A Model of Managerial Talent: Addressing Some Puzzles in CEO Compensation

Stanimir Morfov* and Manuel Santos†

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Abstract

In this paper we present an adverse selection model of managerial talent. The model can account for some empirical regularities in executive compensation such as the higher level of CEO pay and the prominence of incentive pay in large and high-volatility firms as well as the controversial evidence on career concerns. Relative performance evaluation (RPE) is only obtained under rather restrictive separability conditions on the performance measure. Our analysis attests to the importance of adverse selection in executive compensation.

Keywords: Managerial talent, adverse selection, optimal contract, firm's size, volatility of company returns, CEO age, relative performance evaluation (RPE).

JEL Classification: D82, G30, J33

*University of Miami, School of Business Administration, Coral Gables, FL 33124-6550. E-mail: smorfov@bus.miami.edu

†University of Miami, School of Business Administration, Coral Gables, FL 33124-6550. E-mail: m.santos2@miami.edu

1 Introduction

In this paper we present a principal-agent model that appears to be instrumental in analyzing some documented puzzles in CEO compensation. The principal owns a firm subject to productivity shocks. The value of the firm depends on the agent's talent: a high-ability manager may propagate good productivity shocks and mitigate bad ones. The principal sets compensation so as to sort out the high-ability manager while satisfying individual rationality. The sensitivity of pay to performance is conformed by two opposing forces which reflect the dispersion of prior beliefs about managerial productivity and outside options.

CEO compensation has sparked controversy in the public debate, while adding another chapter to the growing concerns about income inequality. The lack of agreement among researchers and practitioners on an analytical framework to rationalize the observed characteristics of top managerial contracts leaves hanging key issues regarding the optimality of CEO pay and the role of regulation and economic policies in minimizing conflicts of interests and managerial rents to boost shareholder value. With the goal of contributing to a vast literature on executive pay and incentives, we here focus on the predictions of an adverse selection model and demonstrate its potential to address some of the puzzles in CEO compensation.[1]

Our analysis rests on the basic observation that motivating effort on the part of the CEO does not seem a focal issue in some contractual relationships; rather, the CEO may have a profound impact on the fate of the corporation. Principles for incentivizing effort may lose validity for attracting top man-

[1]See Edmans, Gabaix and Jenter (2017) for a comprehensive review of most recent work. These authors consider several stylized facts on executive compensation, and follow an eclectic approach spanning over models of job assignment and moral hazard, the rent extraction view, and the impact of institutional factors.

agerial talent. This is exemplified in some salient cases of fancy executives commanding one-dollar salaries and substantial amounts of equity-based pay. Take the late CEO of Apple Inc., Steve Jobs, who in 2000 received a salary of $1 and a grant of 20 million stock options. Most fancy CEOs already own substantial shares of their companies and so a prototypical moral hazard model should essentially predict a flat wage.

Our model offers a complementary view to existing theories of executive compensation based on moral hazard, assortative matching, and rent extraction. These theories often build on primitives that are hard to uncover from the data[2] and are faced with the challenge to consistently explain the cross-sectional and time series properties of CEO pay. Focusing on the adverse selection aspects of managerial performance sheds light on some puzzling empirical regularities in the compensation of senior executives and top-tier professionals, and the ambiguous relationship between risk and incentives. Moreover, there is the well documented lack of relative performance evaluation (RPE) in executive contracts, which in our adverse selection model comes naturally in situations where managerial ability must accommodate sectoral and global uncertainty. Finally, let us mention that adverse selection may account for some long-run trends in the structure of CEO pay which have been difficult to rationalize by theories of CEO power and rent seeking, firm's size, strengthening of managerial incentives, and increasing returns to general managerial skills.

The compensation of senior professionals appears difficult to explain by principal-agent models of hidden action. In academia, a senior candidate with recognized ability is often awarded a flat compensation scheme, whereas ju-

[2]Binding incentive compatibility constraints in tractable models of hidden action imply that the optimal contract would depend on distributions conditional on suboptimal effort levels. The unobservability of these distributions, however, limits the empirical predictions of such models.

nior faculty are usually given stronger incentives to perform well. Of course, the adverse selection problem arises because of the uncertainty as to whether or not a bright junior candidate will succeed in teaching and research.[3] Hence, the wage profile of a junior hire could be quite steep due to the inherent difficulties in identifying talent. Our model also contemplates another dimension of uncertainty: the distribution of agent's outside options. This latter dimension would lessen the sensitivity of pay in junior hiring in the event of a low dispersion of reservation wages among prospective junior candidates. Tenure-track contracts entail a probationary period to assess quality and alleviate the adverse selection problem,[4] but such a probationary period may not be necessary for senior candidates. Similarly, in sports, a senior head coach may be offered a long-term contract with essentially no bonus pay since talent is not under dispute.[5] Merit pay under a short-term contract would nevertheless be the norm for a promising junior head coach whose talent is yet to be validated.

The negative trade-off between risk and incentives is a central prediction of the prototypical model of agency. Conflicting evidence, however, has prompted extensions of the basic theory [Prendergast (2002)]. In our framework, the adverse selection problem stems from uncertainty about managerial productivity, which becomes most dramatic in complex, large corporations, and in risky and new economy firms.

[3] Appendix A considers an extended model in an attempt to deal with the uncertainty about managerial ability in junior hiring, and in complex or risky tasks.

[4] Up-or-out contracts have been justified under asymmetric learning about ability when firm-specific human capital is low [e.g., Ghosh and Waldman (2010)] or under bilateral moral hazard where employees would underinvest in firm-specific human capital and firms would underreport the value of their employees [Kahn and Huberman (1988)].

[5] More generally, age can affect the sensitivity of optimal pay in a non-linear form. An aging or injured athlete may be subject to minimum performance clauses and other compensation contingencies. Say that after a player's knee surgery, there is uncertainty about the type of recovery, which may just be the agent's private information. Then, the new contract may institute pay contingent on performance.

RPE is another aspect of contractual relationships in which the theory of agency does not accord with the prevailing compensation practices for upper level executives. While moral hazard models [Holmstrom (1982)] suggest that common uncertainty should be removed from managerial pay, we demonstrate that weak separability of the performance measure on managerial talent and internal productivity factors is a necessary condition for RPE to hold. Hence, RPE will fail if managerial talent directly interacts with some common shocks—even if firm-specific and common shocks are independent and reservation wages remain invariant to these shocks. Therefore, RPE can be a rather limiting condition in global corporations in which a CEO should be evaluated for the ability to leverage out the company under various economic circumstances and opportunities. As discussed below, firms will condition CEO compensation on various indicators of performance and economic activity, and the weights attached to these indicators will be affected by both firm- and CEO-specific factors. For example, we find that large companies allow CEO compensation to be more sensitive to idiosyncratic returns and to labor market trends, whereas high-volatility companies tend to focus on market share rather than on stock-based measures of performance.

Frydman and Saks (2010) and Murphy (2013) highlight the dramatic increase of stock options and vested stock in CEO compensation in the U.S. over the last decades. The long-run evolution of executive pay [Frydman and Saks (2010)] seems to favor theories based on a greater demand for specialized knowledge and skills, and the advent of the information age and globalization that has increased competition and impacted the productivities of various labor groups. This is consistent with our model in which increased competition as well as uncertainty about managerial ability upon the arrival of new technologies worsens the adverse selection problem—leading to a greater sensitivity of executive pay to performance.

Motivated by the inability of the CEO pay literature to account for observed pay-performance sensitivities as well as the lack of RPE, we review the empirical evidence and expose our theoretical results to the data. Our sample consists of firms in the S&P 1500 and covers the period June 1992 – August 2010. We investigate how the level and structure of CEO pay are affected by firm's size, volatility, new economy, technology, CEO age, tenure, and service as chair of the board. At a later stage, we study how these firm- and CEO-specific factors influence the sensitivity of CEO pay to some internal and external measures of performance.

The paper is organized as follows. Section 2 presents an adverse selection contracting problem. The shape of the optimal contract depends on the interaction of managerial ability with two different sources of uncertainty. Section 3 relates RPE to weak separability of the performance function. Section 4 illustrates the robustness of our results in a restricted setting of two-parameter, affine pay schedules. Section 5 extends the analysis to an equilibrium sorting framework of multiple firms and managerial types. Section 6 discusses the empirics of CEO pay, and confirms some basic predictions of our theory: CEOs of large and high-volatility firms are offered higher and steeper wage schedules, and young CEOs are offered steeper wage schedules. Section 7 analyzes the sensitivity of pay to different measures of performance and confirms the lack of RPE. Section 8 concludes. The Online Appendix contains an extended version of the model as well as all proofs and supporting material for our empirical exercises.

2 Contracting under Adverse Selection

We now introduce the optimization problem of the firm and analyze the structure of the optimal contract. Pay-performance sensitivity is shaped by two dimensions of uncertainty: *(i) Inside the firm*: A greater productivity of the high-ability manager leads to flatter pay, *(ii) Outside the firm*: A greater opportunity cost of the high-ability manager leads to steeper pay.

2.1 The Optimization Problem of the Firm

The distribution of firm's value is stochastically increasing in managerial talent. A manager has been preselected for the position. The prospective candidate could be a high-ability manager of talent $\overline{\tau}$ or a low-ability manager of talent $\underline{\tau}$, where $\overline{\tau} > \underline{\tau}$. The firm offers an incentive contract that will only be accepted by a high-ability manager. Cost minimization requires individual rationality to be binding for each manager type. While the firm may only be interested in hiring the high-ability manager, our model can easily be extended to serve the low-ability manager who would be prescribed a fixed wage [e.g., Jullien (2000)]. We could also consider a setting where the manager observes an imperfect signal about her ability. Hence, both parties would have inherent uncertainty about the manager type: the probability that the prospective candidate is a high-ability manager would always be less than one; see Appendix A for further details.

Let v be a stochastic measure of firm's value. For analytical convenience, we assume that v is positive with compact support $[\underline{v}, \overline{v}]$. Let $F(\cdot|\tau)$ be the cumulative distribution of v conditional on hiring a manager of talent $\tau = \overline{\tau}, \underline{\tau}$. The associated density $f(\cdot|\tau)$ exists for each $\tau = \overline{\tau}, \underline{\tau}$, and is positive at all points as well as continuously differentiable. We furthermore assume *strict monotonicity of the likelihood ratio in* τ. That is, $\frac{f(v|\underline{\tau})}{f(v|\overline{\tau})}$ is decreasing in v. Therefore, talent τ is instrumental in boosting firm's performance in the sense of first-order stochastic dominance, i.e., $F(\cdot|\overline{\tau}) < F(\cdot|\underline{\tau})$ almost everywhere.

The manager is risk averse. Preferences are represented by a utility function $u : \mathbb{R}_+ \to \mathbb{R}$. Function u is increasing and twice continuously differentiable with derivative functions $u' > 0$ and $u'' < 0$, and satisfies the following boundary conditions: $\lim_{w \to 0} u'(w) = \infty$ and $\lim_{w \to +\infty} u'(w) = 0$. The manager's reservation wage $\underline{w}$ is increasing in talent, i.e., $\underline{w}(\overline{\tau}) > \underline{w}(\underline{\tau})$.

The firm is risk-neutral, and seeks to minimize the expected cost of hiring a high-ability manager. The optimization problem is subject to two constraints. The first constraint is individual rationality on the part of the high-ability manager to accept the offer. The second constraint is individual rationality on the part of the low-ability manager not to accept the offer. More formally, the problem can be stated as follows:

$$\min_{w} \int w(v) f(v|\overline{\tau})\, dv \text{ subject to} \tag{P}$$

$$\int u(w(v))\, f(v|\overline{\tau})\, dv \geq u(\underline{w}(\overline{\tau})) \tag{1}$$

$$\int u(w(v))\, f(v|\underline{\tau})\, dv \leq u(\underline{w}(\underline{\tau})) \tag{2}$$

We assume that the set of feasible contracts is non-empty. Then, one can readily show that there exists an optimal contract $w(v)$. Our boundary conditions guarantee that $w(v) \in (0, \infty)$.

2.2 Characterization of the Optimal Contract

As is usual in these optimization problems, we first note that constraints (1) and (2) must be binding, and the associated Lagrange multipliers must both be positive. Note that constraint (1) must necessarily hold with equality; for if not, the principal could propose a slightly reduced wage without violating these two constraints. Also, constraint (2) must hold with equality; for if not, the principal could decrease the cost of hiring the high-ability manager by proposing a flatter wage. A constant wage, however, is not possible under the monotonicity of the outside wage option: $\underline{w}(\overline{\tau}) > \underline{w}(\underline{\tau})$.

The following lemma summarizes the standard properties of the optimal wage schedule.

Lemma 1 *The optimal contract $w(v)$ is unique, increasing, and continuously differentiable.*

Proofs are gathered in Appendix B. The slope of the optimal contract is characterized by two opposing forces that will work unambiguously in the linear case (see Section 4), but in the general case will only hold asymptotically.

Proposition 1 *Let $F(\cdot|\underline{\tau}) - F(\cdot|\overline{\tau}) \rightarrow 0$ pointwise (almost everywhere). Then, $u'(w(v))w'(v)$ becomes unbounded over a set of positive measure.*

The result highlights a general property of the structure of compensation; namely, as the contribution of managerial talent to firm's performance gets infinitesimally small, it becomes rather difficult for the principal to sort out talent. Hence, over some states, either the wage schedule $w(v)$ converges to zero or the derivative $w'(v)$ becomes unbounded. In the limit, a separating equilibrium will simply fail to exist.

