Executive Compensation, Board Compensation, and Managerial Risk-Seeking Activities

Chang Mo Kang[1]

University of Texas

25 November 2013

[1]I am greatly indebted to my committee, Andres Almazan (Chair), Jason Abrevaya, Jay Hartzell, Laura Starks and Sheridan Titman for their feedback and guidance. I am also grateful to Aydogan Alti, Fernando Anjos, Jonathan Cohn, Nicholas Crane, Haiwei Jing, Daehyun Kim, Donghyun Kim, Jordan Nickerson, Carlos Parra and Mitch Towner and all seminar participants at University of Texas at Austin for their comments. All errors are my own.

Abstract

I examine the design of board compensation in a setting in which shareholders delegate to the board the tasks of monitoring managers and setting managerial pay. While high performance-based board compensation induces the board to monitor the firm and to properly design managerial compensation, it also provides the board with incentives to misreport managerial risk-seeking activities and to engage in collusive behavior with the manager at the expense of shareholders. From this trade-off, I develop a number of testable hypotheses and take them to data. Consistent with the model's implications, I find that firms in which (i) managerial risk-seeking activities are more likely to occur (e.g., high R&D firms or banks), (ii) board monitoring costs are likely to be lower (e.g., firms that have non-officer blockholders on the board) and (iii) their projects can exhibit a large variability in quality (e.g., larger or more diversified firms) tend to award higher pay-for-performance compensation to their managers and lower pay-for-performance compensation to their boards.

1 Introduction

Since Jensen and Meckling [1976] financial economists have focused on agency conflicts between the shareholders and the manager of the corporation and have analyzed a number of mechanisms that shareholders can employ to mitigate these conflicts. Among these mechanisms, managerial compensation and board monitoring have been considered essential to reducing these conflicts. Specifically, the standard view in the literature is that the misalignment of incentives between managers and shareholders can be reduced by either adequately designing managerial compensation or alternatively by delegating managerial monitoring to the board of directors.[1]

While the literature has extensively analyzed the effectiveness of these two alternate mechanisms in isolation, this paper departs from the literature by considering the two mechanisms jointly, and in particular, by incorporating two key features of the relationships between shareholders, boards and managers. First, I consider a setting in which shareholders delegate to the board the tasks of managerial monitoring and the design of managerial compensation. Second, I model the board's agency problems in performing these tasks and solve for the board compensation that maximizes shareholder value.[2] By considering a setting in which managerial and board incentives are endogenously determined, I can investigate a number of empirical issues related to board and managerial compensation.

In practice, board compensation has recently exhibited wide variation in its structure across firms. For instance, in 2006 Coca-Cola Co. abandoned the use of non-contingent compensation for outside directors and instead started awarding them

[1]See Frydman and Jenter [2010] and Adams et al. [2010] for surveys of recent research on managerial compensation and board of directors, respectively.

[2]Bebchuk and Fried [2004] highlights the practical importance of board agency conflicts, particularly, in the design of managerial compensation.

performance-based compensation related to earnings-per-share growth. In the same year, IBM moved in the opposite direction by abandoning option grants to outside directors and reinstating a non-contingent annual compensation of $200,000. These contrasting decisions suggest that a trade-off exists in the use of pay-for-performance board compensation. In this analysis, I examine this trade-off by considering how a board compensation structure influences the board's functions within the corporation which, as established by the literature (e.g., Adams et al. 2010), are associated with the monitoring of managerial activities and the design of managerial pay.

Intuitively, the main trade-off in the structure of board compensation is that while high pay-for-performance compensation provides the board with incentives to properly design managerial compensation, it also diminishes the board's incentives to monitor and report unproductive managerial risk-shifting activities. As I show, these competing incentives related to the board's two monitoring functions suggest that the cross-sectional variations in managerial and board pay-for-performance compensation are not mutually independent of one another and that further insight can be gained by analyzing them in tandem.

To formally analyze the double incentive provision problem for managers and boards, I consider a firm that operates a project whose quality is private information to the manager in charge and whose success depends on a specific set of managerial actions. These managerial actions fall into two categories: (i) costly managerial actions (e.g., operational choices that require managerial effort) which enhance the firm's value without affecting the risk of its cash-flows and (ii) costless managerial risk-seeking activities (e.g., financial speculation or over-investment in risky activities) which increase the risk of the firm's cash flows without affecting the firm value.

I model the board as a single agent who can acquire information about the project's quality at some cost, and can also observe managerial risk-seeking activities. Since optimal managerial actions depend on the project's quality, it may appear optimal to delegate to the board the authorities to monitor the manager and to fine tune managerial compensation. This conclusion, however, is not necessarily correct since shareholders, who do not observe the board's information, can only rely on the design of board compensation to influence the board's behavior. As it turns out, depending on parameters related to the nature of the managerial and board agency problems, several optimal governance arrangements are possible. In some of these governance arrangements, shareholders rely on more intense board monitoring and managerial compensation is delegated to the board. In other arrangements shareholders choose less reliance on board monitoring. Each of these arrangements corresponds with an optimal compensation structure for the board and the manager. Therefore, the model analysis gives rise to a number of empirical predictions which link the joint compensation structure to the parameters that characterize the nature of managerial and board agency problems.

First, my analysis proposes a test that considers how the combined use of pay-for-performance for boards and managers is affected by the managerial ability to engage in risk-seeking activities. Specifically, in the absence of agency conflicts regarding risk-seeking activities, the optimal compensation structure exhibits a high pay-for-performance sensitivity in both managerial and board compensation. This result aligns with the intuition that high pay-for-performance board compensation provides the board with incentives to fine-tune the design of managerial compensation by monitoring the project's quality. However, when the manager can easily engage in risk-seeking activities, awarding high pay-for-performance compensation to both managers and boards can produce undesirable effects since such a compensation structure would prompt the manager to engage in risk-seeking activities while simultaneously reducing the board's incentive to disclose the manager's engagement in risk-seeking activities to shareholders. To test this prediction, I examine whether firms reduce the combined use of high pay-for-performance compensation to both managers and boards as the managerial ability to engage in risk-seeking activities increases.

Second, this model proposes that the size of the board's monitoring costs is a key determinant of the optimal joint compensation structure. Specifically, when monitoring costs are low, boards do not require high pay-for-performance compensation to tailor managerial compensation by acquiring information about the project's quality. Thus, as board monitoring costs decrease, shareholders will use reduced pay-for-performance board compensation while inducing the board to grant high pay-for-performance to the manager.

Finally, the model analysis also suggests that when a firm's project exhibits a large variability in quality, it becomes likely that low pay-for-performance board compensation is optimal. Intuitively, even with low pay-for-performance compensation, boards find it costly to design managerial compensation without acquiring information about the project's quality (i.e., to award low pay-for-performance compensation to the manager in charge of a high-quality project or vice versa). Therefore, in these conditions the optimal compensation structure simultaneously grants low pay-for-performance compensation to boards and high pay-for-performance to managers.

To test the empirical predictions provided by the model analysis, I analyze S&P 1500 companies in the years 1996-2005 and use R&D firms and banks as proxies for high managerial risk-shifting ability, outside directors' ownership as a proxy for board monitoring costs and business complexity measures (i.e., firm size and the number of business segments) as proxies for the project's variability in their quality. To empirically measure the combined use of pay-for-performance compensation for managers and boards, I consider information on option grants. Specifically, I classify the sample firm years into four groups, namely, (high-high, high-low, low-high, low-low), which correspond to the magnitudes of manager-board pay-for-performance sensitivities. Then, I estimate the effect of the determinants on the joint compensation structure using the multinomial logit regressions.

The main empirical findings are as follows. First, after controlling for common determinants (e.g., Yermack 1995), I find that when the manager has opportunities to substantially shift the firm's risks, the combined compensation structure exhibits high pay-for-performance for managers and low pay-for-performance for boards. Relative to other firms, R&D firms show around 6% higher odds of awarding options only to managers. Second, firms in which non-officer blockholders sit on the board are also more likely to award high pay-for-performance compensation to managers and low pay-for-performance compensation to boards. Specifically, the presence of blockholders on the board leads to 5% higher likelihood of awarding stock options to managers alone. Finally, I also find that business complexity is positively related to the simultaneous award of high managerial and low board pay-for-performance but it is negatively related to awarding high pay-for-performance to both simultaneously. With all other factors being equal, an additional business segment is associated with a 2% increase in the likelihood of awarding option plans only to the manager.

This study is related to several branches of the corporate governance literature. First, my model contributes to the theoretical literature on corporate governance that considers the interaction between managerial pay and boards. Previous studies have shown that managerial pay is affected by the degree of influence that a manager has on the board (i.e., the board structure) and they have considered the optimal board structure when managerial pay is endogenous.[3] As shown above, by incorporating board agency conflicts and the board's role in the design of managerial pay into the analysis, my study generates a number of cross-sectional implications between firm characteristics and the joint nature of managerial and board compensation.

In addition, my empirical findings offer new evidence on the determinants of board compensation.[4] Previous empirical studies have found a substantial variation in board incentives and have reported a number of determinants of board incentive compensation. For instance, Yermack [2004] shows that, on average, board compensation exhibits a considerable pay-for-performance sensitivity while Ryan and Wiggins [2004] finds that board compensation is related to the firm's internal governance. In this study I propose and test for other important determinants of board compensation and their relationship to managerial pay.

Finally this paper also contributes to the literature on managerial compensation and in particular re-examines how the convexity of managerial compensation affects managerial risk-taking behavior.[5] While agency theory tends to predict that convex managerial compensation leads to risk-seeking corporate policies, the previous empirical studies have led to inconclusive results. My analysis provides a possible explanation for these inconclusive results. Specifically, while highly convex managerial compensation may certainly induce managers to engage in risk-seeking activities, these activities only occur when the board also receives a convex compensation struc-

[3] See, e.g., Almazan and Suarez [2003] and Kadan and Swinkels [2008].

[4] See e.g., Ryan and Wiggins [2004], Yermack [2004], Fich and Shivdasani [2005], Adams and Ferreira [2008], and Kadan and Swinkels [2008] among others.

[5] See, e.g., Coles et al. [2006], Chava and Purnanandam [2010], and Hayes et al. [2012] for the papers that have empirically investigated how managerial compensation affects risk-taking managerial behavior.

ture and allows these activities to materialize. Thus, my analysis suggests that empirical studies should include measures of board compensation convexity when testing the effects of managerial compensation on risk-seeking corporate behavior.

