2 - 2b)\tfrac{\mathbb{E}(y^2)\bar{x}}{2c}. \tag{A.1}$$

Substituting the free entry condition in (9) into (5), we have

$$J_H = 0 \qquad \text{and} \qquad J_F = b(1-b)^2 \tfrac{2\mathbb{E}(y^2)\bar{x}^2}{c(\bar{x} - \underline{x})}.$$

Using (10) to simplify (5), we obtain

$$(A-\lambda)\beta b(1-b)^2 \tfrac{2\mathbb{E}(y^2)\bar{x}^2}{c(\bar{x}-\underline{x})} = H. \tag{A.2}$$

Note that (A.1) and (A.2) only involve b and λ. Therefore, we can solve for both. Once the optimal value for b is obtained, all other equilibrium outcomes as such a and x_d are solved since they are only functions of b.

To solve for b, we obtain an expression for λ from (A.2) and put it into (A.1). This yields the following equation which only involves b:

$$G(b) = (1-A)\beta\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x} b^2(1-b)^2 + 2\beta\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x} b(1-b)^2$$

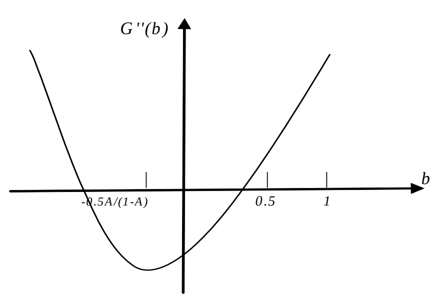
$$+\tfrac{\mathbb{E}(y^2)\bar{x}}{c}(3b^2-2b) + Hb - 2B = 0.$$

Given $x_d = (2b-1)\bar{x}$, the admissible b belongs to (0.5, 1). Therefore, we can show that

$$G''(b) = \tfrac{d^2G}{db^2} = 2\beta\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}\left[(1-A)(1-6b+6b^2)+6b-4\right] + 6\tfrac{\mathbb{E}(y^2)\bar{x}}{c}.$$

This quadratic function reaches its minimum at $-\frac{A}{2(1-A)}$, which is in the inadmissible range for b. Given $0 < \beta < 1$ and $0 < A < 2$, we can easily show that $G''(b = \frac{1}{2}) = \beta\frac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}(\frac{6\sqrt{3}\sigma_x}{\beta\bar{x}} + A - 3) > 0$ with reasonable parameters for σ_x and $\bar{x}$ and $G''(b=1) = 2\beta\frac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}(\frac{3\sqrt{3}\sigma_x}{\beta\bar{x}} + 3 - A) > 0$. Since the coefficient in front of b in the quadratic function is positive, therefore, we can draw a diagram for $G''(b)$ below. The diagram indicates that $G'(b) = \frac{dG}{db}$ is increasing for $b \in (0.5, 1)$.

Fig. A1 : $G''(b)$



It is easy to show that

$$G'(b) = 2(1-A)\beta\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x} b(1-b)(1-2b) + 2\beta\tfrac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}(1-b)(1-3b) + 2\tfrac{\mathbb{E}(y^2)\bar{x}}{c}(3b-1) + H.$$

We then obtain $G^{'}(b=1)=\frac{\mathbb{E}(y^2)\bar{x}^2}{c}+H>0$ and $G^{'}(b=\frac{1}{2})=\frac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x}(\frac{\sqrt{3}\sigma_x}{\bar{x}}-\frac{1}{2}\beta)+H$, whose sign is ambiguous. Hence, there are two possibilities to graph $G^{'}(b)$:

Fig. A2a : $G^{'}(b=\frac{1}{2})>0$

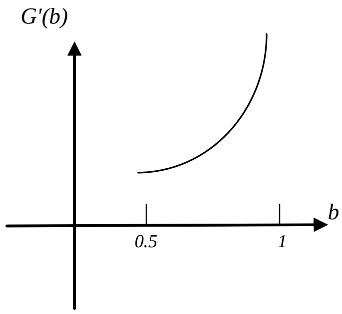
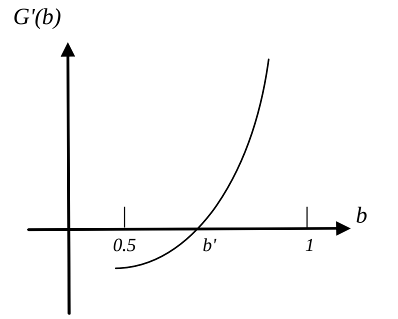