Proposition 2 *Let $\underline{w}(\overline{\tau}) - \underline{w}(\underline{\tau}) \rightarrow 0$. Then, the derivative of the optimal wage $w'(v) \rightarrow 0$.*

The benefits of screening for talent tend to disappear when market conditions are such that the gap between the two outside options $\underline{w}(\overline{\tau}) - \underline{w}(\underline{\tau})$ becomes infinitesimally small. That is, the principal can readily dissuade the low-ability manager from accepting the offer.

In Section 5, the interplay of these two results will ensure the existence of a separating equilibrium with adverse selection. These propositions also suggest some comparative statics exercises that hold globally in the case of affine contracts (see Section 4). For instance, assume that the principal has available a second indicator to evaluate performance. Say that there is a new variable x that could represent the state of the economy or some firm-specific measure of performance such as sales revenue. The optimal wage schedule may then be written as $w(x, v)$. As the distance between the cumulative distribution functions $F(\cdot|\underline{\tau}, x)$ and $F(\cdot|\overline{\tau}, x)$ gets compressed, the principal should offer a steeper wage schedule based on v. And as this distance widens out, the principal should offer a flatter wage schedule. Therefore, as reflected in the distribution functions $F(\cdot|\underline{\tau}, x)$ and $F(\cdot|\overline{\tau}, x)$, talent may flourish in some environments, but may be suppressed in others, which would be manifested in the structure of compensation. In a general equilibrium setting with many firms and manager types, x can also be interpreted as some characteristic of the firm (e.g., size, volatility) or the manager (age). This underlies the empirical analysis of Sections 5 to 7.

3 RPE

There is little (if any) empirical support for RPE in executive pay; see Albuquerque (2009) for a review of the literature. Indeed, several explanations have been advanced to account for the lack of RPE: the ability of the executive to hedge systematic risk [Garvey and Milbourn (2003)], a positive correlation of common shocks with the marginal return of effort [Celentani and Loveira (2006)] or with the reservation wage [Oyer (2004)], the use of a wrong benchmark [Bizjak, Lemmon and Naveen (2008)], and rent extraction under captured boards of directors [Bertrand and Mullainathan (2001)].

In the prototypical moral hazard model [Holmstrom (1979)], the optimal contract depends non-trivially on a signal if and only if the signal is informative about effort. Hence, managerial pay is invariant to common shocks if and only if this same property holds for the likelihood ratio. Our approach to RPE targets the performance function v as a model primitive.

Let us suppose that firm's performance $v = v(\tau, \varepsilon, \theta)$ is subject to both idiosyncratic and systematic risks, where ε affects only the firm in question and θ affects other firms as well. Function $v(\tau, \varepsilon, \theta)$ is continuously differentiable with positive partial derivatives. As in the model of the previous section, the principal cannot observe the agent's type $\tau = \overline{\tau}, \underline{\tau}$, and must offer the contract before the realization of random shocks ε and θ. We also assume that the principal can verify firm's performance v and the realization of θ, but not the realization of ε. Therefore, compensation w is a function of both v and θ. The shocks ε and θ are characterized by continuous density functions, and all previous regularity conditions on utility and density functions are supposed to hold.

We define RPE as a situation in which executive compensation does not depend on the common shock. The definition is in line with the *strong-form* RPE hypothesis [Antle and Smith (1986), Janakiraman, Lambert and Larcker (1992)]; namely, systematic risk is *completely* removed from managerial pay. While some researchers have found evidence that common shocks are partially filtered out from firm's performance in executive compensation contracts, the strong-form RPE hypothesis has been consistently rejected.

Definition 1 *We say that RPE holds if* $w(v(\tau, \varepsilon, \theta), \theta) = w(v(\tau, \varepsilon, \theta'), \theta')$ *for all* $(\tau, \varepsilon, \theta, \theta')$.

In general, random shocks ε and θ both affect the productivity of τ. Under weak separability of v on (τ, ε), the performance ordering over combinations of managerial talent and firm-specific shock realizations is not affected by the common shock.

Definition 2 *Firm's value v is weakly separable on (τ, ε) if $v(\tau, \varepsilon, \theta) > v(\tau', \varepsilon', \theta)$ for some θ implies that $v(\tau, \varepsilon, \theta') > v(\tau', \varepsilon', \theta')$ for all θ'.*

We demonstrate that weak separability is a necessary condition for RPE. The result holds for an arbitrary joint distribution of the shocks.

Proposition 3 *If RPE holds, then v is weakly separable on (τ, ε).*

Holmstrom (1982, Theorem 9) shows that the principal can infer the realization of an unobservable common shock when technology is *additively* or *multiplicatively* separable, the shocks are independent, and the number of peers grows infinitely large. Common uncertainty should then be removed from individual compensation. We next show that RPE holds if the performance function v is *weakly separable* on (τ, ε).

Proposition 4 *Assume that shocks ε and θ are independent. Suppose that function $v(\tau, \varepsilon, \theta)$ is weakly separable on (τ, ε). Then, $w(v(\tau, \varepsilon, \theta), \theta) = w(v(\tau, \varepsilon, \theta'), \theta')$ for all $(\tau, \varepsilon, \theta, \theta')$.*

In other words, managerial compensation should not be conditioned on the common shock because this shock neither interacts with managerial talent nor affects the posterior distribution of the firm-specific shock. This is to be contrasted with Proposition 3: weak separability of the performance function is a necessary condition for RPE even if the shocks are not independent.

One can think of situations in which the performance function $v(\tau, \varepsilon, \theta)$ may or may not be weakly separable on (τ, ε). For instance, an expansion of the company to be executed by the manager could only be profitable under favorable aggregate demand and supply shocks which may either stimulate sales or lower production costs; e.g., sales may be improved under lower interest rates, and costs may be reduced under lower oil prices. Hence, an expansion of the company could violate the assumption of weak separability on managerial talent and internal productivity factors because such an expansion may require favorable economic conditions. At the other extreme, some organizational improvements as well as the launching of enhanced products would satisfy the assumption of weak separability. Say a new procedure for a better use of technology within the factory, an incentive scheme that improves workers' productivity, or a superior design of an existing product that boosts sales under every possible economic scenario. All these examples suggest that RPE should prevail for middle management dealing with internal aspects of the corporation, but RPE would not be adequate for CEOs and top executives coping with sectoral shocks and global uncertainty. Companies would therefore condition CEO pay on measures of individual performance and general economic activity. The optimal weights attached to these measures may vary with firm- and CEO-specific factors; see Section 7.

4 Affine Pay Schedules

The above Propositions 1 and 2 are now shown to hold globally when the choice set is over the space of affine contracts $w(v) = a + bv$. In this simpler setting we offer a complete characterization of the sensitivity of optimal pay to perturbations of primitive parameters. Imposing further restrictions on managerial preferences and the distribution of firm's value will pinpoint some simple channels for risk aversion and volatility to affect the slope of the optimal contract.

4.1 Comparative Statics

Since Holmstrom and Milgrom (1987), various restrictions on the principal-agent model have been shown to yield affine solutions. As many other papers in the executive pay literature [see, e.g., Gibbons and Murphy (1992), Prendergast (2002), Baker and Hall (2004), Cheng, Hong and Scheinkman (2015)], we limit the feasible space of contracts to affine functions: $w(v) = a + bv$, where a is the fixed component of the wage and b will be referred to as the sensitivity of pay to performance. It should be understood that every optimal pair (a^*, b^*) must obey the necessary first-order conditions over this restricted subspace.

In our next proposition, we assume that parameters (a^*, b^*) are positive and the manager is not too risk-averse.[6] Of course, $b^* > 0$ because of the strict monotonicity of the likelihood ratio $\frac{f(v|\underline{\tau})}{f(v|\overline{\tau})}$.

Proposition 5 *Let us restrict the principal's optimization problem* (P) *to the subspace of affine contracts* $w(v) = a + bv$. *Let* (a^*, b^*) *be the unique optimal pair under distribution functions* $F(\cdot|\underline{\tau}, x)$ *and* $F(\cdot|\overline{\tau}, x)$ *and reservation utility values* $u(\underline{w}(\underline{\tau}, x))$ *and* $u(\underline{w}(\overline{\tau}, x))$. *Consider a new realization* x' *near* x. *Let* (a'^*, b'^*) *be the corresponding optimal pair. Then, everything else remaining the same,*

(i) $F(\cdot|\overline{\tau}, x') \leq F(\cdot|\overline{\tau}, x)$ *(or* $F(\cdot|\underline{\tau}, x') \geq F(\cdot|\underline{\tau}, x)$*) implies* $a'^* \geq a^*$ *and* $b'^* \leq b^*$.

(ii) $u(\underline{w}(\overline{\tau}, x')) \geq u(\underline{w}(\overline{\tau}, x))$ *(or* $u(\underline{w}(\underline{\tau}, x')) \leq u(\underline{w}(\underline{\tau}, x))$*) implies* $a'^* \leq a^*$ *and* $b'^* \geq b^*$.

(iii) $u(\underline{w}(\overline{\tau}, x')) \geq u(\underline{w}(\overline{\tau}, x))$ *and* $u(\underline{w}(\underline{\tau}, x')) \geq u(\underline{w}(\underline{\tau}, x))$, *but* $u(\underline{w}(\overline{\tau}, x')) - u(\underline{w}(\overline{\tau}, x)) = u(\underline{w}(\underline{\tau}, x')) - u(\underline{w}(\underline{\tau}, x))$, *implies* $a'^* \geq a^*$ *and* $b'^* \geq b^*$.

[6] The coefficient of relative risk aversion should be less than or equal to 1 at every optimal pair (a^*, b^*). This technical assumption is just a sufficient condition.

This proposition summarizes the main implications of our optimization problem that hold globally for the optimal affine contract. We are considering perturbations over internal and external measures of performance—one at a time. In part (i), a marginal change in some primitive characteristic of the firm leading to a higher productivity advantage of the high-ability manager will decrease the sensitivity of optimal pay to our performance measure. In part (ii), a marginal increase in the gap between the outside option values will make optimal pay more sensitive to performance. In both of these cases, the change in the slope requires an offsetting change in the fixed component of the wage. Part (iii) states that an income effect or a parallel positive shift in the reservation utilities of the two manager types will increase both the fixed component and the sensitivity of compensation.

4.2 Managerial Risk Aversion and Firm's Volatility

In understanding the determinants of optimal pay, another important chapter is risk aversion. As in many other principal-agent problems, however, the effect of risk aversion on optimal pay is hard to characterize analytically. For this purpose, we consider a more simplified setting that admits an analytical solution in which risk aversion interacts with firm's volatility.

Let firm's performance v be normally distributed with mean μ and variance σ^2. Both μ and σ^2 may depend on managerial talent τ. In particular, μ is assumed to be increasing in τ. Managerial preferences exhibit constant absolute risk aversion $\rho > 0$. Manager's reservation wage $\underline{w}$ is increasing in talent. The risk-neutral principal is interested in hiring the high-ability manager and will offer a linear wage schedule: $w(v) = a + bv$. Given our assumptions, the wage is normally distributed with mean $a + b\mu(\tau)$ and variance $b^2\sigma^2(\tau)$ for $\tau = \underline{\tau}, \overline{\tau}$. Hence, the certainty equivalent wage for type τ is

$a + b\mu(\tau) - \frac{\rho}{2}b^2\sigma^2(\tau)$, whereas the expected cost of hiring this agent equals $a + b\mu(\tau)$. Accordingly, the principal's problem becomes:

$$\min_{(a,b)\in\mathbb{R}^2} a + b\mu(\overline{\tau}) \text{ subject to}$$

$$a + b\mu(\overline{\tau}) - \frac{\rho}{2}b^2\sigma^2(\overline{\tau}) \geq \underline{w}(\overline{\tau}) \tag{3}$$

$$a + b\mu(\underline{\tau}) - \frac{\rho}{2}b^2\sigma^2(\underline{\tau}) \leq \underline{w}(\underline{\tau}) \tag{4}$$

Again, constraint (3) is individual rationality for the high-ability manager to accept the wage offer, while constraint (4) is individual rationality for the low-ability manager not to accept the wage offer.

Let us assume that an optimal solution (a^*, b^*) exists over the space of affine contracts.[7] We now study the sensitivity of pay to performance.

Proposition 6 *Parameter b^* has the following properties:*

(i) b^* is decreasing in $(\mu(\overline{\tau}) - \mu(\underline{\tau}))$

(ii) b^* is increasing in $(\underline{w}(\overline{\tau}) - \underline{w}(\underline{\tau}))$

(iii) b^* is decreasing in $(\sigma^2(\underline{\tau}) - \sigma^2(\overline{\tau}))$

(iv) If $\sigma^2(\overline{\tau}) < \sigma^2(\underline{\tau})$, then b^* is decreasing in ρ. If $\sigma^2(\overline{\tau}) = \sigma^2(\underline{\tau})$, then b^* does not change with ρ. And if $\sigma^2(\overline{\tau}) > \sigma^2(\underline{\tau})$, then b^* is increasing in ρ

Parts (i)-(ii) parallel those of Proposition 5. In part (iii), a lower $\sigma^2(\overline{\tau})$ enhances the utility gap between the manager types and results in a flatter optimal wage, for all $\rho > 0$. In part (iv), higher risk aversion decreases the certainty equivalent wage. Hence, the effect of ρ on b^* depends on how managerial talent affects firm's volatility. If a high-ability manager is also better at reducing σ^2, then a higher ρ would translate into a larger difference

[7] This requires that $(\mu(\overline{\tau}) - \mu(\underline{\tau}))^2 \geq 2\rho\left(\sigma^2(\overline{\tau}) - \sigma^2(\underline{\tau})\right)(\underline{w}(\overline{\tau}) - \underline{w}(\underline{\tau}))$. To simplify the exposition, we assume that the inequality is strict.

between the expected utility of the high- and low-ability managers, and so b^* must go down. The opposite result is obtained when σ^2 increases with τ.[8] This would be the case if managerial ability can increase firm's average performance, but only at the cost of greater volatility; e.g., managerial talent may allow the company to expand overseas, but this could be a risky undertaking.