The paper is organized as follows. Section 2 describes the model. Sections 3 and 4 solve the model. Section 5 discusses the results of the model analysis and develops empirical predictions which I take to data in the second part of this paper. Section 6 describes the data. Section 7 presents the empirical results. Finally, section 8 discusses concluding remarks.

2 The model

I consider an all-equity firm that operates in a risk-neutral economy where the market rate of return is normalized to zero. The firm is run by a manager who has no wealth, is protected by limited liability and has a zero reservation utility. There is also a board of directors (the board, hereafter) that can monitor the manager and to whom the design of managerial compensation is delegated. To focus the analysis exclusively on the board's incentives and compensation, I model it as a risk-neutral single agent, protected by limited liability and with zero wealth and zero reservation utility.[6]

In line with previous literature (e.g., Faure-Grimaud et al. 2003), I consider a firm organized as a two tier hierarchy: in the first tier (i.e., the *shareholder-board tier*) shareholders communicate and contract with the board and in the second tier (i.e., the *board-manager tier*), the board subsequently communicates and contracts with the manager.[7] In this setting I solve for the optimal contracting choices made by the

[6]This modelling choice abstracts from issues related to board composition. See Adams et al. [2010] for a recent literature review on board composition.

[7]Faure-Grimaud et al. [2003] also examines a two-tier hierarchy with decentralized contracting structure in which the principal contracts exclusively with an intermediary who is delegated the

shareholders and the board and then consider the implications that emanate from them.

2.1 Firm project and managerial actions

The firm's assets consist of a project that yields a random terminal cash flow $\tilde{r} = \{r^d, r^m, r^u\}$, where $r^m = \frac{r^u+r^d}{2}$ and $0 < r^d < r^u$ and whose probability distribution is affected by (i) a project's productivity type $\theta \in \{\theta_l, \theta_h\}$, where $0 < \theta_l < \theta_h < \frac{1}{3}$ and $prob(\theta = \theta_h) = p$, and (ii) two managerial actions e and Δ described below.

Specifically, the project's cash-flow distribution is as follows:

$$\tilde{r} = \begin{cases} r^u & \text{with prob. } \frac{1}{3} + \theta e + \Delta \\ r^m & \text{with prob. } \frac{1}{3} - 2\Delta \\ r^d & \text{with prob. } \frac{1}{3} - \theta e + \Delta, \end{cases} \quad . \tag{1}$$

I refer to $e \in [0, 1]$ as "managerial effort" which is privately *costly* to the manager

$$c(e) = \frac{1}{2}\gamma_m e^2. \tag{2}$$

As shown in (1), relative to $e = 0$ which is the minimum effort choice, $e > 0$ increases the likelihood of r^u at the expense of r^d and thus increases the firm's expected cash-flow by $\theta(r^u - r^d)e$. Furthermore, I refer to $\Delta \in \{\Delta_0, \Delta_s\}$ (where $0 = \Delta_0 < \Delta_s < \frac{1}{6}$) as the managerial "risk choice" which is *costless* to the manager. Relative to Δ_0, the risk choice Δ_s is a mean-preserving spread which increases the likelihood of extreme cash flows r^u and r^d at the expense of the moderate cash flow r^m.[8]

authority to contract with the agent.

[8]The possibility of costless risk-management choices allows me to consider a particularly relevant case namely the case in which a manager can make financial transactions on behalf of their firms. Net

2.2 Managerial private information and board monitoring

The manager has private information about the project's type θ and takes hidden actions e and Δ. I assume that shareholders cannot observe any of the managerial information, but the board can monitor and obtain information about the project's type and the managerial actions. In particular, in this setting the board monitoring technologies with respect to θ, e and Δ differ in their required monitoring costs (which reflects the level of difficulty that the board encounters in monitoring each type of information) and in the feasibility of producing hard evidence about the acquired information (which reflects the possibility to translate each type of information into a verifiable report).

Relative to the board monitoring costs, I assume that the board cannot observe e at any cost (i.e., the board cannot measure the managerial effort choice) but it can privately observe the project's type θ by incurring a private cost γ_b and also privately observe the manager's choice of Δ at no cost. The assumption of the board's ability to observe managerial risk choices is consistent with regulations such as the Sarbanes-Oxley Act which authorize the board to review the firm's risk-management strategy and to discuss it with management.[9]

With regard to the production of hard evidence, I assume that the board produces none when monitoring θ and that, by contrast, produces some publicly observable hard evidence after monitoring the risk choice Δ. This distinction is consistent with the insight that information about project quality is likely to be soft and thus unverifiable by third parties, while managerial risk choices have a quantitative dimension

of transaction costs, financial transactions are ex-ante zero NPV transactions that affect cash-flow risk without altering the its value. In this sense, this analysis can be interpreted as an analysis of the provision of managerial and board incentives when a manager can engage in financial speculation.

[9] Géczy et al. [2007] finds that management regularly reports to the board about the firm's (speculative) derivative transactions.

that can be communicated to third parties in the form of verifiable reports (e.g., financial statements).[10]

Technically, I assume that θ can only be reported via board announcements $\hat{\theta}_b$ to the shareholders while after observing $\Delta = \{\Delta_0, \Delta_s\}$ the board produces verifiable hard evidence $\hat{\Delta} = \{\hat{\Delta}_0, \hat{\Delta}_s\}$ which is however subject to the following agency conflict. When the manager chooses Δ_s, the board may report otherwise (i.e., the board can either report $\hat{\Delta}_0$ or $\hat{\Delta}_s$) but when the manager chooses Δ_0, the board truthfully reports it (i.e., the board can only report $\hat{\Delta}_0$). In other words, $\hat{\Delta}_s$ is always truthful evidence of the manager's choice of Δ_s while $\hat{\Delta}_0$ does not necessarily reveal the managerial choice of Δ_0.[11]

For the future reference I refer to $(\hat{\Delta}^z, \hat{\theta}^z) \in \{\Delta_0, \Delta_s\} \times \{\bar{\theta}, \theta_l, \theta_h\}$ as the board's information status relative to Δ and θ where Δ_j $(j = 0, s)$ corresponds to the case in which the board observes the manager's risk choice and θ_i $(i = l, h)$ to the case in which the board monitors and observes the project's type θ_i and $\bar{\theta}$ to the case in which the board does not monitor θ.

In summary, as is common in the delegation literature (e.g., Tirole 1986) I analyze a nested informational structure in which the manager's information set is a finer partition of the board's information set which in turn is a finer partition of the information set of shareholders. In the *shareholder-board tier*, shareholders do not observe either the board's information $(\hat{\theta}^z, \hat{\Delta}^z)$ or whether the board forges the evidence $\hat{\Delta}$ and in the *board-manager tier*, the board can monitor to learn θ and Δ (but not e)

[10]For instance, in the financial statements each of derivative transactions is explicitly classified into either hedging or speculative investments.

[11]Since Δ_s corresponds to the case in which the manager takes an action that will be detrimental to shareholder value, the board's inability to forge the evidence $\hat{\Delta}_s$ allows me to rule out the impractical case in which boards incriminate managers by producing a false evidence of managerial misbehavior. This modelling choice is typically considered in the delegation literature (e.g., Tirole 1986) to capture agency conflicts in the production of information supervisors.

while the manager observes $(\hat{\theta}^z, \hat{\Delta}^z)$ i.e., the board's information status.[12]

2.3 Collusion, communication and contracts

The analysis solves for the design of the optimal managerial and board compensation in a sequential contracting framework. As discussed below, the analysis takes into account the aspect that communication is limited to parties within tiers and thus that some contracts are unfeasible due to limited communication. Within this setting, I consider the design of the optimal board compensation by shareholders within the *shareholder-board tier*, and, then, the subsequent design of optimal managerial compensation by the board within the *board-manager tier*.

An important element of the analysis is the possibility that the manager and the board can collude to obtain additional rents at the expense of the shareholders. As in Tirole [1986] collusion is modelled by assuming that the board can pre-commit to produce a certain report about the managerial choice of Δ_s before the manager actually chooses Δ.[13] Formally, I denote the board's commitment as $\phi \in \{t, f\}$, where $\phi = t$ corresponds to truthfully reporting $\hat{\Delta}_s$ and $\phi = f$ to falsely reporting $\hat{\Delta}_0$.[14] I assume that shareholders do not observe ϕ which, as shown below, implies that the possibility of board-manager collusion crucially affects the design of the compensation contracts.

In this setting feasible contracts are limited by the availability of information and by inability to communicate with parties in different tiers. Specifically, feasible

[12]Strictly speaking, not all information structure is nested in this analysis since, as shown below, the manager does not observe the board's messages sent to shareholders.

[13]This resembles the framework in Tirole [1986] in which a supervisor and an agent can collude at the expense of the principal. As in that framework I assume that this commitment is self-enforceable, i.e, that can be implemented without the assistance of a third-party enforcing it.

[14]The board reporting action after managers choose $\Delta = \Delta_0$ is by assumption $\hat{\Delta}_0$, i.e., the board cannot forge the report when the manager chooses Δ_0.

contracts can be written on: (i) the hard information produced by the board's report $\hat{\Delta}$ and (ii) the messages sent by the manager (to the board) and by the board (to the shareholders) relative to the soft private information that they may have. In particular, the manager sends to the board a message $\hat{\theta}_m \in \{\theta_l^m, \theta_h^m\}$ relative to θ while the board sends a message to shareholders $\mu_b = (\hat{\theta}_b, \hat{\theta}_b^m)$, where $\hat{\theta}_b \in \{\theta_l^b, \theta_h^b, \bar{\theta}^b\}$ corresponds to the message about its information $\hat{\theta}^z$ and $\hat{\theta}_b^m \in \{\hat{\theta}_l^b, \hat{\theta}_h^b\}$ to the message about the manager's message $\hat{\theta}_m$.[15] In line with the delegation literature, I assume that these messages are observed by the two parties within each tier but cannot be observed by the party outside a tier.[16] In other words, shareholders and the manager who are not in direct communication with each other do not observe $\hat{\theta}_m$ and $(\hat{\theta}_b, \hat{\theta}_b^m)$, respectively.