Fig. A2b : $G^{'}(b=\frac{1}{2})<0$



It is easy to show that $G(b=1)=\frac{\mathbb{E}(y^2)\bar{x}}{c}+H-2B>G(b=0.5)=\frac{\mathbb{E}(y^2)\bar{x}^2}{16c}\left[\frac{(5-A)\beta\bar{x}}{\sqrt{3}\sigma_x}-4\right]+\frac{1}{2}H-2B$. In order to ensure the existence of an equilibrium, we require $G(b=1)>0$ and $G(b=0.5)<0$. These two conditions imply that the unemployment benefit should satisfy $B\in[B_1,B_2]$, where

$$B_1\equiv\frac{\mathbb{E}(y^2)\bar{x}^2}{32c}\left[\frac{(5-A)\beta\bar{x}}{\sqrt{3}\sigma_x}-4\right]+\frac{1}{4}H,\quad B_2\equiv\frac{\mathbb{E}(y^2)\bar{x}}{2c}+\frac{1}{2}H.$$

A sufficient condition for $B_2>B_1$ is that H is sufficiently high.

Based on this restriction, we can depict the solution for b with respect to the two possibilities depicted in Fig. A2a and Fig. A2b:

Fig. A3a : $G^{'}(b=\frac{1}{2})>0$

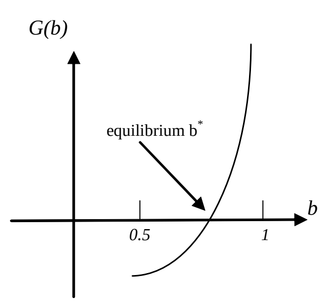
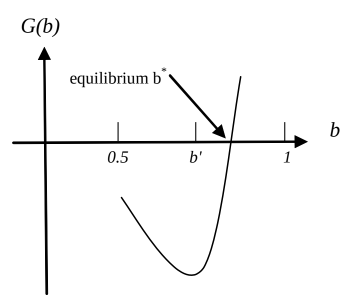


Fig. A3b : $G^{'}(b=\frac{1}{2})<0$



In either case, there exists a unique solution b^* and $\frac{\partial G}{\partial b}\mid_{b=b^*}>0$.

B. Comparative statics for equilibrium incentive contract and firm size

B.1. Profit-sharing ratio and Fixed Salary

Given that $\frac{\partial G}{\partial b}\mid_{b=b^*}>0$, it is easy to derive the comparative statics for the profit-sharing ratio b^* to various model parameters. We focus on the impact of the expected aggregate productivity μ_y, the systematic risk σ_y and the specific risk σ_x. Since

$$\frac{\partial b^*}{\partial \mathbb{E}(y^2)} = -\frac{\partial G/\partial \mathbb{E}(y^2)}{\partial G/\partial b} = \frac{-(2B-Hb)}{\mathbb{E}(y^2)\partial G/\partial b}\mid_{b=b^*}<0,$$

we can obtain

$$\frac{\partial b^*}{\partial \mu_y} = 2\mu_y \frac{\partial b^*}{\partial \mathbb{E}(y^2)} < 0 \qquad \text{and} \qquad \frac{\partial b^*}{\partial \sigma_y} = 2\sigma_y \frac{\partial b^*}{\partial \mathbb{E}(y^2)} < 0.$$

Also,we have

$$\frac{\partial b^*}{\partial \sigma_x} = -\frac{\partial G/\partial \sigma_x}{\partial G/\partial b} = \frac{b(2-3b)\mathbb{E}(y^2)\mu_x}{c\sigma_x \frac{\partial G}{\partial b}} + \frac{(2B-Hb)\underline{x}}{c\bar{x}\sigma_x \frac{\partial G}{\partial b}}.$$

It is easy to show that $\frac{\partial b^*}{\partial \sigma_x}\mid_{b=b^*}>0$ when $b<\frac{2}{3}$, and ambiguous otherwise.

As for the equilibrium salary a stated in (3.2), we can rewrite it as

$$a^* = \left(\frac{\beta \bar{x}^2}{\sqrt{3}\sigma_x} - \bar{x}\right) \frac{\mathbb{E}(y^2)}{c} f(b^*) \qquad \text{with} \qquad f(b) = b(1-b)^2.$$