We should note that the assumption of linear wages is not crucial to the results. Indeed, Proposition 6 continues to hold if the principal is constrained to log-linear wages: $w(v) = \exp(a + b \log v)$, firm's value v is log-normally distributed with mean μ and variance σ^2, and managerial preferences exhibit constant relative risk aversion $\rho > 1$.

5 Equilibrium Sorting and Testable Hypotheses

The optimization problem (P) can be embedded in an equilibrium setting with a discrete number of firms and manager types. Since individual rationality constraints should be binding for each firm's optimization problem, the asymptotic results of Propositions 1 and 2 will continue to hold.

5.1 Pay-Performance Sensitivity in General Equilibrium

To isolate the role of the uncertainty about managerial talent from the effects of firm heterogeneity, we begin with a simple general equilibrium version of

[8] In Edmans and Gabaix (2011), if managers can create value by choosing risky projects, then their contract should be convexified, and the sensitivity of pay to the performance measure should be increasing in risk aversion.

the model of Section 4.2 in which the productivity of the manager is assumed firm-invariant.[9] There are N firms and N types of managers. All managers share the same preferences, which exhibit constant absolute risk aversion. A manager of type n has a reservation wage $\underline{w}_n$.[10] Firm n is defined as the firm that hires manager n. The performance of this firm, v, is normally distributed with mean μ_n and variance σ_n^2. Both $\underline{w}_n$ and μ_n are increasing in n, while σ_n^2 is assumed constant. Hence, in this benchmark case, managerial productivity is unambiguously defined; the manager with the highest ability is of type N. Each firm n offers a linear wage, i.e., $w_n(v) = a_n + b_n v$. The firm hiring the least talented manager will optimally offer a constant wage, i.e., $b_1^* = 0$. All other firms $n > 1$ will offer steeper wages: $b_n^* > 0$.

Proposition 6 dictates the sensitivity of the wage profile. But obviously some other conditions are necessary for the existence of a separating equilibrium. For reasons discussed in Section 2, the existence of such an equilibrium requires that the slope of the optimal contract b_n^* should be increasing in n.

Proposition 7 *In a separating equilibrium, incentive compatibility results in a natural ranking: $b_n^* \geq b_{n-1}^*$, $\forall n = 2, \cdots, N$. The slope of the optimal contract for each firm n is given by: $b_n^* = \frac{\underline{w}_n - \underline{w}_{n-1}}{\mu_n - \mu_{n-1}}, \forall n = 2, \cdots, N$.*

In other words, we need to assume that the marginal contribution of talent outside the firm grows faster than the marginal contribution of talent inside the firm. The intuition is that in a separating equilibrium, the wage schemes intended for higher types should be steep enough to deter imitation by lower types, and the wage schemes intended for lower types should be flat enough

[9] Imagine that the productivity of a scholar does not vary with academic affiliation. Then, job offers may be treated as anonymous—the scholar would be indifferent between any two institutions that offer the same contract.

[10] More generally, these reservation wages can be determined by sorting constraints in equilibrium [cf. Tervio (2008)].

to deter imitation by higher types. Then, the slope of the contract acts as a selection device for managerial talent. In fact, we presently show that firm n focuses on separating type n from type $n-1$, which also guarantees that all managers but n would reject the offer. We should note that the monotonicity of pay to performance still holds if the variance of firm's performance is decreasing in managerial talent.

For the purposes of the next proposition we depart from the normal distribution setting. As in Section 2, we assume that $v > 0$ for all feasible v. This approximates the case of variable compensation based on stock options or what is commonly known as downward rigidity of the contract [e.g., Taylor (2013)].

Proposition 8 *If v is always positive, then $(a_n - a_{n'})(b_n - b_{n'}) \leq 0$, $\forall n, n' = 1, 2, \cdots, N$.*

Therefore, as a result of the adverse selection problem, steeper wage profiles have lower fixed components, while flatter compensation schemes exhibit higher fixed components.

5.2 Sorting and Screening

Allowing for firm-specific managerial productivity does not affect our partial equilibrium results (Propositions 1, 2, 5, and 6), but the general equilibrium results derived earlier in this section would need to be qualified. If the productivity advantage of high-ability managers is firm-specific, the slope of the contract may no longer be monotonic in managerial talent, because flatter wages will now suffice to deter imitation by low-ability managers in firms where they are at a greater disadvantage. A sufficient condition for monotonicity is the submodularity of managerial productivity.

Gabaix and Landier (2008) and Tervio (2008) assume that the production function exhibits complementarity between managerial ability and firm's size, which leads to an equilibrium where the largest firms hire the most talented managers. More generally, supermodularity is a sufficient condition for positive assortative matching (PAM) in sorting models with transferable utility [see, e.g., Becker (1973)].[11]

Obviously, the presence of alternative screening devices mitigates the adverse selection problem, and the optimization problem of the firm will then be limited to a subset of managerial types n' for every firm n.

5.3 Testable Hypotheses and Relation to Literature

Because of the scope and complexity of the tasks involved, large companies may need to devote substantial resources to refine the search for potential job candidates. According to our above results, a fairly homogeneous pool of applicants coupled with the firm's inability to refine out talent would worsen the adverse selection problem, and may require a steeper wage contract. These considerations would also apply to other environments in which talent may be highly productive, but not so easy to identify. Since uncertainty about managerial talent may grow with firm's volatility, riskier firms should also offer steeper wage schedules. Moreover, junior hires with less established track records will generally have steeper compensation profiles.

We can summarize these basic implications of the theory of adverse selection for managerial talent in the following testable hypotheses regarding the structure of CEO compensation.

[11] Legros and Newman (2007) point out that the relevant condition in the presence of imperfectly transferable utility is generalized increasing differences, and can be related to the Spence-Mirrlees single-crossing condition [see Chade, Eeckhout and Smith (2017)].

Hypothesis 1 *CEOs of large and high-volatility firms are offered higher and steeper wage schedules.*

Hypothesis 2 *Young CEOs are offered steeper wage schedules.*

The remaining sections will be devoted to test these hypotheses. Lack of predictability is usually a problem in theories of executive compensation as they are built on non-observable fundamentals such as the productivity and disutility of low effort. Besides, it is often difficult to distinguish empirically between the intensity of effort and managerial talent. Hence, our adverse selection model complements existing theories of moral hazard, assortative matching, and rent extraction, and offers a more natural interpretation of some basic facts in executive compensation.

In contrast to Hypothesis 1, the theory of incentive pay with unobservable effort generally predicts a negative trade-off between risk and incentives [e.g., Holmstrom and Milgrom (1987)]. The relationship could change sign in some further extensions of the basic model, and so the empirical implications will crucially depend on certain parameter values. Cheng, Hong and Scheinkman (2015) posit a higher productivity of effort in riskier firms which may need labor with specialized skills and with significant influence over outcomes. Then, the trade-off could become positive: the level and sensitivity of managerial pay could be higher in risky firms. Uncertain, risky projects may also lead to steeper wage profiles because of the degree of delegation [Prendergast (2002)], and the heterogeneity of the labor force [Lazear (2000)].

In Edmans, Gabaix and Landier (2009), the assignment of CEOs to firms is driven by a multiplicative production function in managerial talent and firm's size, but preferences are also assumed to be multiplicative and so private benefits are treated as a normal good. The multiplicative utility implies that exerting effort is costlier for high-ability managers (who are assigned to larger, more productive firms). This assumption goes against a natural interpretation of ability as a lower disutility of effort. The multiplicative setting leads to "percent-percent" incentives rather than "dollar-dollar" incentives [Jensen and Murphy (1990)] or "dollar-percent" incentives [Hall and Liebman (1998)], and so the slope of the contract (the fraction of total compensation paid in stock, or the elasticity of CEO pay to firm's value) is independent of total pay and firm's size. Baker and Hall (2004) argue that if the marginal product of effort is size-invariant, then the correct incentives are "dollar-dollar", and if the marginal product of effort scales proportionally with firm's size, then incentives should be inferred from CEO's dollar equity stake. Their empirical analysis suggests that effort and size are complementary (the elasticity is positive but below 1). Since it is difficult to disentangle effort from managerial talent, these findings may actually support the premise of talent assignment models [Gabaix and Landier (2008), and Tervio (2008)].

Benabou and Tirole (2016) analyze the implications of labor market competition for incentives and welfare. They use a multitasking model, where effort adds to ability in the output of the measurable task and incentive pay is a device to attract or retain high types. The contract space is restricted to affine schemes. There are two types of workers indexed by high- and low-ability, and both have the same reservation utility. Hence, contrary to our framework, the individual rationality constraint is not always binding for the high type. In a Hotelling model with linear transport costs, where workers are uniformly distributed along the unit interval and have to travel to one of the two extremities to either work or collect their outside option, competition (a decrease in transport costs) is shown to weakly increase incentives for both types. This setting, however, ignores the effects of labor market competition on individual rationality constraints. In our framework, we can differentiate between competition for the job (e.g., a large number of managers), which may dampen differences in managerial productivity, and competition for talent (e.g., a large number of firms), which may lead to narrower differences in reservation wages.

Regarding Hypothesis 2, the evidence is controversial. Gibbons and Murphy (1992) find some support for career concerns as far as CEO-cash compensation is concerned, while Yermack (1995) and Bryan, Hwang and Lilien (2000) find no such support with respect to CEO stock option grants. As already pointed out, some senior professionals are granted a tenure job on essentially fixed pay.

In dynamic agency models with career concerns, the provision of incentives will generally grow with agent's age and tenure. In the finite-horizon setting of Gibbons and Murphy (1992), the principal increases the slope of the contract as the manager nears retirement to compensate for the falling career concerns. Pay-performance sensitivity also rises with tenure because insuring the manager against low ability realizations and fluctuations in output loses importance over time as learning about manager's ability leads to a decrease in the conditional variance of output. Assuming that effort and ability are substitutes, Holmstrom (1999) uses an infinite-horizon setting to analyze how career concerns affect the provision of effort over time. When ability is constant, effort decreases over time as the uncertainty about ability goes down. When ability is a random walk, effort monotonically converges to some stationary level. If the precision of the information about ability increases over time, then the convergence is from above, i.e., effort decreases over time. In Garrett and Pavan (2015), managers are uncertain about their second-period productivity. Whether incentives increase or decrease in time depends on managerial risk aversion and productivity persistence. If the manager is risk-neutral, effort increases over time. And if productivity shocks become very persistent, then effort decreases over time. In Milbourn (2003), an incumbent manager can be replaced before the realization of output. The stock price is more informative about the contribution of managers who are more likely to be retained. Since the probability of retaining an incumbent manager is increasing in her perceived ability (reputation), so is the stock-based pay sensitivity. In Edmans *et al.* (2012), pay-performance sensitivity increases with age because there are fewer periods over which to spread the reward for effort. The sensitivity of the contract may also rise over time to prevent the manager from engaging in short-termism (boosting current returns at the expense of future returns).

6 Level and Structure of CEO Pay

We now review some empirical evidence with the goal of confronting our theoretical results as summarized in Hypotheses 1 and 2 with the data. We first study how the level and structure of CEO pay may vary with firm's size, firm's volatility, and CEO age.

6.1 Data: CEO Pay Measures, and Firm- and CEO-Specific Factors

All individual executive compensation data have been taken from Execu-Comp and cover the firms in the S&P Composite 1500 (S&P 500, S&P MidCap 400, and S&P SmallCap 600) for the period June 1992 - August 2010. We have data for 6,328 CEOs from 3,076 companies for a total of 33,033 CEO-year matches. Balance sheet data for each company have been obtained from Compustat, while corresponding prices and returns have been taken from CRSP. Nominal values have been converted to 2005 constant prices using the CPI of the US Bureau of Labor Statistics.

In our theoretical framework, a contingent wage schedule is offered to the manager before the realization of firm's value; hence, we are interested in *ex ante* measures of CEO compensation such as the *grant-date* value of CEO yearly pay. This measure, hereafter referred to as M1 total pay, is based on a minimal set of assumptions and is readily available in executive compensation databases. It is defined as the sum of CEO cash pay (salary and bonus), the grant-date value of stock and option awards, and other annual compensation.

Some researchers have considered *ex post* measures such as CEO *realized* pay which is the yearly amount of money that the CEO brings home. This measure counts cash pay and the realized value of stock and stock options exercised during the year rather than the value of stock and stock options granted. For the sake of brevity, realized pay is discarded from our analysis since it does not appear to be a good approximation of our theoretical counterpart.