Formally, feasible contractual arrangements in each tier are as follow.[17] First, within the *board-manager tier* the board commits to $\phi(\hat{\theta}_m)$ and offers a managerial compensation contract $w_m(\hat{\theta}_m, \hat{\Delta}, \tilde{r})$ which, for convenience, can be rewritten as:

$$w_m(\hat{\theta}_m, \hat{\Delta}, \tilde{r}) = \left(u_m(\hat{\theta}_m, \hat{\Delta}), m_m(v), d_m(\hat{\theta}_m, \hat{\Delta})\right), \tag{3}$$

where $k_m(.)$ $(k = u, m, d)$ corresponds to the managerial pay for the realized cash flow r^k.

Second, within the *shareholder-board tier* shareholders design the board compen-

[15] By the "generalized revelation principle" (Myerson 1982), the restrictions of the manager and board message spaces are without loss of generality. The board also observes the manager's choice of Δ and therefore can communicate about it with shareholders. As it turns out, considering the board's message about Δ does not affect the results since the managerial compensation which induces the manager's choice of Δ cannot be written upon the board's message to shareholders.

[16] Other studies in the delegation literature (e.g., Baliga and Sjöström 1998 and Faure-Grimaud et al. 2003) also consider a setting in which parties can write contracts contingent on messages sent to each other within a tier but not on messages sent by parties in other tiers.

[17] To facilitate the presentation I describe these arrangements in the reverse order of their actual contracting sequence.

sation contract with limited information about the managerial compensation contract offered by the board. In particular I assume that while the board offers a menu of contracts to the manager, shareholders can observe only the specific part of the menu chosen by the manager and cannot observe other elements in the menu offered to the manager. This assumption, which is consistent with the premise that a party has limited information about contracts made outside its own tier, allows the model to capture in a simple way the trade-off that shareholders face when they delegate managerial compensation to the board.[18] While by delegating the task to a better informed party (i.e., the board) shareholders can use the board's information in the design of managerial compensation, they cannot take full advantage of the board's information since they have only limited access to relevant aspects about the pay-setting process.

Formally, within the *shareholders-board tier* shareholders design the board pay w_b as a function of observables $(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \tilde{r}, \sigma_m)$, where σ_m corresponds to the part of the menu of managerial compensation observed by shareholders, namely, the managerial choice within the menu of contracts. In particular, when the board offers the manager $[w_m(\hat{\theta}_m, \hat{\Delta}, \tilde{r}), \phi(\hat{\theta}_m)]$ and the manager subsequently chooses $(\hat{\theta}_m^*, \Delta^*) \in (\{\theta_l^m, \theta_h^m\}, \{\Delta_0, \Delta_s\})$, shareholders observe

$$\sigma_m = w_m(\hat{\theta}_m^*, \hat{\Delta}^*, \tilde{r}) = (u_m(\hat{\theta}_m^*, \hat{\Delta}^*), m_m(\hat{\theta}_m^*, \hat{\Delta}^*), d_m(\hat{\theta}_m^*, \hat{\Delta}^*)),$$

where $\hat{\Delta}^* \in \{\hat{\Delta}_0, \hat{\Delta}_s\}$ is the board's report $\hat{\Delta}$ that corresponds to $\phi(\hat{\theta}_m^*)$ and Δ^*.

[18]This is also in line with the observation made in Bebchuk and Fried [2004] who document a number of examples in which boards resort to hard-to-observe (i.e., "camouflage") compensation for managers.

Analogously to (3), w_b can be written as:

$$w_b(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \tilde{r}, \sigma_m) = \{u_b(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \sigma_m), m_b(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \sigma_m), d_b(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \sigma_m)\}, \quad (4)$$

where $k_b(.)$ $(k = u, m, d)$ corresponds to the board pay for the realized cash flow r^k. To alleviate the notation, in what follows I will refer to the menus of contracts $w_m(\hat{\theta}_m, \hat{\Delta}, \tilde{r})$ and $w_b(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta}, \tilde{r}, \sigma_m)$ as w_m and w_b when no confusion arises.

2.4 Sequence of events

The sequence of events unfolds as follows. At $t = 0$, shareholders offer w_b to the board. At $t = 1$, the board monitors θ, offers the compensation contract w_m and commits to report ϕ. At $t = 2$, the manager chooses e and Δ and sends a message $\hat{\theta}_m$ to the board. At $t = 3$, the board reports $(\hat{\theta}_b, \hat{\theta}_b^m, \hat{\Delta})$ to the shareholders who, in turn, observe σ_m. At $t = 4$, the firm's cash flows are realized and contracts are enforced.

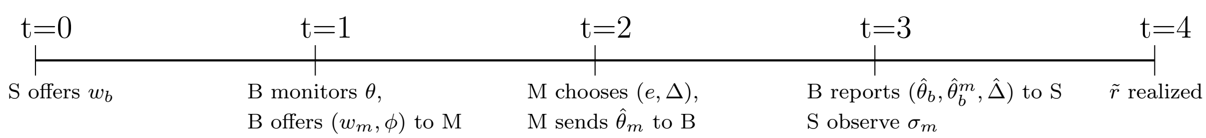

Figure 1. Sequence of events

The analysis of the model can be simplified by solving for the optimal compensation and actions in two mutually exclusive cases that differ on whether or not the board monitors and acquires information on θ. Specifically, in the *uninformed board case*, the board designs managerial compensation without monitoring θ while in the *informed board case*, the board optimally chooses to monitor θ before designing the managerial compensation.[19] While most of the interesting comparative statics arises in the analysis of the informed board case, the analysis of the uninformed board case provides a natural benchmark. Thus, in Section 3 I first solve for the optimal compensation and actions when the board is uninformed and compare them with the informed board case analyzed in Section 4.

Solving the model requires to obtain the managerial and board compensation and to characterize the associated managerial and board choices induced by the compensation contracts. Technically, the model features a sequence of three optimization problems in which: (i) shareholders solve for the optimal board compensation w_b^* to affect the board's incentives to design managerial compensation and to monitor θ and Δ; (ii) the board, in turn, solves for the optimal managerial compensation w_m^* and disclosure commitment ϕ^* taking into account how they affect the managerial choices of $(\hat{\theta}_m, e, \Delta)$; and (iii) the manager chooses $(\hat{\theta}_m^*, e^*, \Delta^*)$ that maximizes his expected utility.

3 Model analysis (I): Uninformed board

The *uninformed board case* corresponds to the case in which shareholders set board compensation w_b^U to induce the board to choose (w_m^U, ϕ^U) without learning θ. Formally, solving this model requires to consider a sequence of two mechanism design problems, one in each organizational tier. In the *board-manager tier*, the board chooses (w_m^U, ϕ^U) to provide incentives to the manager who is privately informed about θ and will take two hidden actions (e, Δ). In the *shareholders-board tier*, shareholders design w_b^U for the board who can observe the managerial choice of Δ and

[19] This is without loss of generality. Considering the possibility of a mixed monitoring strategy in which the board incurs γ_b with probability $q \in (0, 1)$ does not change the results.

communicates with the manager to receive information about θ. In what follows, I denote the sequence of optimal mechanisms chosen by shareholders and the board as $M^{U*} = \{w_b^{U*}, (w_m^{U*}, \phi^{U*})\}$.

By virtue of the generalized revelation principle (Myerson [1982]), M^{U*} belongs to the set of truth-telling mechanisms in which: (i) in the *board-manager tier* the manager sends a message to the board $\hat{\theta}_m \in \{\theta_l^m, \theta_h^m\}$ which truthfully reveals θ and (ii) in the *shareholders-board tier* the board sends a message to shareholders $\hat{\theta}_b^m \in \{\hat{\theta}_l^b, \hat{\theta}_h^b\}$ which truthfully reveals the manager's message $\hat{\theta}_m$.[20] Thus, the shareholders' problem can formally stated as follows:

$$\max_{w_b} \; pV_s\left(w_b \mid \hat{\theta}_h^b\right) + (1-p)V_s\left(w_b \mid \hat{\theta}_l^b\right) \tag{5}$$

subject to

$$(\hat{\theta}_b^{h*}, \hat{\theta}_b^{l*}, w_m^*, \phi^*) = \underset{\hat{\theta}_b^h, \hat{\theta}_b^l, w_m, \phi}{\operatorname{argmax}} \, pV_b\left(\hat{\theta}_b^h, w_m, \phi \mid \theta_h^m, w_b\right) + (1-p)V_b\left(\hat{\theta}_b^l, w_m, \phi \mid \theta_l^m, w_b\right) \tag{5.1}$$

subject to

$$(\hat{\theta}_m^i, e^i, \Delta^i) = \underset{\hat{\theta}_m, e, \Delta}{\operatorname{argmax}} V_m(\hat{\theta}_m, e, \Delta \mid \theta_i, w_m, \phi) \text{ for } i = h, l \tag{5.1.a}$$

$$\hat{\theta}_m^i = \theta_i^m \text{ for } i = h, l \tag{5.1.b}$$

$$u_m(\hat{\theta}_m, \hat{\Delta}) \geq m_m(\hat{\theta}_m, \hat{\Delta}) \geq d_m(\hat{\theta}_m, \hat{\Delta}) \geq 0, \tag{5.1.c}$$

$$\hat{\theta}_b^{i*} = \hat{\theta}_i^b \text{ for } i = h, l \tag{5.2}$$

$$u_b(\hat{\theta}_b^m, \hat{\Delta}, \sigma_m) \geq m_b(\hat{\theta}_b^m, \hat{\Delta}, \sigma_m) \geq d_b(\hat{\theta}_b^m, \hat{\Delta}, \sigma_m) \geq 0 \tag{5.3}$$

[20]Without loss of generality I omit the board's message about its information status relative to the monitoring decision (i.e., $\hat{\theta}^z = \bar{\theta}$) since shareholders can infer that the board optimally remains uninformed about θ.