To ensure positive salary, we require $\beta > \frac{\sqrt{3}\sigma_x}{\bar{x}}$. Given the uniform distribution for x, it is easy to show $\frac{\sqrt{3}\sigma_x}{\bar{x}} < \frac{1}{2}$. That is, $\beta > \frac{\sqrt{3}\sigma_x}{\bar{x}}$ can be easily satisfied. To obtain the comparative statics, we first show

$$\frac{\partial f}{\partial b}\mid_{b=b^*} = (1-b^*)(1-3b^*) < 0,$$

given that $b^* > \frac{1}{2}$. Then we obtain

$$\frac{\partial a^*}{\partial \mu_y} = 2\mu_y \left(\frac{a^*}{\mathbb{E}(y^2)} + \frac{a^*}{f(b^*)}\frac{df}{db^*}\frac{\partial b^*}{\partial \mathbb{E}(y^2)}\right) > 0 \qquad \text{and} \qquad \frac{\partial a^*}{\partial \sigma_y} = 2\sigma_y \left(\frac{a^*}{\mathbb{E}(y^2)} + \frac{a^*}{f(b^*)}\frac{df}{db^*}\frac{\partial b^*}{\partial \mathbb{E}(y^2)}\right) > 0.$$

Also, for $b < \frac{2}{3}$,

$$\frac{\partial a^*}{\partial \sigma_x} = -\frac{1}{\sqrt{3}\sigma_x^2}\left[\left(\beta\bar{x} - \sqrt{3}\sigma_x\right) + \beta\bar{x}^2(1-\beta)\right]\frac{\mathbb{E}(y^2)}{c} f(b^*) + \frac{a^*}{f(b^*)}\frac{df}{db^*}\frac{\partial b^*}{\partial \sigma_x} < 0,$$

ambiguous otherwise.

B.2. Equilibrium Firm Value

We can rewrite the equilibrium firm value J_F^* as

$$J_F^* = \frac{\mathbb{E}(y^2)\bar{x}^2}{c\sqrt{3}\sigma_x} f(b^*).$$

As shown earlier, $\frac{\partial f}{\partial b^*} < 0$ for $b^* > \frac{1}{2}$. It is easy to obtain

$$\frac{\partial J_F^*}{\partial \mu_y} = 2\mu_y \left(\frac{J_F^*}{\mathbb{E}(y^2)} + \frac{J_F^*}{f(b^*)} \frac{df}{db^*} \frac{\partial b^*}{\partial \mathbb{E}(y^2)} \right) > 0 \qquad \text{and} \qquad \frac{\partial J_F^*}{\partial \sigma_y} = 2\sigma_y \left(\frac{J_F^*}{\mathbb{E}(y^2)} + \frac{J_F^*}{f(b^*)} \frac{df}{db^*} \frac{\partial b^*}{\partial \mathbb{E}(y^2)} \right) > 0.$$

Also, for $b < \frac{2}{3}$,

$$\frac{\partial J_F^*}{\partial \sigma_x} = -\frac{\left(\mu_x - \sqrt{3}\sigma_x\right)}{\sqrt{3}\sigma_x^2} \frac{\mathbb{E}(y^2)}{c} f(b^*) + \frac{J_F^*}{f(b^*)} \frac{df}{db^*} \frac{\partial b^*}{\partial \sigma_x} < 0,$$

ambiguous otherwise.

B.3. Ratio between total expected pay and firm size

We know that

$$R_{pay/size} = \frac{a + b\mathbb{E}(\pi)}{J_F^*} = \frac{{b^*}^2}{1-b^*} + \beta - \frac{\sqrt{3}\sigma_x}{\bar{x}} \qquad \text{and} \qquad \frac{\partial R_{pay/size}}{\partial b} = \frac{b(2-b)}{(1-b)^2} > 0.$$

Thus, it is easy to show the following results.

$$\frac{\partial R_{pay/size}}{\partial \mu_y} = 2\mu_y \frac{b(2-b)}{(1-b)^2} \frac{\partial b^*}{\partial \mathbb{E}(y^2)} < 0 \qquad \text{and} \qquad \frac{\partial R_{pay/size}}{\partial \sigma_y} = 2\sigma_y \frac{b(2-b)}{(1-b)^2} \frac{\partial b^*}{\partial \mathbb{E}(y^2)} < 0.$$

$$\frac{\partial R_{pay/size}}{\partial \sigma_x} = \frac{b(2-b)}{(1-b)^2} \frac{\partial b}{\partial \sigma_x} - \frac{\sqrt{3}\mu_x}{\bar{x}^2} \,|_{b=b^*} > 0 \text{ when } \frac{\partial b}{\partial \sigma_x} > \frac{\mu_x}{\sqrt{3}(\mu_x + \sqrt{3}\sigma_x)^2},$$

ambiguous otherwise.