M1 total pay considers only new equity-based grants and ignores CEO's existing stock and option holdings, which may bias estimated pay-performance sensitivities. Hence, we also consider an approach suggested by Antle and Smith (1985) in which CEO compensation is viewed as *the change in CEO's firm-related wealth*. The resulting measure, hereafter referred to as M2 total pay, includes M1 total pay, dividend income, the change in the value of CEO's initial holdings of company stock and options adjusted for stock sales and options exercised, and the net gains from such trades. The difference between M1 and M2 total pay lies in the value of the equity-based component of CEO compensation, hereafter referred to as equity-based pay. M1 equity-based pay measures the grant-date value of stock and option awards in a given year, while M2 equity-based pay estimates the annual change in the value of CEO's equity-based wealth.

We should recognize two issues regarding M2 total pay. First, M2 total pay is actually a measure of *ex post* compensation. As shown in Hall and Liebman (1998) and Murphy (1999), the volatility of this measure is mainly driven by the change in the value of CEO's stock and option holdings, which makes it highly dependent on firm's realized return. Second, M2 total pay requires an estimate of CEO's stock option holdings, but for most of the sample we only have data on the value of stock options that are in the money [see, e.g., Himmelberg and Hubbard (2000), Core and Guay (2002), Clementi and Cooley (2010)]. Further, CEO's reported stock holdings should also be taken with caution since these holdings may refer to some date well after the closing of the company's fiscal year.

A detailed account of our data sources can be found in Appendix C. Table 1 provides various descriptive statistics concerning CEO compensation, firm's size, firm's volatility of returns, and CEO age. M1 total pay has a mean of \$4.7 million and a median of \$2.3 million. M2 total pay has a mean of \$18.4 million and a median of \$3.0 million. Both measures are positively skewed, but M2 total pay is much more volatile. M1 total pay equals 0 in 93 observations and exceeds \$100 million in 53 observations, whereas M2 total pay equals 0 in 2 observations, exceeds \$100 million in 837 observations, and is negative in 6,366 observations.

Figure 1 plots the empirical distribution of company returns, as well as the distribution of the growth rates of M1 and M2 total pay. We can observe that the percentage change in firm's stock price is less volatile than the percentage change in each compensation measure. Firm's annual stock return has a mean of 2.8 percent and a median of 6.8 percent, while the growth rate of M1 total pay has a mean of 0.4 percent and a median of 3.1 percent. The growth rate of cash pay has a mean close to zero, whereas the median is about 2.4 percent. The growth rate of M1 equity-based pay has a mean of 1.2 percent and a median of 2.9 percent. Both the mean and median of the growth rate of M2 total pay are negative and mainly driven by M2 equity-based pay. This negative trend may reflect an effect of CEO tenure: equity-based pay is granted at the beginning of the tenure period, and vested stocks and options are gradually exercised by the CEO.

The median firm in our sample has a market capitalization of 1.3 billion dollars and a workforce of 4.6 thousand employees. As is well known, firm's size is the most prominent determinant of the level of CEO pay [Frydman and Saks (2010), Gabaix and Landier (2008), Murphy (2013)]. We use firm's market capitalization as our preferred measure for firm's size. We have also considered the number of employees, firm's total assets, and net sales, but they all appear to have less explanatory power. With the widespread use of outsourcing and new technologies, these other measures may have become less relevant for gauging the complexity of the organization.

To be consistent with our market-based proxy for firm's size, we measure firm's volatility as the standard deviation of firm's stock return. To capture additional sources of risk, we consider R&D intensity (the ratio of R&D expenditure to net sales), and a dummy for new economy firms as in Ittner, Lambert and Larcker (2003).

The median CEO is 54 years old and has spent 5 years as CEO of the company. We have already highlighted the role of CEO age in our model in which compensation can become steeper under less informative prior beliefs about the candidate's ability (Hypothesis 2). Notwithstanding, CEO age may have non-linear effects on the level and structure of pay (see footnote 5), and may be correlated with firm's size and volatility; i.e., the most experienced CEOs may be managing large and risky companies. In order to control for the quality of the match and the bargaining power of the manager, we also consider the number of years that the executive has been serving as CEO of the company (CEO tenure), and a dummy for serving as chair of the board.

6.2 Level of CEO Pay

Tables 2 and 3 project M1 and M2 total pay on various proxies for firm's size, firm's volatility, and CEO age. All these variables are expressed in logs, except for M2 total pay which has a considerable number of negative values and is expressed in levels. We run median regressions with bootstrapped standard errors. All regressions include industry and fiscal year dummies. We report estimates over the whole sample, but we get similar values when we run separate regressions for each fiscal year.

A positive correlation between firm's size and observed CEO pay has been documented by several authors, but this correlation may have been smaller prior to the mid-1970s as suggested by Frydman and Saks (2010). All our proxies for firm's size (market capitalization, number of employees, total assets, and net sales) are positively correlated with the level of CEO pay. Among our measures of firm's size, market capitalization has the highest predictive power for M1, but not for M2 total pay. Gabaix and Landier (2008) argue that accounting measures such as earnings and sales do not perform as well as market capitalization.

From Tables 2 and 3 we can further observe that the level of CEO pay is positively correlated with firm's stock return volatility. A positive link between company's risk and managerial pay has been found in earlier studies [Bartlett, Grant and Miller (1992), Rose and Shepard (1997)]. The result could be attributed to risk aversion, higher disutility of effort, or higher productivity of talent in risky firms. Kaplan (1998) interprets the positive correlation as driven by the higher ability of executives in risky firms, and not by managerial risk aversion.

Observe that the positive correlation between the level of CEO pay and the volatility of firm's returns holds unambiguously for M1 total pay for all formulations contemplated in Table 2. Moreover, firm's R&D intensity and new economy become statistically insignificant once we condition for firm's volatility. These results do not hold for M2 total pay as shown in Table 3. The correlation between M2 total pay and firm's volatility of returns changes sign when controlling for other firm- and CEO-specific factors. New economy has a positive effect on M2 total pay even after controlling for firm's volatility. The effect of R&D intensity is now significant, but becomes negative when we include a new economy dummy.

The link between CEO age and the level of compensation is less clear. We estimate a positive correlation for M1 total pay which changes sign when we control for firm's R&D intensity and new economy. In contrast, we find a negative correlation for M2 total pay. CEO tenure is negatively correlated with M1 total pay, and positively correlated with M2 total pay. The chair-of-the-board dummy coefficient is statistically significant and positive for both M1 and M2 total pay.

To check the robustness of the results, we estimate the difference in the conditional median of CEO pay associated with these various firm- and CEO-specific factors. We construct two bins corresponding to observations above the third quartile and below the first quartile of the distribution of each factor of interest for every given date (see Appendix C for details). Then, we pool the observations from both bins to estimate a median regression of total pay involving a constant and a top bin dummy. When the factor of interest is measured by a binary variable as new economy or chair of the board, we use this variable in place of the top bin dummy. Table 4 reports the value of the coefficient of the top bin dummy for each factor. In Panel A, we do not control for time, industry, or other firm- or CEO-specific characteristics.

In Panel B, the regression also includes industry and fiscal year dummies, while in Panel C, we additionally control for other firm- and CEO-specific factors. We find that these results accord with our previous analysis. The most noticeable difference is that M2 total pay is now positively correlated with CEO age.

In conclusion, we have gathered some empirical evidence on the correlation of CEO total pay with various proxies for firm's size, firm's volatility, and CEO age. These correlations suggest that managerial talent may have a greater impact on large and high-volatility firms, whereas the link between CEO age and managerial talent—as related to total pay—is less clear.

6.3 Structure of CEO Pay

To understand the role of variable pay in compensation, we now perform an analogous correlation exercise for the equity-based pay ratio, i.e., the ratio between equity-based pay and the sum of cash pay and equity-based pay (see Appendix C for details). This ratio is similar to the equity grant intensity of Ittner, Lambert and Larcker (2003). Of course, a more refined analysis could have distinguished between stock and stock option awards.

The equity-based pay ratio reflects the weight of incentive pay in CEO compensation, and can be readily estimated from our data set. This ratio can also be related to the slope coefficient b of the preceding section as well as to other estimates of the sensitivity of pay to performance for measures of *ex post* compensation. The mean of the M1 equity-based pay ratio is 0.568 and the median is 0.589, whereas the mean of the M2 equity-based pay ratio is 0.246 but the median is 0.896. As with the level of CEO pay, Table 5 projects the M1 equity-based ratio on our measures of firm's size, firm's volatility, and CEO age. Both firm's size and stock return volatility are positively correlated with the M1 equity-based pay ratio. The coefficients of firm's R&D intensity and the new economy dummy are statistically significant even after controlling for firm's volatility. The coefficient of CEO age is always negative, the coefficient of CEO tenure is small, but positive, and the coefficient of the chair-of-the-board dummy is negligible.

In Table 6, we replicate the same computations for the M2 equity-based pay ratio. The coefficient signs do not change substantially, but the M2 measure does not appear to perform so well in terms of the pseudo R^2. Observe that for negative values of M2 equity-based pay, the ratio is no longer monotone. Hence, in Table 7 we censor the sample and only consider observations with positive M2 equity-based pay.[12] This appears to improve the explanatory power of the regressions.

We perform a robustness check by estimating the difference in the conditional median of the equity-based pay ratio over these various firm- and CEO-specific factors. As before, to obtain these differences we use the observations above the third quartile and below the first quartile of the distribution of each factor at any given date. The results are reported in Table 8 and confirm our previous findings from Tables 5-7.

Therefore, we find robust evidence in favor of Hypothesis 1: CEO total pay and equity-based pay ratio are positively correlated with both firm's size and stock return volatility. Regarding Hypothesis 2, a distinction should be made between CEO age and tenure. The equity-based pay ratio is negatively correlated with CEO age and positively correlated with CEO tenure, whereas CEO service as chair of the board appears to have a negligible effect.

[12] More precisely, we consider the subsample of observations with M2 equity-based pay ratios between 0.05 and 0.95.

7 Sensitivity of CEO Pay to Internal and External Measures of Performance

Our goal here is to confirm the lack of RPE in CEO compensation after estimating the elasticities[13] of CEO pay to some internal and external measures of performance. We also explore how these estimates may be affected by various firm- and CEO-specific factors. Our theoretical analysis (see Proposition 3) indicates that a necessary condition for RPE is that firm's value must be separable on managerial talent and internal productivity factors. We should also acknowledge that RPE may fail if the common shock affects the manager's outside option. A positive correlation between the reservation wage and firm's performance has been suggested by Oyer (2004) as a main reason behind the use of broad-based stock option plans. Himmelberg and Hubbard (2000) and Rajgopal, Shevlin and Zamora (2006) assume that this correlation is increasing in manager's ability, and argue that departures from RPE are systematically related to different proxies for CEO's talent.

Changes in the structure of compensation could be interpreted as optimal responses to different economic conditions. For example, a firm with highly volatile stock returns may need to offer a steep wage because of higher uncertainty about the ability of the candidate, but may as well find it profitable to condition pay on some other performance measures (e.g., market share) as additional selection devices. To keep the analysis simple, we consider four performance measures. The first two measures are standard in the literature, and are obtained by decomposing firm's stock return into an idiosyncratic and a systematic component with respect to the market return. The third

[13] Pay-performance elasticities have been advocated by Murphy (1999) on empirical grounds [see Gibbons and Murphy (1992)] and justified theoretically by Edmans *et al.* (2012).

measure is the average pay on the market for CEOs. It is intended to capture systematic productivity shocks that also affect managerial outside options. The fourth measure is the growth in firm's market share in net sales which is a natural performance benchmark.

For a given firm i in fiscal year t, we consider the following empirical specification:

$$\text{Growth rate of CEO total pay}_{i,t} = a_0 + a_1 \times \text{ idiosyncratic stock return}_{i,t} +$$
$$a_2 \times \text{ systematic stock return}_{i,t} + a_3 \times \text{ growth rate of average CEO pay}_{i,t} +$$
$$a_4 \times \text{ growth rate of firm's market share}_{i,t} + \text{error}_{i,t} \tag{5}$$

Observe that strong-form RPE implies that $a_2 = a_3 = 0$. That is, managerial compensation should not be sensitive to external measures of performance. This hypothesis may be erroneously rejected if there are measurement errors in our decomposition of stock returns into idiosyncratic and systematic components; see Appendix C for detailed definitions. Since we only have annual data on sales and CEO total pay, we estimate aggregate and average values based on companies that end their fiscal year in the same month as the company in question. The use of growth rates (log differences) is prompted by the non-stationarity of CEO pay. We censor the data set by excluding observations in which the executive in question has served as a company CEO for less than two thirds of the time in either the current or the previous fiscal year.

As in our previous section, M1 total pay becomes more appropriate than M2 total pay for estimating pay-performance elasticities since M2 is directly affected by company returns. Indeed, when we regress the growth rate of CEO total pay against firm's stock return, we obtain an elasticity equal to

0.255 for M1 total pay and 1.05 for M2 total pay. Thus, it is unlikely that RPE may hold for M2 total pay.

All our estimates come from median regressions with bootstrapped standard errors, and are reported in Table 9 for M1 total pay and Table 10 for M2 total pay. We always include two-digit SIC industry dummies. In panel B, we also include fiscal year dummies. The explanatory power of the regressions is low, but comparable to previous studies of CEO pay that estimate a log-differenced specification [see, e.g., Albuquerque (2009), Table 9].