where, for $i = h, l$,

$$V_m\left(\hat{\theta}_m, e, \Delta \mid \theta_i, w_m, \phi\right) = \left(\frac{1}{3} + \theta_i e + \Delta\right) u_m(\hat{\theta}_m, \hat{\Delta}) + \left(\frac{1}{3} - 2\Delta\right) m_m(\hat{\theta}_m, \hat{\Delta}) + \left(\frac{1}{3} - \theta_i e + \Delta\right) d_m(\hat{\theta}_m, \hat{\Delta}) - \frac{\gamma_m e^2}{2}, \tag{6}$$

for $\hat{\Delta} = \begin{cases} \hat{\Delta}_s & \text{if } \Delta = \Delta_s \text{ and } \phi(\theta_i^m) = t \\ \hat{\Delta}_0 & \text{otherwise,} \end{cases}$

$$\begin{aligned} &V_b\left(\hat{\theta}_b^i, w_m, \phi \mid \theta_i^m, w_b\right) \\ &\quad = \left(\frac{1}{3} + \theta_i e^i + \Delta^i\right) u_b\left(\hat{\theta}_b^i, \hat{\Delta}, \sigma_m\right) + \left(\frac{1}{3} - 2\Delta^i\right) m_b\left(\hat{\theta}_b^i, \hat{\Delta}, \sigma_m\right) \\ &\qquad + \left(\frac{1}{3} - \theta_i e^i + \Delta^i\right) d_b\left(\hat{\theta}_b^i, \hat{\Delta}, \sigma_m\right) \end{aligned} \tag{7}$$

and

$$\begin{aligned} &V_s\left(w_b \mid \hat{\theta}_i^b\right) \\ &\quad = \left(\frac{1}{3} + \theta_i e^i + \Delta^i\right) [r^u - u_b\left(\hat{\theta}_i^b, \hat{\Delta}, \sigma_m\right) - u_m(\theta_i^m, \hat{\Delta})] \\ &\qquad + \left(\frac{1}{3} - 2\Delta^i\right) [r^m - m_b\left(\hat{\theta}_i^b, \hat{\Delta}, \sigma_m\right) - m_m(\theta_i^m, \hat{\Delta})] \\ &\qquad + \left(\frac{1}{3} - \theta_i e^i + \Delta^i\right) [r^d - d_b\left(\hat{\theta}_i^b, \hat{\Delta}, \sigma_m\right) - d_m(\theta_i^m, \hat{\Delta})]. \end{aligned} \tag{8}$$

for $\sigma_m = w_m(\theta_i^m, \hat{\Delta}, \tilde{r})$ and $\hat{\Delta} = \begin{cases} \hat{\Delta}_s & \text{if } \Delta^i = \Delta_s \text{ and } \phi(\theta_i^m) = t \\ \hat{\Delta}_0 & \text{otherwise.} \end{cases}$

Constraints (5.1)-(5.1.c) are the board's incentive compatibility constraints relative to its choice of messages, managerial compensation and disclosure commitment

$(\hat{\theta}_b^h, \hat{\theta}_b^l, w_m, \phi)$, respectively. In particular, the board's choice of $(\hat{\theta}_b^h, \hat{\theta}_b^l, w_m, \phi)$ maximizes its expected compensation taking into account managerial incentives. Specifically, (5.1.a) ensures that the manager's choices of message and actions $(\hat{\theta}_m, e, \Delta)$ are incentive compatible, (5.1.b) imposes truth-telling on managerial messages and (5.1.c) states that managerial compensation contracts must be a non-decreasing function of firm output and subject to managerial limited liability. Constraint (5.2) corresponds to the board's truth-telling constraints and (5.3) states that board compensation contracts must also be a non-decreasing function of firm output and subject to limited liability.

The following lemma states the optimal compensation of the uninformed board:

Lemma 3.1. *The optimal compensation for uninformed board is* $w_b^{U*}(\hat{\theta}_b^m, \hat{\Delta}, \sigma_m, \tilde{r}) = (0, 0, 0)$ *for any* $(\hat{\theta}_b^m, \hat{\Delta}, \sigma_m)$.

Lemma 3.1 states that the uninformed board pay is independent of the firm's cash flows $\tilde{r}$. This feature, which greatly simplifies the analysis, implies that to the extent that shareholders do not want to induce board monitoring on θ, the board will act as a surrogate of the shareholders and will not be exposed to any other agency problem. In particular, the board will truthfully report $\hat{\theta}_m$, make a commitment $\phi^{U*}(\hat{\theta}_m) = t$ and offer the managerial compensation w_m^{U*} most desired by shareholders.[21] Lemma 3.1 also implies that the sequence of mechanism design problems that characterizes the shareholders' problem can be rewritten as a simple mechanism design problem.

[21] While in this solution the board is indifferent in communicating its private information to shareholders, it is immediate to obtain a scheme in which the board strictly prefers such communications. For instance, $w_b^{U*}(\hat{\theta}_b^m, \hat{\Delta}_0, \sigma_m^h) = \begin{cases} \{\epsilon, \frac{\epsilon}{2}, 0\} & \text{if } (\hat{\theta}_b^m, \hat{\Delta}, \sigma_m) = (\hat{\theta}_h^b, \hat{\Delta}_0, \sigma_m^h) \\ \{\epsilon', \epsilon', \epsilon'\} & \text{if } (\hat{\theta}_b^m, \hat{\Delta}, \sigma_m) = (\hat{\theta}_l^b, \hat{\Delta}_0, \sigma_m^l) \\ \{0, 0, 0\} & \text{otherwise,} \end{cases}$
for $\epsilon, \epsilon' \simeq 0$ where σ_m^j $(j = h, l)$ corresponds to the managerial compensation that shareholders desire to offer to the manager who reports θ_j^m.

In particular, this simpler problem can be described as one in which shareholders (who can observe Δ) designs managerial compensation

$$w_m'(\hat{\theta}_m, \tilde{r}) = \{u_m'(\hat{\theta}_m), m_m'(\hat{\theta}_m), d_m'(\hat{\theta}_m)\}$$

and commits to impose a risk choice $\Delta(\hat{\theta}_m) \in \{\Delta_0, \Delta_s\}$ as a function of the manager's message $\hat{\theta}_m$. Formally, the shareholders' problem can be rewritten as:

$$\max_{w_m', \Delta} \; pV_s\left(w_m^{'}, \Delta \mid \theta_h^m\right) + (1-p)V_s\left(w_m^{'}, \Delta \mid \theta_l^m\right) \tag{9}$$

subject to

$$(\hat{\theta}_m^i, e^i) = \operatorname*{argmax}_{\hat{\theta}_m, e} V_m\left(\hat{\theta}_m, e \mid \theta_i, w_m^{'}\right) \text{ for } i = h, l \tag{9.1}$$

$$\hat{\theta}_m^i = \theta_i^m \text{ for } i = h, l \tag{9.2}$$

$$u_m^{'}(\hat{\theta}_m) \geq m_m^{'}(\hat{\theta}_m) \geq d_m^{'}(\hat{\theta}_m) \geq 0 \tag{9.3}$$

where, for i=h,l

$$\begin{aligned} V_s\left(w_m^{'}, \Delta \mid \theta_i^m\right) = &\left(\frac{1}{3} + \theta_i e^i + \Delta(\theta_i^m)\right)\left[r^u - u_m^{'}(\theta_i^m)\right] + \left(\frac{1}{3} - 2\Delta(\theta_i^m)\right)\left[r^m - m_m^{'}(\theta_i^m)\right] \\ &+ \left(\frac{1}{3} - \theta_i e^i + \Delta(\theta_i^m)\right)\left[r^d - d_m^{'}(\theta_i^m)\right] \end{aligned} \tag{10}$$

and for j=h,l

$$\begin{aligned} V_m\left(\hat{\theta}_m, e \mid \theta_i, w_m^{'}\right) = &\left(\frac{1}{3} + \theta_i e + \Delta(\hat{\theta}_m)\right) u_m^{'}(\hat{\theta}_m) + \left(\frac{1}{3} - 2\Delta(\hat{\theta}_m)\right) m_m^{'}(\hat{\theta}_m) \\ &+ \left(\frac{1}{3} - \theta_i e + \Delta(\hat{\theta}_m)\right) d_m^{'}(\hat{\theta}_m) - \frac{\gamma_m e^2}{2}. \end{aligned} \tag{11}$$

To solve the problem, consider first the manager's optimization problem stated in (9.1). Given a menu of managerial compensation $w_m^{'}(\hat{\theta}_m, \tilde{r})$, managerial effort depends on the managerial message $\hat{\theta}_m$ since such a message determines the relation between managerial compensation and the firm's cash flows. In particular, managerial effort denoted as $e(\hat{\theta}_m \mid \theta_i, w_m^{'})$ solves the first order condition of (11) and can be characterized as follows:[22]

Lemma 3.2. *A manager who observes θ_i $(i = h, l)$ and receives a menu of compensation contracts $w'_m(\hat{\theta}_m, \tilde{r})$ exerts effort*

$$e(\hat{\theta}_m \mid \theta_i, w'_m) = \frac{\theta_i \left[u'_m \left(\hat{\theta}_m \right) - d'_m \left(\hat{\theta}_m \right) \right]}{\gamma_m}. \tag{12}$$

Lemma 3.2 shows that the manager chooses higher effort as (i) the difference $u'_m(\hat{\theta}_m) - d'_m(\hat{\theta}_m)$ increases, (ii) the project's type θ is higher and (iii) the effort is less costly to the manager (γ_m decreases). By (12), I can substitute $e(\theta_i^m \mid \theta_i, w'_m)$ into e^i which corresponds to the optimal managerial effort choice for θ_i.

Proposition 3.3 summarizes the solution of the shareholders' problem:

Proposition 3.3. *In the uninformed board case: (i) the board receives flat compensation $w_b^{U*} = (0, 0, 0)$ and truthfully reports managerial risk choices, i.e., $\phi^{U*}(\hat{\theta}_m) = t$ and (ii) the manager receives the following compensation contract:*

$$w_m^{U*}(\hat{\theta}_m, \hat{\Delta}, \tilde{r}) = \begin{cases} \left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6(p\theta_h^2 + (1-p)\theta_l^2)}, 0, 0 \right) & \textit{if } (\hat{\theta}_m, \hat{\Delta}) = (\theta_h^m, \hat{\Delta}_0) \textit{ or } (\theta_l^m, \hat{\Delta}_0) \\ (0, 0, 0) & \textit{otherwise.} \end{cases}$$

Proposition 3.3 shows that shareholders induce the board to prevent the manager's choice of Δ_s which would decrease shareholder value by increasing the expected value

[22] The use of first order approach is valid in this setting since the manager's maximization problem in (9.1) has a unique global maximum with respect to e (Grossman and Hart [1983]).

of managerial compensation without increasing the expected value of the project. Proposition 3.3 also shows that the optimal managerial compensation ignores the information provided in the managerial message, i.e., it is a pooling contract with respect to θ. While separating compensation contracts (i.e., contracts that depend on the managerial message) would induce the manager to choose higher effort when he observes $\theta = \theta_h$, these contracts should inefficiently compensate the manager who observe θ_l when r^m or r^d is realized. In particular, the manager reveals $\theta = \theta_l$ only if the expected compensation from truthfully reporting θ_l^m is as large as the alternative compensation that corresponds to θ_h^m. Intuitively, for any separating contract that satisfies the manager's truth-telling constraints, shareholders find it more beneficial to withdraw the managerial compensation that corresponds to θ_l^m and alternately offer the managerial compensation that corresponds to θ_h^m as a pooling contract since this alternative contract induces higher managerial effort while providing the manager with truth-telling incentives.