Table 1: summary statistics

This table reports the summary statistics on the executive compensation and characteristics, the firm characteristics, and macroeconomic variables for the period of 1992 to 2005 with a sample size of 10,837 firm-years. The executive compensation and characteristics data are retrieved from ExecuComp. New equity incentive is the pay-to-performance sensitivity of a CEO based on the stock and option grant for the fiscal year with respect to the $1,000 change in shareholders' wealth. Total equity incentive is the sensitivity for a CEO based on the cumulative stock and option grants with respect to the $1,000 change in shareholder's wealth. Firm characteristics data are from COMPUSTAT and CRSP. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. The annual GDP growth data are retrieved from the website of the Bureau of Economic Analysis at www.bea.gov/beahome.html. The commercial paper spread is defined as the difference between the annualized rate on three-month commercial paper and the three-month T-bill rate, which are retrieved from the website of the Federal Reserve Board at www.federalreserve.gov.

Variables	Mean	Std Dev	Min.	25% Percentile	Median	75% Percentile	Max.	Skewness	Kurtosis
	Panel A: Executive Characteristics and Compensation								
Salary (Thousand)	$627	$307	$29	$400	$572	$800	$1,700	0.96	4.11
Bonus (Thousand)	$640	$842	$0	$100	$375	$822	$4,901	2.59	11.25
Total Compensation (Thousand)	$3,991	$5,177	$210	$1,058	$2,145	$4,634	$30,835	2.95	13.10
New Equity Incentive (Per $1,000 Change in Shareholders' Wealth)	$2.10	$3.27	$0.00	$0.15	$1.00	$2.52	$19.58	3.12	14.51
Total Equity Incentive (Per $1,000 Change in Shareholders' Wealth)	$27.56	$58.63	$0.03	$2.29	$5.95	$18.87	$332.76	3.40	14.98
Executive Tenure	8.30	7.64	0.42	2.84	5.89	11.17	38.02	1.68	5.94
Executive Age	55.75	7.64	29.00	51.00	56.00	61.00	90.00	0.20	3.56
	Panel B: Firm Characteristics								
Total Firm Return Volatility (Annualized)	45%	21%	16%	30%	39%	55%	116%	1.27	4.53
Specific Firm Return Volatility (Annualized)	41%	19%	14%	27%	37%	51%	108%	1.20	4.39
Systematic Firm Return Volatility (Annualized)	15%	10%	1%	8%	13%	19%	54%	1.55	6.01
Market Capitalization (Million)	$5,947	$15,520	$42	$446	$1,196	$3,954	$108,684	4.86	28.78
Assets (Million)	$4,283	$9,795	$55	$416	$1,074	$3,330	$76,836	4.86	31.30
Sales Growth	13%	24%	-48%	1%	9%	20%	119%	1.49	8.00
	Panel C: Macroeconomic Variables								
GDP (Trillion)	$9.09	$1.93	$6.34	$7.82	$9.01	$10.13	$12.49	0.23	-1.01
Commercial Paper Spread (Basis Points)	24	13	1	15	26	33	43	-0.38	-0.87

Table 2: correlation

This table reports the correlations among explanatory variables and control variables for the period of 1992 to 2005 with a sample size of 10,837 firm-years. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. The dollar risks are obtained by multiplying the corresponding return volatilities to the market capitalization.

	GDP	Lagged CP Spread	Market Capitalization	Assets	Sales Growth	Tenure	Age	Total Firm Return Volatility	Specific Firm Return Volatility	Systematic Firm Return Volatility
GDP	1.000									
Lagged CP Spread	-0.544	1.000								
Market Capitalization	0.046	0.005	1.000							
Assets	0.044	-0.033	0.799	1.000						
Sales Growth	-0.023	0.030	0.034	-0.008	1.000					
Tenure	-0.031	0.028	-0.050	-0.075	0.058	1.000				
Age	-0.047	0.014	0.039	0.071	-0.055	0.420	1.000			
Total Firm Return Volatility	0.348	-0.270	-0.193	-0.225	0.087	0.013	-0.202	1.000		
Specific Firm Return Volatility	0.342	-0.245	-0.216	-0.249	0.092	0.012	-0.204	0.989	1.000	
Systematic Firm Return Volatility	0.249	-0.275	-0.019	-0.036	0.031	0.015	-0.121	0.667	0.557	1.000

Table 3: test of prediction 1 - effects of macroeconomic variable and firm risks on Pay-to-Performance Sensitivity (PPS)

This table reports the results for regression (4.1): $PPS\ b = a_1 + a_2$ (GDP %/NCP spread) + a_3 Firm-specific risk + a_4 Firm-systematic risk + a_5 Age + a_6 Tenure + a_7 Firm size + a_8 Firm growth + ε. The sample size is 10,837 firm-years for the period of 1992 to 2005. The dependent variables in Panels A and B are, respectively, the new equity incentive calculated with stock and option grants for the fiscal year and the total equity incentive calculated with the cumulative stock and option grants, with respect to the $1,000 change in shareholders' wealth. GDP % is the GDP growth in the fiscal year. NCP spread is the negative lagged commercial paper spread. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. Firm size and firm growth are proxied by the firm's asset value and its sales growth, respectively. We also run regression (4.1) by replacing "specific " and "systematic" risks with "total risk". The coefficient and *t*-value for "total risk" are reported at the bottom of the table. For all regressions, we control for industry-fixed effects. For OLS, standard errors are clustered at firm level. For median regressions, standard errors are calculated by bootstrapping with 500 replications. *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