Observe that CEO pay is sensitive to both internal and external measures, and hence RPE does not hold. More specifically, the sensitivity of M1 and M2 total pay to the systematic component of firm's stock return always remains positive and significant. For M1, all four measures of performance display positive coefficients with values around 0.2. When we include fiscal year dummies in the regression, the coefficient of average CEO pay falls to 0.03, but remains statistically significant. As expected, M2 total pay is mainly driven by firm's stock return. The coefficients of the idiosyncratic and systematic components are both about 1 and the pseudo R^2 is much higher.

We next analyze how CEO pay-performance elasticities vary with firm- and CEO-specific factors. As in the previous section, we form two bins corresponding to observations above the third quartile and below the first quartile of the distribution of each factor at any given date. Then, we estimate our empirical specification (5) for the pooled sample of high and low values of the factor in question, but allow the coefficients to vary across bins. That is, to account for the incremental effect of the factor, we interact the independent variables with a top bin dummy. The coefficients of these interaction terms are reported in Table 11 for M1 total pay and in Table 12 for M2 total pay. We always include fiscal year and two-digit SIC industry dummies. In Panel

B, we additionally control for other firm- and CEO-specific factors.

In Table 11, we observe that M1 total pay is more sensitive to idiosyncratic returns in large, R&D intensive, and low-volatility firms, and for CEOs serving as chairs of the board. After controlling for CEO tenure, the sensitivity of M1 total pay to firm's idiosyncratic returns shows no significant difference between old and young CEOs. M1 total pay tends to be more correlated with average CEO pay in large, high-volatility, R&D intensive, and new economy firms. The elasticity of M1 total pay to firm's market share is greater in high-volatility firms, and for young CEOs. These results are somewhat confirmed for M2 total pay in Table 12. As with M1 total pay, we get that compensation is more sensitive to idiosyncratic returns in large firms, and less sensitive to idiosyncratic returns in high-volatility firms.

All this evidence reveals the lack of RPE in CEO contracts. Indeed, when CEO's ability to handle firm-specific shocks depends non-trivially on the realization of aggregate uncertainty, firms would base executive compensation on both internal and external measures of performance. Large and technology firms may place more emphasis on idiosyncratic returns and average CEO pay because these companies are faced with more complex managerial tasks and may have access to a wide pool of workers. As it is to be expected, high-volatility companies tend to focus on average CEO pay and market share rather than on stock-based measures of performance (such as idiosyncratic and systematic returns). Market share appears to be more prevalent for the compensation of young CEOs whose talent is yet to be verified. Garvey and Milbourn (2003) consider age as a proxy for CEO's ability to hedge the market, and suggest that the compensation of young CEOs would be less exposed to market risk. While the pay of young CEOs is indeed less sensitive to firm's systematic returns, the difference is not statistically significant.

8 Concluding Remarks

This paper is an attempt to extend the theory of adverse selection to executive compensation. The sensitivity of the optimal contract is shaped by the dispersion of beliefs about the productivity of talent and the dispersion of beliefs about the reservation wage or outside options. We emphasize two basic implications of our theory: CEOs of large and high-volatility firms should be offered higher and steeper wage schedules, and young CEOs should be offered steeper wage schedules. Our model also indicates that RPE is a rather limiting condition for CEOs of global corporations who must leverage on aggregate uncertainty when taking care of idiosyncratic shocks. In their quest for top managerial talent, companies will optimize over various measures of performance and proxies for productivity and labor market shocks. Our empirical analysis supports the predictions of the model and underscores the importance of adverse selection in CEO pay.

Competing theories of executive compensation seek to explain certain aspects of contracting and agency, but are often difficult to expose and reconcile with the data. Several puzzles in CEO pay have challenged the premises of these theories and have spurred extensions with less clear-cut predictions. Inherent difficulties in identifying managerial talent can account for the low base salaries of fancy CEOs, the contractual differences between junior and senior hiring, the controversies on the sign of the trade-off between risk and incentives, and the systematic departures from RPE in managerial compensation. The lack of consensus among researchers on how to approach these issues poses a challenge to economic policy evaluation. Some tax laws, bonus caps, and social pressures may be justified from the perspective of incentivizing effort but could restrict the potential of the firm to attract and retain top managerial talent. This may be particularly true for fancy executives, and for large and risky corporations. While a moral hazard model would prescribe a relatively flat compensation scheme for CEOs who have already invested in their companies, our adverse selection model of Section 2 may stipulate a substantially steeper contract. Indeed, in a world of rapid technological change and globalization, a primary task is to single out the best candidate to head the corporation. Both the structure of compensation and the sensitivity of CEO pay to individual performance measures and general economic indicators should vary with firm's size, volatility, industry, and other factors reflecting uncertainties about managerial productivity and outside options. For instance, a new economy firm may use various benchmarks and a higher fraction of equity-based pay than a traditional utility company facing a less severe adverse selection problem in managerial contracting. Certainly, some firm- and CEO-specific factors may bear on other theories of executive compensation, albeit their alleged effects often come with the wrong sign.

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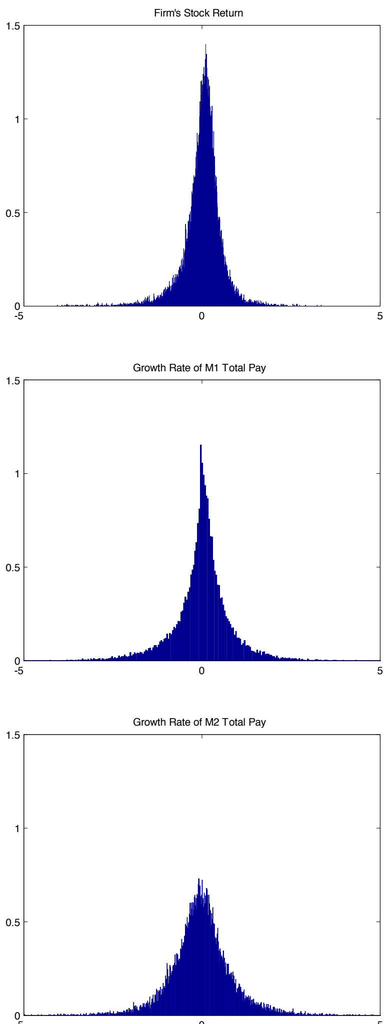
Graphs

Figure 1. Firm's Stock Return and Growth Rates of M1 and M2 Total Pay



See the Appendix for definitions and data sources.

Tables

Table 1. Descriptive Statistics

	Mean	Median	Min	Max	St. Dev.	Skewness	N
CEO Total Pay							
M1	4,744.453	2,304.334	0.001	775,812.085	11,050.068	25.384	33,033
M2	18,369.280	3,009.944	-33,282,603.565	47,116,800.941	604,332.106	31.123	24,442
Cash Pay	1,283.566	873.138	0.001	126,155.385	1,876.459	19.086	33,746
Equity-Based Pay							
M1	3,713.055	1,456.056	0.002	770,324.808	11,429.752	28.775	25,070
M2	16,363.106	1,600.329	-33,282,650.763	47,116,534.748	604,690.676	31.113	24,409
Equity-Based Pay Ratio							
M1	0.568	0.589	0.000	1.000	0.239	-0.296	24,957
M2	0.246	0.896	-10,136.175	357.159	66.836	-144.454	24,322
Growth Rate of CEO's Total Pay							
M1	0.004	0.031	-19.334	20.179	0.889	-0.146	26,513
M2	-0.025	-0.038	-8.579	7.074	0.869	-0.017	18,205
Growth Rate of Cash Pay	-0.002	0.024	-14.748	17.562	0.692	-0.086	27,392
Growth Rate of Equity-Based Pay							
M1	0.012	0.029	-14.137	13.151	1.106	-0.513	17,648
M2	-0.028	-0.041	-11.818	8.204	0.928	-0.051	18,218
Firm's Stock Return	0.028	0.068	-4.062	3.349	0.507	-0.929	28,669
Firm's Size							
Market Capitalization	6,336.309	1,258.302	2.945	588,588.302	21,715.475	10.555	32,661
Number of Employees	17.335	4.600	0.002	2,100.000	49.987	15.308	32,946
Total Assets	11,982.016	1,395.556	0.080	2,034,148.119	63,488.200	15.129	33,850
Net Sales	4,707.955	1,119.374	0.024	394,887.295	13,978.448	10.391	33,770
Firm's Risk							
Volatility	0.415	0.366	0.061	1.776	0.204	1.386	31,753
R&D Intensity	0.384	0.049	0.000	509.421	7.206	46.600	14,171
New Economy (Dummy Variable)	0.102	0.000	0.000	1.000	0.303	2.630	32,681
CEO-Specific Factors							
CEO Age	54.191	54.000	23.000	95.000	7.659	0.140	33,057
CEO Tenure	7.355	5.003	0.003	57.789	7.382	1.971	29,919
Chair of the Board (Dummy Variable)	0.414	0.000	0.000	1.000	0.493	0.348	34,010

Descriptive statistics of CEO compensation measures, firm- and CEO-specific factors. See the Appendix for definitions and data sources.

Table 2. Determinants of M1 Total Pay

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	4.926***	7.272***	4.856***	4.833***	4.183***	4.609***	4.192***	3.986***	4.004***	3.984***	4.720***	4.153***
	(0.048)	(0.033)	(0.044)	(0.035)	(0.027)	(0.047)	(0.030)	(0.031)	(0.038)	(0.025)	(0.062)	(0.030)
Firm's Size												
Market Capitalization	0.442***				0.467***	0.446***	0.467***	0.468***	0.466***	0.464***	0.444***	0.464***
	(0.004)				(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)
Number of Employees		0.371***										
		(0.004)										
Total Assets			0.430***									
			(0.004)									
Net Sales				0.427***								
				(0.003)								
Firm's Risk												
Firm Volatility					0.589***	0.231***	0.591***	0.592***	0.545***	0.579***	0.186***	0.551***
					(0.027)	(0.037)	(0.030)	(0.029)	(0.027)	(0.025)	(0.038)	(0.025)
R&D Intensity						0.001					0.001	
						(0.001)					(0.001)	
New Economy							-0.023				0.041*	-0.006
							(0.019)				(0.023)	(0.005)
CEO-Specific Factors												
CEO Age								0.049***	0.047***	0.027***	-0.058***	-0.016***
								(0.007)	(0.009)	(0.007)	(0.015)	(0.006)
CEO Tenure									-0.006	-0.011**	-0.011**	-0.012***
									(0.004)	(0.004)	(0.005)	(0.005)
Chair of the Board										0.122***	0.110***	0.121***
										(0.011)	(0.014)	(0.011)
N	27,959	27,484	27,963	27,936	27,174	11,275	27,174	26,767	25,320	25,320	10,452	25,320
Pseudo R^2	0.301	0.218	0.285	0.271	0.309	0.328	0.309	0.309	0.31	0.312	0.334	0.312

Median regressions of M1 total pay on firm- and CEO-specific factors. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. See the Appendix for definitions and data sources.

Table 3. Determinants of M2 Total Pay

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	54521.303***	16713.865***	32325.799***	19288.039***	30642.222***	64475.847***	22084.246***	41164.939***	53445.793***	53438.193***	59725.686***	70338.006***
	(112.173)	(78.334)	(330.469)	(186.185)	(99.828)	(368.671)	(97.566)	(115.096)	(325.995)	(186.888)	(250.289)	(108.436)
Firm's Size												
Market Capitalization	1225.905***				1408.706***	1360.448***	1243.529***	1255.137***	834.853***	1640.357***	708.027***	1196.227***
	(18.327)				(16.542)	(51.467)	(17.229)	(29.737)	(26.969)	(29.503)	(46.444)	(23.640)
Number of Employees		1277.575***										
		(38.408)										
Total Assets			3265.434***									
			(45.405)									
Net Sales				2610.031***								
				(32.102)								
Firm's Risk												
Volatility					932.147***	-5790.967***	1714.041***	-791.733***	-8909.072***	5536.674***	-8394.991***	-3334.222***
					(152.474)	(713.534)	(260.009)	(133.942)	(362.621)	(430.352)	(627.523)	(306.857)
R&D Intensity						990.605***					-383.980***	
						(34.919)					(43.346)	
New Economy							396.800***				2557.667***	214.791***
							(86.183)				(349.378)	(63.088)
CEO-Specific Factors												
CEO Age								-4810.686***	-122.577	-8080.796***	-16349.169***	-6649.368***
								(42.264)	(94.618)	(45.020)	(65.612)	(40.334)
CEO Tenure									205.903***	542.436***	749.602***	389.571***
									(43.165)	(62.050)	(93.678)	(54.865)
Chair of the Board										1565.793***	1195.721***	1335.452***
										(133.761)	(219.402)	(138.470)
N	21,856	21,540	21,851	21,835	21,795	9,049	21,795	21,649	20,641	20,641	8,533	20,641
Pseudo R^2	-0.022	-0.015	-0.009	-0.053	-0.009	-0.017	-0.009	-0.006	-0.025	-0.015	-0.059	-0.009

Median regressions of M2 total pay on firm- and CEO-specific factors. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. See the Appendix for definitions and data sources.