4 Model analysis (II): Informed board

The *informed board case* considers the case in which shareholders design board compensation w_b to induce board monitoring on θ before the board chooses (w_m, ϕ). In what follows, I denote the sequence of optimal mechanisms chosen by shareholders and the board as $M^{I*} \equiv \{w_b^{I*}, (w_m^{I*}, \phi^{I*})\}$. Three features of the problem simplify the analysis. First, the board's mechanism design problem is simplified since board's monitoring incorporates θ to the board's information set. Thus, if the board does not monitor θ, managerial disclosures of private information about θ can affect board choices while if the board monitors, such managerial disclosures will have no effect on board choices. Second, the search of M^{I*} can be limited to the set of truth-telling mechanisms (on the equilibrium path) in which: (i) the board induces the manager to send a message $\hat{\theta}_m \in \{\theta_l^m, \theta_h^m\}$ that thuthfully reveals θ (when the board is uninformed about θ); (ii) shareholders induce the informed board to send a message $\hat{\theta}_b \in \{\theta_l^b, \theta_h^b\}$ which truthfully reveals its information about θ.[23]

Therefore, the sequence of optimal mechanisms chosen by shareholders and the board can be described by the triple

$$M^{I*} = \left[w_b^*(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}), \left(w_m^{I*}(\hat{\Delta}, \tilde{r}), \phi^{I*} \right), \left(w_m^{o*}(\hat{\theta}_m, \hat{\Delta}, \tilde{r}), \phi^{o*}(\hat{\theta}_m) \right) \right]$$

where:

1. $w_b^*(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}) \equiv \{u_b^*(\hat{\theta}_b, \hat{\Delta}, \sigma_m), m_b^*(\hat{\theta}_b, \hat{\Delta}, \sigma_m), d_b^*(\hat{\theta}_b, \hat{\Delta}, \sigma_m)\}$ describes the optimal board compensation.

2. $\left(w_m^{I*}(\hat{\Delta}, \tilde{r}), \phi^{I*}\right) \equiv \left(\{u_m^{I*}(\hat{\Delta}), m_m^{I*}(\hat{\Delta}), d_m^{I*}(\hat{\Delta})\}, \phi^{I*}\right)$ describes the optimal board's choices (on-the-equilibrium path) when the board monitors θ.

3. $\left(w_m^{o*}(\hat{\theta}_m, \hat{\Delta}, \tilde{r}), \phi^{o*}(\hat{\theta}_m)\right) \equiv \left(\{u_m^{o*}(\hat{\theta}_m, \hat{\Delta}), m_m^{o*}(\hat{\theta}_m, \hat{\Delta}), d_m^{o*}(\hat{\theta}_m, \hat{\Delta})\}, \phi^{o*}(\hat{\theta}_m)\right)$ describes the off-equilibrium path board's choices (i.e., choices taken if the board does not monitor θ).

[23]Without loss of generality I consider the case in which M^{I*} does not induce the uninformed board to admit that it is uninformed. On the equilibrium path, M^{I*} lead to the same compensation contracts with the optimal truth-telling mechanisms that induce the uninformed board to truthfully report about its information status, i.e., report $\hat{\theta}_b = \bar{\theta}^b$ and $\hat{\theta}_b^m = \hat{\theta}_i^b$ $(i = h, l)$ when it receives $\hat{\theta}_m = \theta_i^m$.

Shareholders' problem consists of a nested sequence of optimization problems:

$$\max_{w_b} \; pV_s\left(w_b \mid \theta_h^b\right) + (1-p)V_s\left(w_b \mid \theta_l^b\right) \tag{13}$$

subject to

$$(\hat{\theta}_{ib}^i, w_m^i, \phi^i) = \underset{\hat{\theta}_b, w_m, \phi}{\text{argmax}} V_{ib}\left(\hat{\theta}_b, w_m, \phi \mid \theta_i, w_b\right) \text{ for } i = h, l \tag{14.1}$$

$$\text{s.t. } (e^i, \Delta^i) = \underset{e,\Delta}{\text{argmax}} V_m(e, \Delta \mid \theta_i, w_m, \phi) \text{ for } i = h, l \tag{14.1.a}$$

$$u_m(\hat{\Delta}) \geq m_m(\hat{\Delta}) \geq d_m(\hat{\Delta}) \geq 0, \tag{14.1.b}$$

$$(\hat{\theta}_{ub}^h, \hat{\theta}_{ub}^l, w_m^o, \phi^o)$$

$$= \underset{\hat{\theta}_b^h, \hat{\theta}_b^l, w_m, \phi}{\text{argmax}} \; pV_{ub}\left(\hat{\theta}_b^h, w_m, \phi \mid \theta_h^m, w_b\right) + (1-p)V_{ub}\left(\hat{\theta}_b^l, w_m, \phi \mid \theta_l^m, w_b\right) \tag{14.2}$$

$$\text{s.t. } (\hat{\theta}_m^{i^o}, e^{i^o}, \Delta^{i^o}) = \underset{\hat{\theta}_m, e, \Delta}{\text{argmax}} \; V_m^o(\hat{\theta}_m, e, \Delta \mid \theta_i, w_m, \phi) \text{ for } i = h, l \tag{14.2.a}$$

$$\hat{\theta}_m^{i^o} = \theta_i^m \text{ for } i = h, l \tag{14.2.b}$$

$$u_m(\hat{\theta}_m, \hat{\Delta}) \geq m_m(\hat{\theta}_m, \hat{\Delta}) \geq d_m(\hat{\theta}_m, \hat{\Delta}) \geq 0, \tag{14.2.c}$$

$$pV_{ib}(\hat{\theta}_{ib}^h, w_m^h, \phi^h \mid \theta_h, w_b) + (1-p)V_{ib}(\hat{\theta}_{ib}^l, w_m^l, \phi^l \mid \theta_l, w_b) - \gamma_b$$

$$\geq pV_{ub}\left(\hat{\theta}_{ub}^h, w_m^o, \phi^o \mid \theta_h^m, w_b\right) + (1-p)V_{ub}\left(\hat{\theta}_{ub}^l, w_m^o, \phi^o \mid \theta_l^m, w_b\right) \tag{14.3}$$

$$\hat{\theta}_{ib}^i = \theta_i^b \text{ for } i = h, l \tag{14.4}$$

$$u_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m) \geq m_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m) \geq d_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m) \geq 0, \tag{14.5}$$

where

$$V_m\left(e, \Delta \mid \theta_i, w_m, \phi\right)$$

$$= \left(\frac{1}{3} + \theta_i e + \Delta\right) u_m(\hat{\Delta}) + \left(\frac{1}{3} - 2\Delta\right) m_m(\hat{\Delta}) + \left(\frac{1}{3} - \theta_i e + \Delta\right) d_m(\hat{\Delta}) - \frac{\gamma_m e^2}{2}, \tag{14}$$

$$\text{for } \hat{\Delta} = \begin{cases} \hat{\Delta}_s & \text{if } \Delta = \Delta_s \text{ and } \phi = t \\ \hat{\Delta}_0 & \text{otherwise,} \end{cases}$$

$V_m^o(\hat{\theta}_m, e, \Delta \mid \theta_i, w_m, \phi)$ and $V_{ub}\left(\hat{\theta}_b^i, w_m, \phi \mid \theta_i^m, w_b\right)$ are defined in (6) and (7), respectively,

$$V_{ib}\left(\hat{\theta}_b, w_m, \phi \mid \theta_i, w_b\right) \tag{15}$$
$$= \left(\frac{1}{3} + \theta_i e^i + \Delta^i\right) u_b\left(\hat{\theta}_b, \hat{\Delta}, \sigma_m\right) + \left(\frac{1}{3} - 2\Delta^i\right) m_b\left(\hat{\theta}_b, \hat{\Delta}, \sigma_m\right) + \left(\frac{1}{3} - \theta_i e^i + \Delta^i\right) d_b\left(\hat{\theta}_b, \hat{\Delta}, \sigma_m\right),$$

and

$$V_s\left(w_b \mid \theta_i^b\right)$$
$$= \left(\frac{1}{3} + \theta_i e^i + \Delta^i\right)\left[r^u - u_b\left(\theta_i^b, \hat{\Delta}, \sigma_m\right) - u_m^i(\hat{\Delta})\right] + \left(\frac{1}{3} - 2\Delta^i\right)\left[r^m - m_b\left(\theta_i^b, \hat{\Delta}, \sigma_m\right) - m_m^i(\hat{\Delta})\right]$$
$$+ \left(\frac{1}{3} - \theta_i e^i + \Delta^i\right)\left[r^d - d_b\left(\theta_i^b, \hat{\Delta}, \sigma_m\right) - d_m^i(\hat{\Delta})\right] \tag{16}$$

for $\sigma_m = \{u_m^i(\hat{\Delta}), m_m^i(\hat{\Delta}), d_m^i(\hat{\Delta})\}$ and $\hat{\Delta} = \begin{cases} \hat{\Delta}_s & \text{if } \Delta^i = \Delta_s \text{ and } \phi^i = t \\ \hat{\Delta}_0 & \text{otherwise.} \end{cases}$