		Panel A: New Equity Incentive				Panel B: Total Equity Incentive			
	Prediction	OLS Regression		Median Regression		OLS Regression		Median Regression	
	This Model								
GDP (%)	-	-0.073 ***		-0.039 ***		-0.913 ***		-0.235 ***	
		(2.972)		(3.038)		(3.045)		(3.175)	
NCP Spread (basis points)	-		-0.020 ***		-0.006 ***		-0.165 ***		-0.035 ***
			(8.271)		(5.176)		(3.291)		(5.529)
Firm-Specific Risk (annualized)	+	2.748 ***	3.218 ***	2.167 ***	2.459 ***	6.908	11.096	3.877 ***	5.141 ***
		(8.505)	(9.575)	(12.409)	(12.212)	(0.927)	(1.395)	(5.347)	(6.530)
Firm-Systematic Risk (annualized)	-	-1.166 **	-0.759	-0.608 **	-0.551 **	-17.852	-14.688	-3.536 ***	-3.442 ***
		(2.280)	(1.496)	(2.221)	(1.987)	(1.618)	(1.331)	(3.085)	(2.805)
Age		-0.018 ***	-0.016 **	-0.011 ***	-0.011 ***	-0.337	-0.325	-0.080 ***	-0.072 ***
		(2.598)	(2.386)	(4.301)	(4.287)	(1.571)	(1.516)	(5.328)	(4.760)
Tenure		-0.022 ***	-0.023 ***	-0.019 ***	-0.021 ***	3.212 ***	3.201 ***	1.142 ***	1.135 ***
		(3.482)	(3.708)	(7.472)	(7.802)	(11.623)	(11.589)	(21.292)	(21.662)
Firm Size		-0.419 ***	-0.384 ***	-0.185 ***	-0.167 ***	-6.723 ***	-6.424 ***	-1.786 ***	-1.715 ***
		(13.277)	(12.008)	(14.433)	(12.589)	(6.644)	(6.144)	(24.273)	(22.377)
Firm Growth		0.015	-0.090	-0.012	-0.055	2.139	1.035	0.697	0.476
		(0.091)	(0.551)	(0.140)	(0.662)	(0.830)	(0.406)	(1.509)	(1.082)
Adjusted R^2		0.115	0.121			0.248	0.249		
Pseudo R^2				0.067	0.067			0.090	0.091
	Traditional Model								
Firm Total Risk	-	2.068 ***	2.682 ***	1.736 ***	1.924 ***	-0.344	4.927	2.150 ***	3.565 ***
		(8.305)	(9.914)	(12.301)	(12.146)	(0.055)	(0.702)	(3.705)	(5.556)
Adjusted R^2		0.113	0.119			0.247	0.248		
Pseudo R^2				0.065	0.066			0.090	0.090

Table 4: median statistics for annual pay, firm Size, ratio between annual pay and firm size and firm risks during 1993–2005

This table reports the median statistics for annual compensation, firm size, ratio between annual pay and firm size, and firm risks. Firm size is either proxied by the firm's asset value or the firm's market capitalization. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. The sample size is 10,810 firm-years for the period of 1993 to 2005.

Year	Total	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Sample Size	10,810	126	678	770	818	861	907	901	890	949	1,005	1,016	1,051	838
Annual Pay (millions)														
Salary		0.469	0.500	0.500	0.517	0.538	0.536	0.550	0.551	0.575	0.600	0.636	0.650	0.677
Salary plus Bonus		0.726	0.800	0.800	0.835	0.916	0.881	0.931	0.941	0.856	0.979	1.039	1.212	1.304
Total Compensation		1.315	1.510	1.447	1.638	2.015	1.991	2.164	2.381	2.474	2.569	2.386	3.079	3.107
Firm Size (billions)														
Size 1 = Asset		0.967	1.048	0.998	1.057	1.158	1.094	1.110	1.145	1.184	1.189	1.217	1.459	1.494
Size 2 = Market Capitalization		0.871	1.000	1.041	1.204	1.449	1.144	1.121	1.145	1.201	1.066	1.437	1.759	1.786
$R_{pay/size}$ = Total Pay/Size														
Total Pay / Size 1		0.136%	0.144%	0.145%	0.155%	0.174%	0.182%	0.195%	0.208%	0.209%	0.216%	0.196%	0.211%	0.208%
Total Pay / Size 2		0.151%	0.151%	0.139%	0.136%	0.139%	0.174%	0.193%	0.208%	0.206%	0.241%	0.166%	0.175%	0.174%
Firm Risks														
Firm-Systematic Risk		0.161	0.143	0.139	0.100	0.081	0.084	0.127	0.134	0.137	0.156	0.167	0.160	0.151
Firm-Specific Risk		0.317	0.295	0.305	0.300	0.303	0.312	0.326	0.377	0.418	0.443	0.459	0.446	0.406
Macroeconomic Variables														
GDP (Trillion $)		6.657	7.072	7.398	7.817	8.304	8.747	9.268	9.817	10.128	10.470	10.971	11.734	12.487
Commerical Paper Spread (basis points)		24	15	29	27	26	38	43	40	31	17	5	8	1