Table 4. Contribution of Firm- and CEO-Specific Factors to M1 and M2 Total Pay

CEO Total Pay	**Firm-Specific Factors**				**CEO-Specific Factors**		
	Size	Volatility	R&D Intensity	New Economy	CEO Age	CEO Tenure	Chair of the Board
				Panel A			
M1	1.731***	-0.550***	-0.290***	0	0.199***	-0.083***	0.215***
	(0.018)	(0.022)	(0.039)	(0.029)	(0.025)	(0.022)	(0.017)
M2	6175.314***	-1620.700***	-1025.556***	-337.08	803.525***	1293.161***	1521.329***
	(131.988)	(146.812)	(297.243)	(215.858)	(174.230)	(193.020)	(122.562)
				Panel B			
M1	1.733***	-0.708***	-0.083*	0.071**	0.197***	-0.058***	0.291***
	(0.019)	(0.028)	(0.045)	(0.028)	(0.019)	(0.022)	(0.017)
M2	4198.860***	-645.044***	4245.873***	-35932.650***	2289.036***	480.062***	1522.369***
	(213.074)	(135.375)	(437.141)	(243.233)	(264.130)	(80.134)	(114.964)
				Panel C			
M1	1.730***	0.317***	-0.014	-0.001	0.013	-0.002	0.122***
	(0.017)	(0.020)	(0.020)	(0.003)	(0.013)	(0.005)	(0.011)
M2	4908.837***	-2297.919***	1842.088***	-10676.906***	11.166***	8473.783***	1606.148***
	(240.336)	(211.225)	(390.909)	(358.201)	(3.931)	(403.293)	(130.901)

Contribution of firm- and CEO-specific factors to M1 and M2 total pay. Two bins are formed by taking observations above the third quartile and below the first quartile of the distribution of a factor. These observations are pooled to estimate a median regression of CEO total pay on a constant and a top bin dummy. The coefficient of the latter variable is reported in the table. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Panel B includes industry dummies and fiscal year dummies. In Panel C, we also control for other firm- and CEO-specific factors. We always control for firm's size and volatility when estimating the contribution of any other factor. Additionally, we control for CEO tenure when estimating the impact of CEO age, for CEO age when investigating the contribution of CEO tenure, and for both CEO age and tenure when studying the effect of the CEO serving as a chair of the board. See the Appendix for definitions and data sources.

Table 5. Determinants of M1 Equity-Based Pay Ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	0.262***	0.600***	0.343***	0.395***	-0.231***	-0.179***	-0.224***	0.537***	0.583***	0.564***	0.679***	0.513***
	(0.014)	(0.011)	(0.013)	(0.010)	(0.006)	(0.009)	(0.005)	(0.005)	(0.005)	(0.005)	(0.009)	(0.005)
Firm's Size												
Market Capitalization	0.054***				0.070***	0.064***	0.070***	0.070***	0.070***	0.070***	0.066***	0.070***
	(0.001)				(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of Employees		0.024***										
		(0.001)										
Total Assets			0.038***									
			(0.001)									
Net Sales				0.032***								
				(0.001)								
Firm's Risk												
Volatility					0.369***	0.356***	0.366***	0.339***	0.334***	0.337***	0.305***	0.329***
					(0.011)	(0.012)	(0.011)	(0.009)	(0.010)	(0.010)	(0.013)	(0.010)
R&D Intensity						0.001**					0.000*	
						(0.000)					(0.000)	
New Economy							0.035***				0.028***	0.031***
							(0.007)				(0.007)	(0.007)
CEO-Specific Factors												
CEO Age								-0.193***	-0.208***	-0.203***	-0.218***	-0.189***
								(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
CEO Tenure									0.003**	0.004***	0.009***	0.003**
									(0.001)	(0.001)	(0.002)	(0.001)
Chair of the Board										-0.000**	-0.005	0
										(0.000)	(0.003)	(0.000)
N	21,756	21,396	21,756	21,741	21,256	9,219	21,256	20,969	19,698	19,698	8,485	19,698
Pseudo R^2	0.192	0.139	0.157	0.149	0.23	0.238	0.231	0.236	0.239	0.239	0.253	0.239

Median regression of M1 equity-based pay ratio on firm- and CEO-specific factors. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. See the Appendix for definitions and data sources.

Table 6. Determinants of M2 Equity-Based Pay Ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	-0.402***	0.212***	-0.851***	-0.547***	-0.493***	0.399***	-0.728***	0.379**	-0.285***	7.210***	-2.198***	-1.633***
	(0.008)	(0.005)	(0.006)	(0.004)	(0.007)	(0.008)	(0.008)	(0.177)	(0.005)	(0.009)	(0.007)	(0.004)
Firm's Size												
Market Capitalization	0.022***				0.034***	-0.001*	0.040***	0.035***	0.046***	0.068***	0.010***	0.037***
	(0.001)				(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
Number of Employees		-0.012***										
		(0.001)										
Total Assets			0.021***									
			(0.001)									
Net Sales				0.012***								
				(0.001)								
Firm's Risk												
Volatility					0.364***	0.008*	0.360***	0.244***	0.521***	0.054***	0.017***	0.406***
					(0.013)	(0.005)	(0.014)	(0.019)	(0.016)	(0.016)	(0.004)	(0.014)
R&D Intensity						0.030***					-0.017***	
						(0.001)					(0.002)	
New Economy							0.045***				-0.211***	-0.035***
							(0.010)				(0.014)	(0.007)
CEO-Specific Factors												
CEO Age								-0.306***	-0.183***	-2.491***	-1.028***	-0.362***
								(0.012)	(0.002)	(0.002)	(0.002)	(0.001)
CEO Tenure									0.060***	0.154***	0.044***	0.072***
									(0.002)	(0.004)	(0.004)	(0.002)
Chair of the Board										0.034***	0.018***	0.063***
										(0.008)	(0.004)	(0.005)
N	21,759	21,445	21,754	21,738	21,698	9,012	21,698	21,552	20,546	20,546	8,498	20,546
Pseudo R^2	-0.018	-0.026	-0.027	-0.023	-0.015	-0.047	-0.029	-0.055	-0.037	-0.132	-0.12	-0.093

Median regressions of M2 equity-based pay ratio on firm- and CEO-specific factors. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. See the Appendix for definitions and data sources.

Table 7. Determinants of M2 Equity-Based Pay Ratio for the Censored Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	0.638***	0.729***	0.668***	0.681***	0.813***	0.369***	0.810***	0.740***	1.089***	1.078***	0.616***	1.082***
	(0.015)	(0.012)	(0.013)	(0.012)	(0.006)	(0.012)	(0.007)	(0.006)	(0.006)	(0.005)	(0.010)	(0.005)
Firm's Size												
Market Cap	0.017***				0.023***	0.023***	0.023***	0.024***	0.026***	0.025***	0.023***	0.025***
	(0.001)				(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of Employees		0.008***										
		(0.001)										
Total Assets			0.010***									
			(0.001)									
Net Sales				0.010***								
				(0.001)								
Firm's Risk												
Volatility					0.155***	0.156***	0.156***	0.163***	0.162***	0.167***	0.150***	0.167***
					(0.010)	(0.016)	(0.011)	(0.011)	(0.012)	(0.012)	(0.016)	(0.011)
R&D Intensity						-0.001**					-0.003***	
						(0.000)					(0.001)	
New Economy							0.014*				0.016*	0.018***
							(0.007)				(0.010)	(0.006)
CEO-Specific Factors												
CEO Age								0.016***	-0.069***	-0.063***	-0.077***	-0.065***
								(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
CEO Tenure									0.029***	0.027***	0.029***	0.028***
									(0.002)	(0.002)	(0.002)	(0.002)
Chair of the Board										0.009***	0.005	0.007**
										(0.003)	(0.003)	(0.003)
N	11,629	11,479	11,628	11,618	11,603	4,636	11,603	11,522	10,827	10,827	4,281	10,827
Pseudo R^2	0.092	0.085	0.087	0.087	0.101	0.078	0.101	0.101	0.113	0.113	0.096	0.113

Median regressions of M2 equity-based pay ratio on firm- and CEO-specific factors. Here, we report the results for the subsample of ratios between 0.05 and 0.95. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. See the Appendix for definitions and data sources.

Table 8. Contribution of Firm- and CEO-Specific Factors to M1 and M2 Equity-Based Pay Ratios

CEO Equity-Based Pay Ratio	**Firm-Specific Factors**				**CEO-Specific Factors**		
	Size	Volatility	R&D Intensity	New Economy	CEO Age	CEO Tenure	Chair of the Board
Panel A							
M1	0.207***	0.123***	0.196***	0.166***	-0.105***	-0.027***	-0.050***
	(0.007)	(0.006)	(0.008)	(0.008)	(0.007)	(0.007)	(0.005)
M2	0.047***	0.139***	0.119***	0.085***	0.001	0.167***	0.007*
	(0.005)	(0.004)	(0.006)	(0.007)	(0.006)	(0.004)	(0.004)
Censored M2	0.048***	0.091***	0.096***	0.066***	-0.005	0.093***	0.001
	(0.006)	(0.007)	(0.012)	(0.009)	(0.007)	(0.007)	(0.005)
Panel B							
M1	0.232***	0.053***	0.175***	0.107***	-0.062***	-0.026***	-0.001
	(0.005)	(0.008)	(0.012)	(0.008)	(0.005)	(0.005)	(0.002)
M2	0.049***	-0.020***	-0.445***	-0.444***	-0.017***	0.140***	0.018***
	(0.005)	(0.006)	(0.036)	(0.016)	(0.005)	(0.004)	(0.004)
Censored M2	0.057***	0.041***	0.078***	0.068***	0.006	0.082***	0.020***
	(0.006)	(0.009)	(0.012)	(0.008)	(0.005)	(0.006)	(0.004)
Panel C							
M1	0.276***	0.193***	0.103***	0.040***	-0.060***	0.009*	-0.000**
	(0.005)	(0.006)	(0.008)	(0.006)	(0.004)	(0.005)	(0.000)
M2	0.081***	-0.120***	-1.288***	-0.021***	-0.050***	0.172***	0.033***
	(0.005)	(0.008)	(0.037)	(0.007)	(0.007)	(0.005)	(0.005)
Censored M2	0.087***	0.103***	0.052***	0.034***	-0.020***	0.091***	0.009***
	(0.006)	(0.008)	(0.011)	(0.009)	(0.006)	(0.005)	(0.003)

Contribution of firm- and CEO-specific factors to the M1 and M2 equity-based pay ratios. Censored M2 refers to the subsample of M2 ratios between 0.05 and 0.95. Two bins are formed by taking observations above the third quartile and below the first quartile of the distribution of a factor. These observations are pooled to estimate a median regression of CEO total pay on a constant and a top bin dummy. The coefficient of the latter variable is reported in the table. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Panel B includes industry dummies and fiscal year dummies. In Panel C, we also control for other firm- and CEO-specific factors. We always control for firm's size and volatility when estimating the contribution of any other factor. Additionally, we control for CEO tenure when estimating the impact of CEO age, for CEO age when investigating the contribution of CEO tenure, and for both CEO age and tenure when studying the effect of the CEO serving as a chair of the board. See the Appendix for definitions and data sources.

Table 9. Sensitivity of M1 Total Pay to Measures of Performance

	Panel A				Panel B			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	-0.159***	-0.195***	-0.178***	-0.202***	-0.289***	-0.265***	-0.290***	-0.325***
	(0.013)	(0.012)	(0.011)	(0.012)	(0.014)	(0.013)	(0.01)	(0.013)
Idiosyncratic return	0.241***	0.251***	0.226***	0.228***	0.265***	0.260***	0.245***	0.246***
	(0.007)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)
Systematic return	0.170***	0.148***	0.164***	0.145***	0.188***	0.184***	0.156***	0.167***
	(0.012)	(0.01)	(0.011)	(0.009)	(0.019)	(0.017)	(0.015)	(0.015)
Average CEO pay		0.146***		0.145***		0.053***		0.031**
		(0.013)		(0.011)		(0.016)		(0.014)
Market share			0.197***	0.205***			0.194***	0.195***
			(0.014)	(0.012)			(0.013)	(0.012)
N	21,981	21,943	21,729	21,698	21,981	21,943	21,729	21,698
Pseudo R^2	0.022	0.025	0.026	0.028	0.030	0.030	0.033	0.034

Median regression estimates of the sensitivity of M1 total pay to internal and external measures of performance. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies are included in all regressions. Panel B also includes fiscal year dummies. See the Appendix for definitions and data sources.

Table 10. Sensitivity of M2 Total Pay to Measures of Performance

	Panel A				Panel B			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	-0.224***	-0.192***	-0.020	0.007	0.115***	0.093***	0.310***	0.269***
	(0.02)	(0.02)	(0.014)	(0.01)	(0.037)	(0.035)	(0.036)	(0.033)
Idiosyncratic return	1.060***	1.041***	1.091***	1.088***	1.039***	1.042***	1.090***	1.092***
	(0.011)	(0.01)	(0.011)	(0.011)	(0.01)	(0.009)	(0.011)	(0.011)
Systematic return	0.986***	1.000***	0.976***	1.002***	1.128***	1.132***	1.161***	1.145***
	(0.016)	(0.017)	(0.016)	(0.017)	(0.028)	(0.026)	(0.031)	(0.032)
Average CEO pay		-0.170***		-0.166***		-0.028*		0.002
		(0.016)		(0.017)		(0.017)		(0.004)
Market share			-0.424***	-0.429***			-0.425***	-0.410***
			(0.019)	(0.019)			(0.018)	(0.017)
N	16,401	16,395	16,219	16,219	16,401	16,395	16,219	16,219
Pseudo R^2	0.187	0.189	0.198	0.200	0.235	0.235	0.246	0.246

Median regression estimates of the sensitivity of M2 total pay to internal and external measures of performance. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies are included in all regressions. Panel B also includes fiscal year dummies. See the Appendix for definitions and data sources.