Constraints (14.1)-(14.1.b) are incentive compatibility constraints relative to the informed board's choices $(\hat{\theta}_b, w_m^I, \phi^I)$ and (14.2)-(14.2.c) are the incentive compatibility constraints relative to the uninformed board's choices $(\hat{\theta}_b, w_m^o, \phi^o)$. Notice that the optimization problems of the informed and uninformed board differ on the reliance on the managerial message $\hat{\theta}_m$. Specifically, the informed board only takes into account the effect of its choice on the managerial actions (e, Δ) specified in (14.1.a) but does not rely on the managerial message. In contrast, the uninformed board takes into account how its choices affect not only managerial actions (e, Δ) but also the managerial message $\hat{\theta}_m$. Furthermore, (14.2.a) ensures that the managerial choice of message and actions $(\hat{\theta}_m, e, \Delta)$ is incentive compatible and (14.2.b) that the managerial message is truthful. Constraints (14.1.b) and (14.2.c) state that managerial compensation contracts must be a non-decreasing function of firm output and subject to managerial limited liability. Analogously, (14.3) is the board monitoring incentive compatibility, (14.4) is the truth-telling constraint of the informed board and (14.5) limits board compensation contracts to be a non-decreasing function of firm output and subject to limited liability. The following lemma simplifies the analysis:

Lemma 4.1. *Without loss of generality, the search of optimal board compensation can be limited to contracts which specify the board's reports* $\left(\hat{\Delta}^h, \hat{\Delta}^l\right) \in \left(\{\hat{\Delta}_0, \hat{\Delta}_s\}, \{\hat{\Delta}_0, \hat{\Delta}_s\}\right)$ *and managerial compensation* $\left(\sigma_m^h, \sigma_m^l\right) = \left((u_m^h, m_m^h, d_m^h), (u_m^l, m_m^l, d_m^l)\right)$ *that lead to non-zero board pay as follows:*

$$w_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}) = \begin{cases} \left(u_b^h, m_b^h, d_b^h\right) & \textit{if } (\hat{\theta}_b, \hat{\Delta}, \sigma_m) = (\theta_b^h, \hat{\Delta}^h, \sigma_m^h) \\ \left(u_b^l, m_b^l, d_b^l\right) & \textit{if } (\hat{\theta}_b, \hat{\Delta}, \sigma_m) = (\theta_b^l, \hat{\Delta}^l, \sigma_m^l) \\ (0,0,0) & \textit{otherwise,} \end{cases}$$

Lemma 4.1 implies that the search of optimal board compensation can be limited to contracts that award non-zero pay only to when the board's message $\hat{\theta}_b^i$ is in line with the board's choices $(\hat{\Delta}^i, \sigma_m^i)$, for $i = h, l$. As an example, consider a case in which lemma 4.1 limits non-zero board compensations to situations in which $\hat{\Delta}^h = \hat{\Delta}_s$, $\hat{\Delta}^l = \hat{\Delta}_0$, $\sigma_m^h = (100, 0, 0)$ and $\sigma_m^l = (50, 0, 0)$. In this case the board would be compensated only when: (i) it reports to shareholders $\hat{\theta}_b = \theta_h^b$, provides evidence $\hat{\Delta} = \hat{\Delta}_s$ and awards managerial compensation $\sigma_m^h = (100, 0, 0)$; or (ii) it reports $\hat{\theta}_b = \theta_l^b$, provides evidence $\hat{\Delta} = \hat{\Delta}_0$ and awards managerial compensation $\sigma_m^l = (50, 0, 0)$.

By virtue of lemma 4.1, I limit the search of the optimal mechanism M^{I*} to those mechanisms that include board compensation contracts of the form described in lemma 4.1. More specifically, I proceed by first characterizing the informed board choices (w_m^i, ϕ^i) for $i = h, l$ and the uninformed board choices (w_m^o, ϕ^o) and then solving for the optimal board compensation w_b^{I*} among those that induce the board to become informed i.e., to monitor θ.

4.1 Board's choices and managerial actions

4.1.1 Informed board's choices

Consider the informed board's choice of (w_m^I, ϕ^I) and the associated managerial choices (e, Δ). Lemma 4.1 shows that when the board sends a message to shareholders $\hat{\theta}_h$ (resp. $\hat{\theta}_l$), the board must report to shareholders $\hat{\Delta}^h$ (resp. $\hat{\Delta}^l$) and award managerial compensation σ_m^h (resp. σ_m^l) in order to receive a non-zero pay. Thus, I can search the informed board's optimal choice of w_m^I within the following forms of contracts:

Lemma 4.2. *An informed board that reports to shareholders $\hat{\theta}_b = \theta_j^b$ for $j \in \{h, l\}$ offers the manager:*

$$w_m^I(\hat{\Delta}, \tilde{r}) = \begin{cases} \sigma_m^j = (u_m^j, m_m^j, d_m^j) & \text{if } \hat{\Delta} = \hat{\Delta}^j \\ (0, 0, 0) & \text{otherwise,} \end{cases}$$

where $(\theta_j^b, \hat{\Delta}^j, \sigma_m^j)$ is the board's choice that makes board compensation non-zero as stated in Lemma 4.1.

Now consider the informed board's choice of ϕ^I. The disclosure commitment ϕ^I affects the managerial choice of Δ which in turn affects the board's report $\hat{\Delta}$. Since, as shown in lemma 4.1, the board receives non-zero compensation only when $\hat{\Delta}$ is consistent with $\hat{\theta}_b$, the board's decision on ϕ^I is affected by its message choice $\hat{\theta}_b$. Thus, I define ϕ_j^I $(j = h, l)$ as the informed board's optimal disclosure commitment when it chooses $\hat{\theta}_b = \theta_j^b$. To solve for ϕ_j^I, I consider the two mutually exclusive cases in which $\hat{\Delta}^j = \hat{\Delta}_s$ (i.e., the board should report to shareholders $\hat{\Delta}_s$ to receive non-zero pay) or $\hat{\Delta}^j = \hat{\Delta}_0$ (i.e., the board should report $\hat{\Delta}_0$ to receive non-zero pay).

If $\hat{\Delta}^j = \hat{\Delta}_s$, the board induces the manager to choose Δ_s since Δ_0 makes it impossible for the board to report $\hat{\Delta}_s$. To induce Δ_s, the board commits to a truthful report $\phi_j^I = t$ (i.e., to report $\hat{\Delta}_0$ only when the manager indeed chooses Δ_0) and offers the managerial compensation as characterized in lemma 4.2, i.e., the manager receives non-zero compensation only when he chooses Δ_s.

If $\hat{\Delta}^j = \hat{\Delta}_0$, lemma 4.2 implies that the board offers managerial compensation $w_m^I(\hat{\Delta}_0, \tilde{r}) = (u_m^j, m_m^j, d_m^j)$ and $w_m^I(\hat{\Delta}_s, \tilde{r}) = (0, 0, 0)$. While the board can report $\hat{\Delta}_0$ for any managerial choice of $\Delta \in \{\Delta_0, \Delta_s\}$, it still needs to design managerial compensation to induce the manager to choose the desirable alternative of Δ. In particular, when $u_m^j + d_m^j \leq 2m_m^j$, the risky choice Δ_s vis-à-vis Δ_0 decreases the expected value of managerial compensation $w_m^I(\hat{\Delta}_0, \tilde{r})$. Furthermore, since the board cannot falsely report $\hat{\Delta}_s$, the manager chooses Δ_0 for any ϕ_j^I. Alternatively, if $u_m^j + d_m^j > 2m_m^j$, the manager prefers Δ_s and will chooses it when the board commits to falsely reporting $\hat{\Delta}_0$, i.e., $\phi_j = f$. Therefore, ϕ_j^I can be used by the board to affect the managerial choice Δ. Specifically, if the board compensation $w_b(\theta_j^b, \hat{\Delta}^j, \sigma_m^j, \tilde{r}) = (u_b^j, m_b^j, d_b^j)$ satisfies $u_b^j + d_b^j > 2m_b^j$, the board also prefers the managerial choice of Δ_s and therefore commits to a false report $\phi_j^I = f$. Otherwise, the board induces the manager to choose Δ_0 by committing to a truthful report $\phi_j^I = t$. The following lemma characterize the optimal disclosure commitment:

Proposition 4.3. *When the informed board sends message to shareholders* $\hat{\theta}_b = \theta_j^b$

($j = h, l$), its optimal disclosure commitment

$$\phi_j^I = \begin{cases} t & \text{if (i) } \hat{\Delta}^j = \hat{\Delta}_s \text{ or (ii) } \hat{\Delta}^j = \hat{\Delta}_0, C_m^j > 0 \text{ and } C_b^j \leq 0 \\ f & \text{if } \hat{\Delta}^j = \hat{\Delta}_0, C_m^j > 0 \text{ and } C_b^j > 0 \\ \in \{t, f\} & \text{otherwise} \end{cases}$$

where $C_m^j \equiv u_m^j + d_m^j - 2m_m^j$ for managerial compensation $w_m^I(\hat{\Delta}^j, \tilde{r}) = (u_m^j, m_m^j, d_m^j)$ and $C_b^j \equiv u_b^j + d_b^j - 2m_b^j$ for board compensation $w_b(\theta_j^b, \hat{\Delta}^j, \sigma_m^j, \tilde{r}) = (u_b^j, m_b^j, d_b^j)$, respectively.

Proposition 4.3 shows that the board does not truthfully report about the manager's choice of Δ_s when $\hat{\Delta}^j = \hat{\Delta}_0$ and both C_m^j and C_b^j are strictly positive. Notice that C_m^j (resp. C_b^j) measures the convexity of managerial compensation (u_m^j, m_m^j, d_m^j) (resp. board compensation (u_b^j, m_b^j, d_b^j)) since, when $C_m^j > 0$ (resp. $C_b^j > 0$), the risky choice Δ_s increases the expected value of (u_m^j, m_m^j, d_m^j) (resp. (u_m^j, m_m^j, d_m^j)) relative to the risk-free choice Δ_0. Thus, proposition 4.3 captures the insight that a simultaneous award of convex compensation to the board and the manager can foster their collusive behavior at the expense of shareholders. Specifically, such a compensation structure induces the manager to choose Δ_s while providing incentives to the board to falsely report to shareholders $\hat{\Delta}_0$. Proposition 4.3 also suggests the following corollary with respect to the manager's optimal risk choice Δ^j.