Fig. 3: Time Trend for Median Annual Pay during 1993–2005

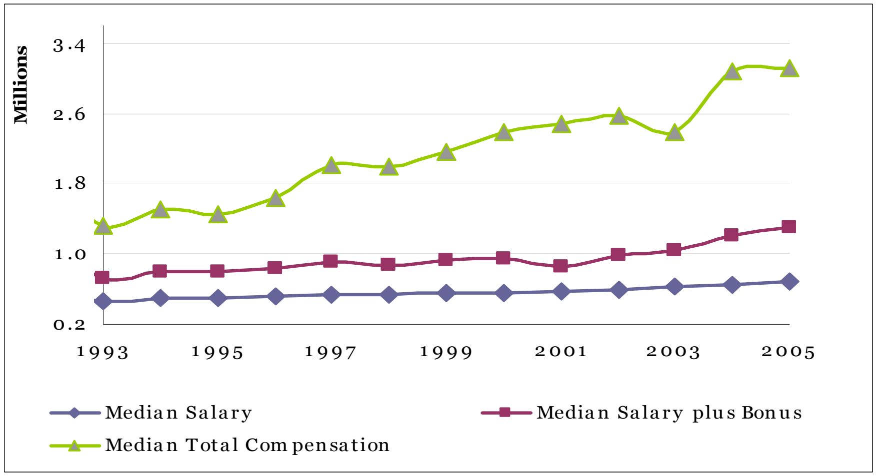


Fig. 4: Time Trend for Median GDP, CP Spread and Firm Size during 1993-2005

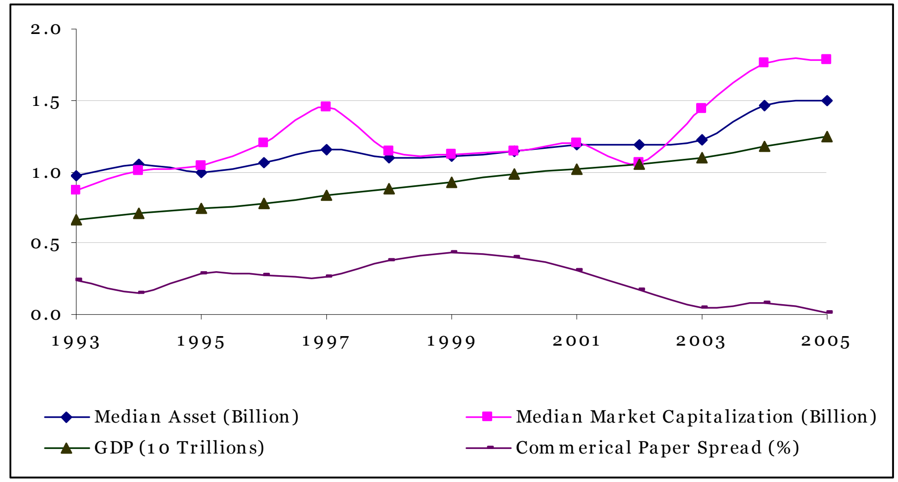


Fig. 5: Time Trend for Median Ratio between Pay and Size during 1993–2005

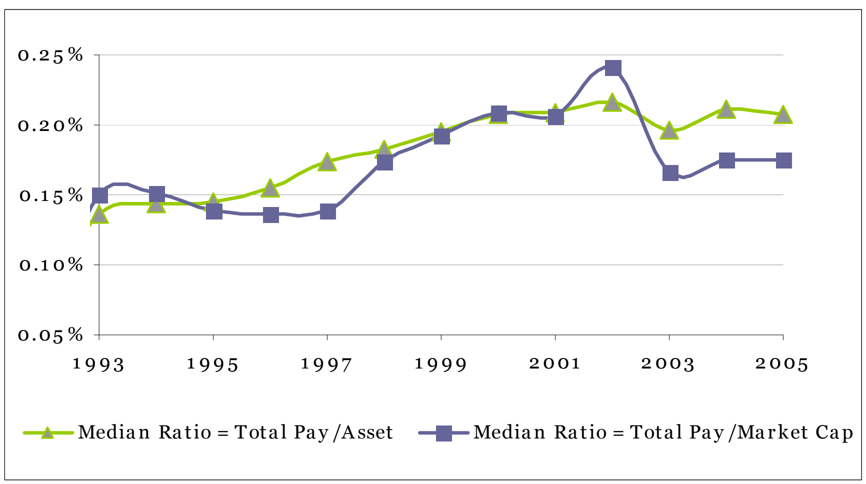


Fig. 6: Time Trend for Median Firm Risks during 1993-2005

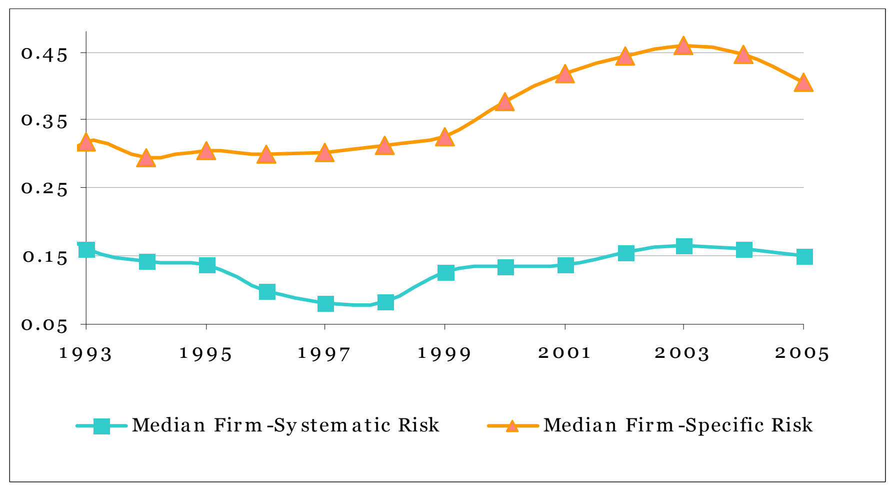


Table 5: test of prediction 2 – effects of macroeconomic variable and firm risks on annual compensation and firm size

This table reports median regression results for (4.2): *log(annual compensation/firm size)* = $a_1 + a_2$ (log(GDP) / NCP spread) + a_3 Firm-specific risk + a_4 Firm-systematic risk + a_5 Age + a_6 Tenure + a_7 Firm growth + ε. The sample size is 10,837 firm-years for the period of 1992 to 2005. The dependent variables in Panels A and B are firm size and annual compensation, respectively. log(GDP) is the logarithemic of GDP in the fiscal year. NCP spread is the negative lagged commercial paper spread. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. "b" is the pay-to-performance sensitivity computed from the stock and option grants for the fiscal year with respect to the $1,000 change in shareholders' wealth. Firm size and firm growth are proxied by its asset value and sales growth, respectively. We also run (4.2) by replacing "specific " and "systematic" risks with "total risk". The coefficient and *t*-value for "total risk" are reported at the bottom of the table. We control for industry-fixed effects. Standard errors are calculated by bootstrapping with 500 replications. *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