Table 11. Contribution of Firm- and CEO-Specific Factors to Sensitivity Measures of M1 Total Pay

	Firm-Specific Factors				CEO-Specific Factors		
	Size	Volatility	R&D Intensity	New Economy	CEO Age	CEO Tenure	Chair of the Board
Panel A							
Constant	0.002	-0.008	-0.003	-0.012	-0.013*	-0.009	0.009*
	(0.002)	(0.009)	(0.006)	(0.011)	(0.007)	(0.008)	(0.005)
Idiosyncratic return	0.048**	-0.066**	0.049	0.026	0.035**	-0.039**	0.020*
	(0.022)	(0.028)	(0.030)	(0.018)	(0.017)	(0.018)	(0.011)
Systematic return	-0.005	-0.164***	0.102**	0.012	0.029	-0.037	-0.020
	(0.007)	(0.044)	(0.046)	(0.026)	(0.020)	(0.031)	(0.018)
Average CEO pay	0.126***	0.160***	0.110*	0.194***	-0.030*	-0.045	0.012
	(0.035)	(0.033)	(0.058)	(0.045)	(0.018)	(0.033)	(0.010)
Market Share	0.035	0.104***	-0.031	-0.007	-0.124***	0.046	-0.000
	(0.026)	(0.030)	(0.043)	(0.018)	(0.029)	(0.031)	(0.001)
Panel B							
Constant	-0.010	-0.026**	-0.000	-0.008	-0.017**	-0.017*	0.013**
	(0.009)	(0.013)	(0.000)	(0.012)	(0.008)	(0.010)	(0.006)
Idiosyncratic return	0.052**	-0.075***	0.089***	0.019	0.016	0.006	0.049***
	(0.022)	(0.026)	(0.032)	(0.018)	(0.013)	(0.006)	(0.012)
Systematic return	0.012	-0.151***	0.040	0.019	0.041	0.013	0.015
	(0.013)	(0.043)	(0.040)	(0.028)	(0.025)	(0.012)	(0.013)
Average CEO pay	0.145***	0.134***	0.143**	0.195***	-0.024	0.005	0.007
	(0.035)	(0.026)	(0.067)	(0.045)	(0.016)	(0.004)	(0.007)
Market Share	0.036	0.095***	-0.028	-0.021	-0.092***	0.050	0.000
	(0.027)	(0.033)	(0.042)	(0.035)	(0.028)	(0.034)	(0.001)

Contribution of firm- and CEO-specific factors to the sensitivity of M1 total pay to internal and external measures of performance. Two bins are formed by taking observations above the third quartile and below the first quartile of the distribution of a factor. These observations are pooled to obtain a median regression estimate that captures the incremental effect of the factor in question by interacting the performance measures with a top bin dummy. The coefficients of these interactions are reported in the table. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. In Panel B, we also control for other firm- and CEO-specific factors. We always control for firm's size and volatility when estimating the contribution of any other factor. Additionally, we control for CEO tenure when estimating the impact of CEO age, for CEO age when investigating the contribution of CEO tenure, and for both CEO age and tenure when studying the effect of the CEO serving as a chair of the board. See the Appendix for definitions and data sources.

Table 12. Contribution of Firm- and CEO-Specific Factors to Sensitivity Measures of M2 Total Pay

	Firm-Specific Factors				CEO-Specific Factors		
	Size	Volatility	R&D Intensity	New Economy	CEO Age	CEO Tenure	Chair of the Board
Panel A							
Constant	-0.221***	0.086***	0.062**	0.036*	0.001	0.091***	0.000
	(0.016)	(0.016)	(0.026)	(0.020)	(0.003)	(0.013)	(0.000)
Idiosyncratic return	0.314***	-0.259***	0.007	0.077***	0.041	0.056**	-0.036*
	(0.031)	(0.033)	(0.007)	(0.027)	(0.027)	(0.026)	(0.021)
Systematic return	0.239***	0.047	0.188***	0.001	0.026	0.136***	0.004
	(0.045)	(0.041)	(0.062)	(0.002)	(0.038)	(0.049)	(0.009)
Average CEO pay	-0.190***	-0.238***	-0.426***	-0.222***	0.130***	-0.175***	-0.112***
	(0.059)	(0.051)	(0.079)	(0.056)	(0.049)	(0.047)	(0.041)
Market Share	-0.213***	-0.242***	0.311***	-0.408***	-0.063	-0.303***	0.004
	(0.051)	(0.049)	(0.078)	(0.062)	(0.044)	(0.049)	(0.008)
Panel B							
Constant	-0.200***	0.017	0.076**	0.049***	-0.020	0.084***	-0.002
	(0.018)	(0.012)	(0.030)	(0.017)	(0.013)	(0.014)	(0.003)
Idiosyncratic return	0.322***	-0.234***	0.001	0.036	0.017	0.018	-0.057***
	(0.030)	(0.034)	(0.001)	(0.026)	(0.019)	(0.023)	(0.021)
Systematic return	0.267***	-0.053	0.210***	0.020	0.023	0.117**	0.022
	(0.048)	(0.037)	(0.060)	(0.029)	(0.031)	(0.050)	(0.022)
Average CEO pay	-0.210***	-0.231***	-0.482***	-0.241***	0.183***	-0.124***	-0.107***
	(0.062)	(0.056)	(0.075)	(0.053)	(0.047)	(0.044)	(0.036)
Market Share	-0.259***	-0.303***	0.306***	-0.408***	-0.018	-0.305***	0.022
	(0.058)	(0.051)	(0.074)	(0.059)	(0.028)	(0.054)	(0.021)

Contribution of firm- and CEO-specific factors to the sensitivity of M2 total pay to internal and external measures of performance. Two bins are formed by taking observations above the third quartile and below the first quartile of the distribution of a factor. These observations are pooled to obtain a median regression estimate that captures the incremental effect of the factor in question by interacting the performance measures with a top bin dummy. The coefficients of these interactions are reported in the table. Bootstrapped standard errors based on 100 replications are reported in parentheses. ***, **, and * denote significance at 0.01, 0.05, and 0.10 respectively. Industry dummies and fiscal year dummies are included in all regressions. In Panel B, we also control for other firm- and CEO-specific factors. We always control for firm's size and volatility when estimating the contribution of any other factor. Additionally, we control for CEO tenure when estimating the impact of CEO age, for CEO age when investigating the contribution of CEO tenure, and for both CEO age and tenure when studying the effect of the CEO serving as a chair of the board. See the Appendix for definitions and data sources.

Online Appendix to "A Model of Managerial Talent: Addressing Some Puzzles in CEO Compensation"

A. An Extension of the Basic Model

Assume that there are two types of managers who differ in talent or productivity. The distribution of firm's value v is characterized by a cumulative distribution function F_H under a high-ability manager and F_L under a low-ability manager. The *strict monotonicity of the likelihood ratio* implies that $F_H(\cdot) < F_L(\cdot)$ almost everywhere. The ability of the manager is unobservable by the principal, and only imperfectly observable by the manager. That is, there is common uncertainty about managerial talent. A good candidate for the job is a high-ability manager with probability $1 > p_G > 0$ and a low-ability manager with probability $1 - p_G$, whereas a bad candidate is a high-ability manager with probability $1 > p_L > 0$ and a low-ability manager with probability $1 - p_L$, and $p_G > p_L$. The non-degenerate probabilities p_G and p_L may stem from the complexity of the tasks and skills necessary for the job in question. A related interpretation comes from the manager's degree of seniority. For a junior manager, p_G would always be away from 1, even for the most talented types. In case of a senior hire whose ability has been amply validated, we could expect p_G to be close to 1.

The quality of the candidates also bears on the value of the reservation wages, $\underline{w}_G > \underline{w}_L$. One may expect this difference to be smaller for junior candidates.

Assume that the risk-neutral principal minimizes the expected cost of hiring a good candidate:

$\min_{w} \int w(v)\left(p_G dF_H(v) + (1-p_G)\, dF_L(v)\right)$ subject to

$$\int w(v)\left(p_G dF_H\left(v\right)+\left(1-p_G\right)dF_L\left(v\right)\right)\geq u(\underline{w}_G) \tag{6}$$

$$\int w(v)\left(p_L dF_H\left(v\right)+\left(1-p_L\right)dF_L\left(v\right)\right)\leq u(\underline{w}_L) \tag{7}$$

Note that this setting reduces to the principal's problem (P) presented in Section 2. Indeed, let $F\left(\cdot|\overline{\tau}\right) = p_G F_H\left(\cdot\right) + \left(1-p_G\right)F_L\left(\cdot\right)$, $F\left(\cdot|\underline{\tau}\right) = p_L F_H\left(\cdot\right) + \left(1-p_L\right)F_L\left(\cdot\right)$, $\underline{w}(\overline{\tau}) = \underline{w}_G$, and $\underline{w}(\underline{\tau}) = \underline{w}_L$.

B. Proofs

All our theoretical results as well as the underlying assumptions should be understood to hold almost everywhere.

Proof of Lemma 1. We can re-write the principal's problem in terms of the agent's utility of compensation so that the objective is a strictly convex function and the constraints are linear. Hence, the optimal wage schedule $w(v)$ is unique. Consider the first-order condition:

$$\frac{1}{u'(w)}=\lambda_1-\lambda_2\frac{f\left(\cdot|\underline{\tau}\right)}{f\left(\cdot|\overline{\tau}\right)}, \tag{8}$$

where $\lambda_1, \lambda_2 \geq 0$ are the Lagrange multipliers corresponding to constraints (1) and (2) respectively. Both multipliers must be positive because $u'(w) > 0$ and $\underline{w}(\overline{\tau}) > \underline{w}(\underline{\tau})$. Then, $w(v)$ is increasing in v because of the strict monotonicity of the likelihood ratio. Under the strong concavity of function u, the continuous differentiability of the optimal wage $w(v)$ follows from an application of the implicit-function theorem to the first-order condition. ■

Proof of Proposition 1. As both (1) and (2) bind at the optimum, the following equality must be satisfied:

$$\int u\left(w(v)\right)\left(f\left(v|\overline{\tau}\right)-f\left(v|\underline{\tau}\right)\right)dv=\Delta\underline{u} \tag{9}$$

Now, integrating by parts, we have:

$$\int u'\left(w(v)\right)w'(v)\left(F\left(v|\underline{\tau}\right)-F\left(v|\overline{\tau}\right)\right)dv=\Delta\underline{u} \tag{10}$$

Note that all the elements in the integrand of this latter equation are non-negative. Further, $F\left(\cdot|\underline{\tau}\right)-F\left(\cdot|\overline{\tau}\right)\rightarrow 0$, and $\Delta\underline{u}$ is a positive constant. Hence, $u'\left(w(v)\right)w'(v)$ must get unbounded over a set of positive measure. This proves the proposition. ■

Proof of Proposition 2. Let $\underline{w}(\overline{\tau})-\underline{w}(\underline{\tau})\rightarrow 0$. Then, the right-hand side of (10) converges to 0 and so does the left-hand side. Note that $w'(v)\geq 0$ and $u'(w(v))\left(F\left(v|\underline{\tau}\right)-F\left(v|\overline{\tau}\right)\right)>0$ almost everywhere. By Fatou's lemma [Billingsley (1979, p. 180)], we then get that $\liminf w'(v)=0$ for almost all v. By (8), we obtain that $\lim\lambda_2=0$. Therefore, $\lim w'(v)=0$ in the sup norm. ■

Proof of Proposition 3. Suppose that RPE holds, i.e., $w(v(\tau,\varepsilon,\theta),\theta)=w(v(\tau,\varepsilon,\theta'),\theta')$ for all (θ,θ'). Let $v(\tau,\varepsilon,\theta)>v(\tau',\varepsilon',\theta)$ for some θ. Note that by Lemma 1 the optimal wage $w(v)$ is increasing in v. Hence, $w\left(v(\tau,\varepsilon,\theta),\theta\right)>w\left(v(\tau',\varepsilon',\theta),\theta\right)$. As RPE holds, we have $w\left(v(\tau,\varepsilon,\theta'),\theta'\right)>w\left(v(\tau',\varepsilon',\theta'),\theta'\right)$ for all θ'. It follows that $v(\tau,\varepsilon,\theta')>v(\tau',\varepsilon',\theta')$ for all θ' as $w(v)$ is increasing in v. Therefore, v is weakly separable on (τ,ε). ■

For the proof of the next proposition we will make use of the following property of weakly separable functions with positive partial derivatives.