Corollary 4.4. *When the informed board sends a message to shareholders $\hat{\theta}_b = \theta_j^b$ ($j = h, l$), it induces the manager to choose $\Delta^j = \Delta_0$ if and only if (i) $\hat{\Delta}^j = \Delta_0$ and (ii) $C_m^j \leq 0$ or $C_b^j \leq 0$.*

Now consider the manager's effort choice induced by the informed board. When the board learns $\theta = \theta_i$ ($i = h, l$) and reports to shareholders θ_j^b, it induces the managerial effort choice $e^{i,j}$ which solves the first order condition of (14.1.a) and can be characterized as follows:

Proposition 4.5. *When the board learns $\theta = \theta_i$ and reports to shareholders θ_j^b, the corresponding managerial compensation σ_m^j induces the managerial effort*

$$e^{i,j} = \frac{\theta_i(u_m^j - d_m^j)}{\gamma_m}. \tag{17}$$

From corollary 4.4 and proposition 4.5 it follows that the informed board's expected compensation that corresponds to the project's type θ_i and the message choice θ_j^b can be written as

$$V_b^{i,j}(w_b) = \left(\frac{1}{3} + \theta_i e^{i,j} + \Delta^j\right) u_b^j + \left(\frac{1}{3} - 2\Delta^j\right) m_b^j + \left(\frac{1}{3} - \theta_h e^{i,j} + \Delta^j\right) d_b^j. \tag{18}$$

4.1.2 Uninformed board's choices

To complete the analysis of the informed board actions it is necessary to describe what choice would be made by a board that remains uninformed. I refer to these off-equilibrium path choices as (w_m^o, ϕ^o). As in the choice of the informed board, the uninformed board's choice of w_m^o crucially hinges on the form of board compensation contracts stated in lemma 4.1. That is, when the board sends a message to shareholders $\hat{\theta}_h$ (resp. $\hat{\theta}_l$), the board should report to shareholders $\hat{\Delta}^h$ (resp. $\hat{\Delta}^l$) and award managerial compensation σ_m^h (resp. σ_m^l) in order to receive a non-zero pay. Furthermore, in contrast to the informed board, the uninformed board chooses (w_m^o, ϕ^o) to induce the manager to send a message $\hat{\theta}_m$ that truthfully reveals managerial private information about θ and after receiving $\hat{\theta}_m$ the uninformed board subsequently sends a message to shareholders $\hat{\theta}_b$. To facilitate the presentation, I define $(\hat{\theta}^h_{ub}, \hat{\theta}^l_{ub}) \in (\{\theta^b_h, \theta^b_l\}, \{\theta^b_h, \theta^b_l\})$ as the uninformed board's message choice when it receives a managerial message $\hat{\theta}_m = \theta^m_h$ and θ^m_l, respectively.[24]

In what follows, I solve the shareholders' problem by assuming that the uninformed board's optimal message choice does not depend on the managerial message, i.e., $\hat{\theta}^h_{ub} = \hat{\theta}^l_{ub} \equiv \hat{\theta}_{ub}$ and after solving the problem, check the conditions in which this assumption indeed holds.[25] Lemma 4.1 implies that under this assumption the uninformed board receives non-zero pay only when $\left(\hat{\theta}_{ub}, \hat{\Delta}, w^o_m(\theta^i_m, \hat{\Delta}, \tilde{r})\right) = \left(\theta^b_h, \hat{\Delta}^h, \sigma^h_m\right)$ or $\left(\theta^b_l, \hat{\Delta}^l, \sigma^l_m\right)$ for $i = h, l$ and therefore the search of optimal w^o_m can be limited to the following forms of contracts:

Lemma 4.6. *An uninformed board that reports to shareholders $\hat{\theta}_{ub} = \theta^b_j$ for $j \in \{h, l\}$ offers the manager:*

$$w^o_m(\hat{\theta}_m, \hat{\Delta}, \tilde{r}) = \begin{cases} \sigma^j_m = (u^j_m, m^j_m, d^j_m) & \textit{if } (\hat{\theta}_m, \hat{\Delta}) = (\theta^m_h, \hat{\Delta}^j) \textit{ or } (\theta^m_l, \hat{\Delta}^j) \\ (0, 0, 0) & \textit{otherwise,} \end{cases}$$

where $(\theta^b_h, \hat{\Delta}^h, \sigma^h_m)$ and $(\theta^b_l, \hat{\Delta}^l, \sigma^l_m)$ are the board's choices that make the board compensation non-zero as stated in Lemma 4.1.

With respect to the uninformed board's disclosure commitment $\phi^o(\hat{\theta}_m)$, in contrast to the informed board, the uninformed board chooses $\phi^o(\hat{\theta}_m)$ taking into account its effect not only on the managerial choice of Δ but also on the managerial message choice $\hat{\theta}_m$. In particular, the optimal ϕ^o should induce the manager's truthful report

[24] For instance, $(\hat{\theta}^h_{ub}, \hat{\theta}^l_{ub}) = (\theta^b_h, \theta^b_l)$ refers to the case in which the board reports to shareholders θ^b_h (resp. θ^b_l) when it receives managerial message $\hat{\theta}_m = \theta^m_h$ (resp. θ^m_l).

[25] As it turns out, this assumption holds in relaxed conditions, and furthermore, the optimal mechanisms obtained under this assumption illustrate the main insights without loss of generality.

about θ.[26] Moreover, since the project's type θ does not affect the managerial choice of Δ, the optimal ϕ^o needs not be contingent upon $\hat{\theta}_m$ and can be characterized as follows:

Proposition 4.7. *When the uninformed board reports to shareholders $\hat{\theta}_{ub} = \theta_j^b$ for $j \in \{h, l\}$, its optimal disclosure commitment is as follows:*

$$\phi^o(\hat{\theta}_h^m) = \phi^o(\hat{\theta}_l^m) = \begin{cases} t & \text{if (i) } \hat{\Delta}^j = \hat{\Delta}_s \text{ or (ii) } \hat{\Delta}^j = \hat{\Delta}_0, C_m^j > 0 \text{ and } C_b^j \leq 0 \\ f & \text{if } \hat{\Delta}^j = \hat{\Delta}_0, C_m^j > 0 \text{ and } C_b^j > 0 \\ \in \{t, f\} & \text{otherwise} \end{cases}$$

where $C_m^j \equiv u_m^j + d_m^j - 2m_m^j$ corresponds to the convexity of managerial compensation $w_m^o(\hat{\theta}_h^m, \hat{\Delta}^j, \tilde{r}) = w_m^o(\hat{\theta}_l^m, \hat{\Delta}^j, \tilde{r}) = (u_m^j, m_m^j, d_m^j)$ and $C_b^j \equiv u_b^j + d_b^j - 2m_b^j$ to the convexity of board compensation $w_b(\theta_j^b, \hat{\Delta}^j, \sigma_m^j, \tilde{r}) = (u_b^j, m_b^j, d_b^j)$, respectively.

Proposition 4.7 is analogous to the informed board's optimal commitment stated in proposition 4.3. As before, the uninformed board commits to the manager to falsely reporting $\hat{\Delta}$ when both managerial compensation and board compensation are convex (i.e., $C_m^j > 0$ and $C_b^j > 0$ for $j = h, l$) and shareholders induce the board to report $\hat{\Delta}_0$. The following corollary is immediate:

Corollary 4.8. *When the informed board sends a message to shareholders $\hat{\theta}_{ub} = \theta_j^b$ $(j = h, l)$, it induces the manager to choose $\Delta^j = \Delta_0$ if and only if (i) $\hat{\Delta}^j = \Delta_0$ and (ii) $C_m^j \leq 0$ or $C_b^j \leq 0$.*

Finally, consider the managerial effort choice induced by the uninformed board. The uninformed board offers the manager (w_m^o, ϕ^o) which is not contingent upon the

[26] As stated in lemma 4.6, the optimal w_m^o chosen by the uninformed board is not contingent on $\hat{\theta}_m$.

managerial message $\hat{\theta}_m$ and, thus, which induces the manager to truthfully report about $\theta = \theta_i$ $(i = h, l)$, i.e., $\hat{\theta}_m = \theta_i^m$. Therefore, when the uninformed board receives $\hat{\theta}_m = \theta_i^m$ and subsequently reports to shareholders $\hat{\theta}_{ub}^i = \theta_j^b$ $(j = h, l)$, the corresponding managerial compensation σ_m^j induces the managerial effort choice as follows:

Proposition 4.9. *When the uninformed board receives θ_i^m for $i \in \{h, l\}$ and subsequently reports to shareholders θ_j^b for $j \in \{h, l\}$, the corresponding managerial compensation σ_m^j induces the managerial effort*

$$e^{i,j} = \frac{\theta_i(u_m^j - d_m^j)}{\gamma_m}. \tag{19}$$

Corollary 4.8 and proposition 4.9 imply that when the uninformed board receives $\hat{\theta}_m = \theta_i^m$ $(i = h, l)$ and reports to shareholders $\hat{\theta}_m = \theta_j^b$ $(j = h, l)$, the managerial actions (e, Δ) induced by the uninformed board equals the managerial actions induced by the informed board who learns θ_i and reports to shareholders θ_j^b, and thus, the uninformed board's expected compensation corresponds to $V_b^{i,j}$ defined in (18).