	Prediction	Panel A: Annual Compensation						Panel B: Firm Size			
	This Model	Salary		Salary plus Bonus		Total Compensation		Asset		Market Capitalization	
log (GDP)	+	1.003 ***		1.418 ***		1.982 ***		2.156 ***		2.224 ***	
		(29.48)		(27.94)		(27.45)		(22.28)		(23.40)	
NCP Spread (basis points)	+		0.007 ***		0.011 ***		0.011 ***		0.015 ***		0.018 ***
			(19.98)		(16.97)		(11.63)		(14.97)		(13.85)
Firm-Specific Risk (annualized)	-	-1.262 ***	-1.046 ***	-1.935 ***	-1.554 ***	-2.341 ***	-1.729 ***	-5.299 ***	-4.791 ***	-5.606 ***	-5.153 ***
		(32.08)	(27.53)	(30.93)	(27.14)	(24.76)	(18.49)	(39.79)	(42.17)	(39.18)	(42.11)
Firm-Systematic Risk (annualized)	+	0.712 ***	0.638 ***	1.056 ***	0.852 ***	2.13 ***	1.864 ***	4.385 ***	4.168 ***	4.676 ***	4.532 ***
		(11.41)	(9.94)	(10.33)	(7.44)	(13.34)	(10.26)	(21.44)	(20.47)	(20.31)	(19.25)
Age		0.010 ***	0.011 ***	0.011 ***	0.012 ***	0.005 **	0.005 **	0.014 ***	0.015 ***	0.005 **	0.005 **
		(11.33)	(12.43)	(7.80)	(8.04)	(2.52)	(2.57)	(5.84)	(5.38)	(1.96)	(2.02)
Tenure		-0.003 ***	-0.003 ***	-0.004 ***	-0.006 ***	-0.012 ***	-0.015 ***	-0.02 ***	-0.019 ***	-0.012 ***	-0.01 ***
		(3.16)	(3.67)	(3.34)	(4.89)	(6.53)	(7.86)	(10.55)	(9.67)	(4.84)	(4.43)
Firm Growth		-0.086 ***	-0.101 ***	0.324 ***	0.305 ***	0.485 ***	0.465 ***	0.206 ***	0.177 **	0.891 ***	0.907 ***
		(4.67)	(4.89)	(8.82)	(7.43)	(9.77)	(8.38)	(3.04)	(2.36)	(10.34)	(11.96)
Pseudo R^2		0.184	0.147	0.149	0.116	0.112	0.070	0.215	0.195	0.199	0.181
Firm Total Risk		-0.932 ***	-0.763 ***	-1.412 ***	-1.208 ***	-1.483 ***	-1.047 ***	-3.42 ***	-3.1 ***	-3.778 ***	-3.436 ***
		(29.02)	(25.71)	(30.09)	(27.20)	(20.16)	(13.53)	(29.17)	(32.57)	(28.04)	(27.27)
Pseudo R^2		0.165	0.133	0.130	0.105	0.091	0.055	0.162	0.149	0.149	0.137

Table 6: test of prediction 3 – effects of macroeconomic variable and firm risks on ratio between total compensation and firm size

This table reports median regression results for (4.3): $R_{pay/size} \times 10^3 = a_1 + a_2$ (GDP % / NCP spread) + a_3 Firm-specific risk + a_4 Firm-systematic risk + a_5 Age + a_6 Tenure + a_7 Firm growth + a_8 Year + ε. The sample size is 10,837 firm-years for the period of 1992 to 2005. The dependent variable in Panel A is the ratio between an executive's total compensation and the firm's asset value while the dependent variable in Panel B is the ratio between an executive's total compensation and the firm's market capitalization. GDP % is the GDP growth in the fiscal year. NCP spread is the negative lagged commercial paper spread. Total firm return volatility is the stock return volatility over the 60 months prior to the fiscal year. Systematic firm return volatility is equal to a firm's beta multiplied by the stock market risk while specific firm return volatility is the square root of the difference between the total return variance and the systematic return variance. Firm growth is proxied by the firm's sales growth. We also run regression (4.3) by replacing "specific " and "systematic" risks with "total risk". The coefficient and *t*-value for "total risk" are reported at the bottom of the table. We control for industry-fixed effects. Standard errors are calculated by bootstrapping with 500 replications. *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

	Prediction	Panel A: $R_{pay/size}$ = Annual Total Pay/Asset Value		Panel B: $R_{pay/size}$ = Annual Total Pay/Market Cap	
	This Model				
GDP (%)	-	0.028 *		0.006	
		(1.704)		(0.345)	
NCP Spread (basis points)	-		-0.010 ***		-0.011 ***
			(6.682)		(7.474)
Firm-Specific Risk (annualized)	+	7.432 ***	7.526 ***	6.947 ***	6.878 ***
		(29.367)	(29.744)	(32.963)	(34.366)
Firm-Systematic Risk (annualized)	-	-4.605 ***	-4.355 ***	-4.360 ***	-4.086 ***
		(14.492)	(13.352)	(15.109)	(15.322)
Age		-0.014 ***	-0.016 ***	0.001	0.001
		(4.825)	(5.338)	(0.208)	(0.459)
Tenure		0.002	0.002	-0.003	-0.002
		(0.600)	(0.851)	(1.031)	(0.796)
Firm Growth		0.507 ***	0.532 ***	-0.816 ***	-0.873 ***
		(4.556)	(4.153)	(8.337)	(8.923)
Year		-0.056 ***	-0.038 ***	-0.052 ***	-0.032 ***
		(9.605)	(7.013)	(10.363)	(5.498)
Pseudo R^2		0.129	0.130	0.117	0.119
Firm Total Risk		5.474 ***	5.595 ***	5.046 ***	5.177 ***
		(29.463)	(27.806)	(23.751)	(25.825)
Pseudo R^2		0.108	0.111	0.095	0.099