Lemma 2 *Assume that function $v(\tau,\varepsilon,\theta)$ is weakly separable on (τ,ε). Then, we can write $v(\tau,\varepsilon,\theta)$ as $v(\tau,\varepsilon,\theta)=v^*(h(\tau,\varepsilon),\theta)$, where functions v^* and h are continuously differentiable with positive partial derivatives.*

Proof of Proposition 4. By the previous lemma, let $v^*(h(\tau,\varepsilon),\theta) = v(\tau,\varepsilon,\theta)$. Then, we can write the optimal wage as $w^*(h(\tau,\varepsilon),\theta) = w(v(\tau,\varepsilon,\theta),\theta)$. As pointed out above, $h(\tau,\varepsilon)$ is continuously differentiable with positive partial derivatives. Hence, the conditional density $f(h|\tau,\theta)$ is well defined since ε is assumed to have a well defined density. (Note that $f(h|\tau,\theta)$ does not depend on θ since ε and θ are independent.) For convenience, let us rewrite the joint density $f(v|\tau)$ as $f(h,\theta|\tau)$. Note that this density function can be decomposed as $f(h,\theta|\tau) = f(\theta)f(h|\tau,\theta)$. Further, the likelihood ratio $\frac{f(\theta)f(h|\underline{\tau},\theta)}{f(\theta)f(h|\overline{\tau},\theta)}$ does not depend on θ. Therefore, from the first-order condition (8) the optimal wage $w^*(h(\tau,\varepsilon),\theta) = w(v(\tau,\varepsilon,\theta),\theta)$ does not depend on θ. ■

Proof of Proposition 5. We will prove the result for the reservation wages. The same method of proof works for perturbations of the cumulative distribution functions. Without loss of generality, consider a small drop in $\underline{w}(\underline{\tau})$. Then, (1) remains unchanged, which implies that a^* and b^* must move in opposite directions.

Totally differentiating (10) for $w(v) = a + bv$, we obtain:

$$\left(b^* \int u'' \Delta F dv\right) da^* + \left(b^* \int v u'' \Delta F dv + \int u' \Delta F(v) dv\right) db^* = d\Delta\underline{u} \quad (11)$$

where $\Delta F := F(\cdot|\underline{\tau}) - F(\cdot|\overline{\tau}) > 0$ almost everywhere and da^*, db^*, and $d\Delta\underline{u}$ denote marginal changes in a^*, b^*, and $\Delta\underline{u}$ resulting from the marginal change in $\underline{w}(\underline{\tau})$. The right-hand side of (11) is positive and so should be the left-hand side. Observe that the coefficient of da^* is negative because $u'' < 0$. Also, the coefficient attached to db^* is positive because the coefficient of relative risk aversion is assumed to be less than or equal to 1. Further, $da^* db^* < 0$ by virtue of (1). Therefore, the left-hand side of (11) is positive if and only if $da^* < 0$ and $db^* > 0$.

Next, consider a marginal increase in the reservation utilities for both manager types so that the right-hand side of (11) is equal to 0. Note that the increase in the reservation utility in (1) implies some positive change in either a^* or b^*. But the left-hand side of (11) would equal 0 only if $da^* > 0$ and $db^* > 0$. ■

Let $\Delta\mu := \mu(\overline{\tau}) - \mu(\underline{\tau})$, $\Delta\sigma^2 := \sigma^2(\underline{\tau}) - \sigma^2(\overline{\tau})$, and $\Delta\underline{w} := \underline{w}(\overline{\tau}) - \underline{w}(\underline{\tau})$, Note that we have assumed that $\Delta\mu > 0$ and $\Delta\underline{w} > 0$.

Proof of Proposition 6. Since (3) must be binding, we can express a as a function of b. Then, we can rewrite the objective as $\underline{w}(\overline{\tau}) + \frac{\rho\sigma^2(\overline{\tau})}{2}b^2$, and we can rewrite (4) as $\frac{\rho\Delta\sigma^2}{2}b^2 + \Delta\mu b - \Delta\underline{w} \geq 0$. This latter constraint must also be binding. Hence, the optimization problem amounts to searching for the smallest $b \geq 0$ satisfying $\frac{\rho\Delta\sigma^2}{2}b^2 + \Delta\mu b - \Delta\underline{w} = 0$. If $\Delta\sigma^2 > 0$, then one root is positive and the other root is negative. If $\Delta\sigma^2 = 0$, then $b^* = \frac{\Delta\underline{w}}{\Delta\mu}$. If $\Delta\sigma^2 < 0$, then both roots are positive, and we should pick the smallest. Parts (i)-(iv) follow immediately from differentiating b^* with respect to $\Delta\mu$, $\Delta\underline{w}$, $\Delta\sigma^2$, and ρ. ■

Let $\delta_{n,k} := \frac{\underline{w}_n - \underline{w}_{n-k}}{\mu_n - \mu_{n-k}}$ for $n = 2, \cdots, N$ and $k = 1, \cdots, n-1$.

Proof of Proposition 7. Consider firm n's problem for some arbitrary $n = 2, \cdots, N$. From the individual rationality of manager $n-1$ to reject the contract and the binding individual rationality of manager n to accept the contract, we obtain $b_n^* \geq \delta_{n,1}$. Applying the same reasoning to firm $n-1$'s problem results in $b_{n-1}^* \leq \delta_{n,1}$. Hence, in a separating equilibrium, both b_n^* and $\delta_{n,1}$ increase with n. The binding individual rationality constraint of manager n to accept the offer allows us to express a_n as a function of b_n. Hence, we can eliminate a_n from the objective of the principal and from the individual rationality constraints of all other managers to reject the offer. Then, firm n's problem amounts to finding the smallest b_n that satisfies $\delta_{n,k'} \leq b_n \leq \delta_{n+k'',k''}$, $\forall k' = 1, \cdots, n-1, \forall k'' = 1, \cdots, N-n$. From before, we have $\delta_{n-1,1} \leq \delta_{n,1}$. Adding $\frac{w_n - w_{n-1}}{\mu_{n-1} - \mu_{n-2}}$ to both sides of the inequality and then dividing them by $\frac{\mu_n - \mu_{n-2}}{\mu_{n-1} - \mu_{n-2}}$ results in $\delta_{n,2} \leq \delta_{n,1}$. Applying the argument recursively, we obtain that $\delta_{n,k}$ decreases with k. Similarly, we can show that $\delta_{n+k,k}$ increases with k. Then, the constraint set simplifies to $\delta_{n,1} \leq b_n \leq \delta_{n+1,1}$. Therefore, $b_n^* = \delta_{n,1}$. ■

Proof of Proposition 8. Multiplying the individual rationality constraint of manager n to reject the offer of firm n' by -1 and adding it to the binding individual rationality constraint of manager n to accept the offer of firm n results in:

$$\int_{-\infty}^{+\infty} \left(u\left(a_n + b_n v\right) - u\left(a_{n'} + b_{n'} v\right)\right) f_n(v) dv \geq 0, \tag{12}$$

where u is the utility function of the manager and f_n is the density of v conditional on hiring a manager of type n. Since $u' > 0$, we see that it is not possible to have both $a_n < a_{n'}$ and $b_n < b_{n'}$. Analogously, from the individual rationality constraint of manager n' to reject the offer of firm n and the binding individual rationality of manager n' to accept the offer of firm n', we obtain that it is not possible to have both $a_n > a_{n'}$ and $b_n > b_{n'}$.

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C. Data Definitions

- **M1 total pay** is the grant-date value of CEO pay within a fiscal year. This corresponds to entry TDC1 in ExecuComp. M1 total pay equals the sum of cash pay, M1 equity-based pay, and other annual pay, as defined below. All compensation measures are expressed in thousands of constant 2005 dollars.

- **Cash pay** is the sum of salary and bonus corresponding to entries SALARY and BONUS in ExecuComp. Following the adoption of FAS 123R in 2006, only discretionary payouts are reported as bonuses, while non-discretionary short-term and long-term cash incentives are reported as non-equity incentive plan compensation. Therefore, after 2006 our measure may underestimate cash compensation in the bonus component.

- **M1 equity-based pay** is the grant-date value of stock and stock option awards. For data prior to 2006, we use the sum of ExecuComp entries RSTKGRNT and OPTION_AWARDS_BLK_VALUE, i.e., the grant-date market value of restricted stock and the ExecuComp Black-Scholes valuation of stock option awards. After the adoption of FAS123R in 2006, firms are required to report the fair value of company stock and options[14] granted to the CEO during the fiscal year, so we take the sum of the corresponding ExecuComp entries STOCK_AWARDS_FV and OPTION_AWARDS_FV. We use OLD_DATAFMT_FLAG to identify the reporting format of the data: the variable equals 1 for older reports and 0 for reports that comply with FAS123R.

- **Other annual pay** includes items of CEO compensation that are not covered by cash or M1 equity-based pay. More specifically, it is equal to the sum of LTIP Payouts, Other Annual, and All Other Total Pay prior to 2006; and the sum of Non-Equity Incentive Plan Compensa-

[14] For stock options, firms commonly report the Black-Scholes value of the grant.

tion, Deferred Compensation Earnings Reported as Compensation, and Other Compensation after 2006.

- **M1 equity-based pay ratio** is the ratio of M1 equity-based pay to the sum of cash pay and M1 equity-based pay for all CEOs with positive cash and M1 equity-based pay in a given fiscal year. While dropping zeros generates an upward bias in the ratio, there is also an existing downward bias since equity-based pay granted in one year would also link CEO's wealth to firm's performance in the next few years as the vesting period may be longer than one year. To minimize the effects of these biases, we also estimate the ratio using M2 equity-based pay, as defined below.

- **M2 total pay** is the change in CEO's firm-related wealth within a fiscal year. It equals the sum of M1 total pay, the change in the value of CEO's initial holdings of company stock and options adjusted for stock sales and options exercised, the net gains from such trades, and related dividend income. M2 total pay can be decomposed into cash pay, M2 equity-based pay, and other annual pay.

- **M2 equity-based pay** is the change in CEO's firm-related equity-based wealth within the fiscal year. In particular, it equals M2 total pay less cash and other annual pay. Note that it includes both the change in the value of CEO's initial equity-based holdings and the grant-date value of new stock and option awards.

- **Growth rates:** For every positive variable, the growth rate is computed as $\log(\frac{w_t}{w_{t-1}})$, where w_t is the value of the variable for (or at the end of) fiscal year t. As M2 total pay is often negative, we approximate its growth rate by $\log\left(\frac{1+\frac{w_t}{W_{t-1}}}{1+\frac{w_{t-1}}{W_{t-2}}}\right)$, where w_t is M2 total pay for fiscal year t and W_{t-1} is the value of CEO's holdings of company stock and options at the end of fiscal year $t-1$. We follow the same approach to approximate the growth rate of M2 equity-based pay.

- **Industry dummies** are based on firms' 2-digit SIC codes which are taken from CRSP.

- **Fiscal year dummies** are based on Compustat fiscal years. For example, a dummy variable corresponding to fiscal year 2005 equals 1 if the company's fiscal year ended between June 01, 2005 and May 31, 2006, and equals 0 otherwise.

- **Firm's size** is firm's market capitalization: the market value of firm's equity at the end of the previous fiscal year as taken from CRSP. We have also considered alternative measures such as the number of employees, firm's total assets, and net sales, as reported in Compustat. All monetary measures of firm's size are expressed in millions of constant 2005 dollars. The number of employees is in thousands.

- **Firm's volatility** is the standard deviation of firm's monthly logarithmic stock returns for the 60 months prior to the beginning of firm's current fiscal year. In case of missing data on company returns, we estimate firm's volatility only if we have at least 12 available observations. We have used CUSIP numbers to match the return data taken from CRSP with the company data taken from Compustat.

- **Firm's R&D intensity** is the ratio of R&D expenditure to net sales, both of which are taken from Compustat. We ignore firms that report no R&D expenditure.

- **New economy firms** are defined from 4-digit SIC codes as in Ittner, Lambert and Larcker (2002) and Murphy (2003).

- **CEO age** is the (integer) number of years from the date of birth of the CEO and is taken from ExecuComp. Some missing data have been recovered from previous ExecuComp entries.

- **CEO tenure** is the number of years the executive has been serving as current CEO of the company. Identifying executives as current CEOs and estimating their CEO tenure is based on the date on which the executive became a CEO of the company and the date (if any) on which the executive left the CEO office, as reported in the corresponding ExecuComp entries BECAMECEO and LEFTOFC.

- **Chair of the Board** refers to CEOs who serve as company board chairs, co-chairs, vice-chairs, and co-vice-chairs, based on their titles as reported in ExecuComp.

- **Decomposing firm's stock return into an idiosyncratic and a systematic component with respect to the market return**: For each company-year, we run an OLS regression of firm's total return on the total return of S&P 500. More specifically, we use monthly real log returns for 60 months prior to the beginning of the firm's current fiscal year (or at least 12 in case of missing data). We use the regression estimate of firm's beta to construct firm's systematic annualized return for the current fiscal year. The remaining part of the firm's realized return is the idiosyncratic component.

- **Average CEO pay** is the sample mean of M1 total pay. For a given CEO and fiscal year, this is the average compensation of the CEOs of all other companies that end their fiscal year in the same month as the company of the CEO in question.

- **Firm's market share** is the ratio of company's net sales over the fiscal year to the sum of the net sales of all companies in our sample that finish their fiscal year in the same month as the company in question.

- **Bins for firm- and CEO-specific factors:** For each company-year, we consider the distribution of a factor of interest at the end of the previous fiscal year and check whether the particular firm or CEO is located above the third quartile or below the first quartile of the distribution. Since the end of the fiscal year may vary across firms, we have estimated the distribution by matching firms that end their fiscal year in the same month. Repeating the process for all company-years, we end up with two bins corresponding to firms or CEOs above the third quartile (top bin) and below the first quartile (bottom bin). Note that the composition of each bin may change over time.