4.2 Optimal mechanism M^{I*}

The shareholders' problem can be simplified by using the board's optimal choices and the associated managerial actions characterized in section 4.1.1 and 4.1.2. First, I can rewrite the board's truth-telling constraint (14.4) as follows:

$$V_b^{h,h}(w_b) \geq V_b^{h,l}(w_b) \tag{20}$$

$$V_b^{l,l}(w_b) \geq V_b^{l,h}(w_b), \tag{21}$$

where $V_b^{i,j}$ defined in (18). Second, the board's expected compensation from reporting $\hat{\theta}_{ub} = \theta_b^j$ ($j \in \{h, l\}$) without monitoring θ is $pV_b^{h,j}(w_b) + (1-p)V_b^{l,j}(w_b)$ while its expected compensation from monitoring and truthfully reporting θ is $pV_b^{h,h}(w_b) + (1-p)V_b^{l,l}(w_b)$. Thus, the board's monitoring incentive compatibility condition (14.3) can be rewritten as:

$$pV_b^{h,h}(w_b) + (1-p)V_b^{l,l}(w_b) - \gamma_b \geq pV_b^{h,h}(w_b) + (1-p)V_b^{l,h}(w_b) \tag{22}$$

$$pV_b^{h,h}(w_b) + (1-p)V_b^{l,l}(w_b) - \gamma_b \geq pV_b^{h,l}(w_b) + (1-p)V_b^{l,l}(w_b). \tag{23}$$

Notice that (20) and (21) are necessary conditions for (23) and (22), respectively. In other words, any board compensation that induces the board to monitor θ will always induce the board to truthfully reveal θ after monitoring. Using the board compensation arrangements specified in lemma 4.1 and the associated managerial actions (e, Δ) characterized in corollary 4.4 and proposition 4.5, the shareholders' problem can be written as:

$$\max_{\substack{\sigma_b^h,\sigma_b^l,\sigma_m^h,\\ \sigma_m^l,\hat{\Delta}^h,\hat{\Delta}^l}} p\left[\left(\frac{1}{3} + \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} + \Delta^h\right)u_s^h + \left(\frac{1}{3} - 2\Delta^h\right)m_s^h + \left(\frac{1}{3} - \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} + \Delta^h\right)d_s^h\right]$$
$$+ (1-p)\left[\left(\frac{1}{3} + \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^l\right)u_s^l + \left(\frac{1}{3} - 2\Delta^l\right)m_s^l + \left(\frac{1}{3} - \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^l\right)d_s^l\right] \tag{24}$$

subject to

$$\left(\frac{1}{3} + \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^h\right)u_b^l + \left(\frac{1}{3} - 2\Delta^l\right)m_b^l + \left(\frac{1}{3} - \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^l\right)d_b^l$$
$$\geq \left(\frac{1}{3} + \frac{\theta_l^2(u_m^h - d_m^h)}{\gamma_m} + \Delta^l\right)u_b^h + \left(\frac{1}{3} - 2\Delta^h\right)m_b^h + \left(\frac{1}{3} - \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^h\right)d_b^h + \frac{\gamma_b}{1-p} \tag{25}$$

$$\left(\frac{1}{3} + \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} + \Delta^h\right)u_b^h + \left(\frac{1}{3} - 2\Delta^h\right)m_b^h + \left(\frac{1}{3} - \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} + \Delta^h\right)d_b^h$$
$$\geq \left(\frac{1}{3} + \frac{\theta_h^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^l\right)u_b^l + \left(\frac{1}{3} - 2\Delta^l\right)m_b^l + \left(\frac{1}{3} - \frac{\theta_h^2(u_m^l - d_m^l)}{\gamma_m} + \Delta^l\right)d_b^l + \frac{\gamma_b}{p} \tag{26}$$

$$u_b^i \geq m_b^i \geq d_b^i \geq 0 \text{ for } i = h, l \tag{27}$$

$$u_m^i \geq m_m^i \geq d_m^i \geq 0 \text{ for } i = h, l \tag{28}$$

where

1. $\sigma_m^i = (u_m^i, m_m^i, d_m^i)$: managerial compensation that shareholders induce the board to offer when the board sends a message $\hat{\theta}_b = \theta_i^b$ for $i = h, l$.

2. $\hat{\Delta}^i$: the alternative of $\hat{\Delta}$ that shareholders induce the board to report when the board reports $\hat{\theta}_b = \theta_i^b$ for $i = h, l$.

3. $\sigma_b^i = (u_b^i, m_b^i, d_b^i)$: board compensation when the board chooses $(\hat{\theta}_b, \hat{\Delta}, \sigma_m) = (\theta_i^b, \hat{\Delta}^i, \sigma_m^i)$ for $i = h, l$.

4. $\Delta^i = \begin{cases} \Delta_0 & \text{if (i) } \hat{\Delta}^i = \Delta_0 \text{ and (ii) } u_m^i + d_m^i - 2m_m^i < 0 \text{ or } u_b^i + d_b^i - 2m_b^i < 0 \\ \Delta_s & \text{otherwise} \end{cases}$
   corresponds to the managerial choice of Δ induced by the board when the board reports $\hat{\theta}_b = \theta_i^b$ for $i = h, l$.

Constraints (25) and (26) are derived from the board's monitoring incentive compatibility constraints (22) and (23), respectively. Constraints (27) and (28) ensure that both managerial and board compensation are non-decreasing function of firm's cash flows and subject to the limited liability. The optimal board and managerial compensation that solve the shareholders' problem is characterized as follows:

Proposition 4.10. *In the optimal board and managerial compensation* $\left[\sigma_b^{l^*}, \sigma_m^{l^*}\right] = \left[\left(f_b^{l^*}, f_b^{l^*}, f_b^{l^*}\right), \left(u_m^{l^*}, 0, 0\right)\right]$. *Furthermore, depending on parameter values, three cases can arise with respect to* $\left[\sigma_b^{h^*}, \sigma_m^{h^*}\right]$*:*

Case 1: $[\sigma_b^{h^*}, \sigma_m^{h^*}] = [(u_b^{h^*}, 0, 0), (u_m^{h^*}, 0, 0)]$

Case 2: $[\sigma_b^{h^*}, \sigma_m^{h^*}] = [(u_b^{h^*}, \frac{u_b^{h^*}}{2}, 0), (u_m^{h^*}, 0, 0)]$

Case 3: $[\sigma_b^{h^*}, \sigma_m^{h^*}] = [(u_b^{h^*}, 0, 0), (u_m^{h^*}, \frac{u_m^{h^*}}{2}, 0)]$.

Proposition 4.10 shows three key features of the optimal board and managerial compensation. First, the optimal board compensation $\sigma_b^{h^*}$ and $\sigma_b^{l^*}$ exhibit contrasting forms: while $\sigma_b^{h^*}$ corresponds to a performance-based pay, i.e., an increasing function of the firm's cash flows, $\sigma_b^{l^*}$ corresponds to a fixed wage. These contrasting forms of contracts provide the board's incentives to monitor θ. Specifically, relative to the project with $\theta = \theta_l$, the project with $\theta = \theta_h$ is more likely to yield r^u and less likely to yield r^d. Therefore, in the absence of the constraint (27), the optimal board compensation that induces the board's monitoring on θ consists of σ_b^h which compensates only for the realization of r^u and σ_b^l which compensates only for r^d. While (27) ensures that $\sigma_b^{l^*}$ corresponds to a fixed wage rather than a decreasing function of the firm's cash flows, the constraint does not change the main insight that the optimal board compensation awards the board with higher performance-based compensation when the board reports $\hat{\theta}_b = \theta_h^b$.

Second, proposition 4.10 shows that the optimal managerial compensation $\sigma_m^{h^*}$ and $\sigma_m^{l^*}$ feature a performance-based pay structure. Intuitively, shareholders induce the board to offer the minimum managerial compensation which induces certain managerial choices of (e, Δ). As shown in proposition 4.5, to induce the managerial effort, optimal managerial compensation $\sigma_m^{i^*}$ $(i = h, l)$ should feature that $u_m^{i^*} - d_m^{i^*} > 0$.

Finally, proposition 4.10 states that depending on the parameter values, the optimal board and managerial compensation that corresponds to the board's message θ_h^b, i.e., $\left[\sigma_b^{h^*}, \sigma_m^{h^*}\right]$ has different forms. Intuitively, the optimal form of $\left[\sigma_b^{h^*}, \sigma_m^{h^*}\right]$ is related to the optimal managerial risk choice Δ^{h^*}. While the convex compensation $\sigma_b^{h^*} = (u_b^{h^*}, 0, 0)$ and $\sigma_m^{h^*} = (u_m^{h^*}, 0, 0)$ provide board incentives to monitor θ and managerial incentives to put effort, respectively, the simultaneous award of convex compensation induces the managerial choice of Δ_s. Specifically, corollary 4.4 states that to induce the managerial choice $\Delta^{h^*} = \Delta_0$, either $\sigma_m^{h^*}$ or $\sigma_b^{h^*}$ should feature a (weakly) negative convexity, i.e., $u_m^{h^*} + d_m^{h^*} - 2m_m^{h^*} \leq 0$ or $u_b^{h^*} + d_b^{h^*} - 2m_b^{h^*} \leq 0$. Since the compensation for r^m does not affect the managerial effort choice or the board's monitoring on θ, the optimal compensation structure that induces the managerial choice $\Delta^{h^*} = \Delta_0$ should compensate the board or the manager for r_m just enough to make $\sigma_b^{h^*}$ or $\sigma_m^{h^*}$, but not both, exhibit zero convexity.

It is noteworthy that by contrast $\left[\sigma_b^{l^*}, \sigma_m^{l^*}\right]$ exhibits a fixed wage and convex compensation, respectively, since the fixed wage induces the board to monitor and truthfully reveal the managerial choice of Δ_s. From these observations, the following corollary which characterizes the optimal managerial risk choice $\left(\Delta^{h^*}, \Delta^{l^*}\right)$ is immediate.

Corollary 4.11. *The optimal managerial risk choice* $\left(\Delta^{h^*}, \Delta^{l^*}\right) = (\Delta_s, \Delta_0)$ *in case 1 and* (Δ_0, Δ_0) *in other cases.*

For the future reference, I refer to case 1 as *speculation case* since the manager optimally chooses Δ_s when the board reports θ_b^h, case 2 as *disciplinary board case* since non-convex board compensation $\sigma_b^{h^*} = (u_b^{h^*}, u_b^{h^*}/2, 0)$ provides the board with incentives to induce the managerial choice $\Delta^h = \Delta_0$ and case 3 as *contracting board case* since in this case the board plays a meaningful role only in the design of managerial compensation (i.e., monitoring θ) and managerial choice $\Delta^h = \Delta_0$ is induced by the non-convex managerial compensation $\sigma_m^{h^*} = (u_m^{h^*}, u_m^{h^*}/2, 0)$.

Proposition 4.10 also implies that the full description of the optimal compensation structure requires to find two managerial compensation components $\left(u_m^{h^*}, u_m^{l^*}\right)$ and two board compensation components $\left(u_b^{h^*}, f_b^{l^*}\right)$. For simplicity, I denote by $\left[\left(u_{m,s}^{h^*}, u_{m,s}^{l^*}\right), \left(u_{b,s}^{h^*}, f_{b,s}^{l^*}\right)\right]$ the optimal compensation components in the *speculation case*, $\left[\left(u_{m,d}^{h^*}, u_{m,d}^{l^*}\right), \left(u_{b,d}^{h^*}, f_{b,d}^{l^*}\right)\right]$ in the *disciplinary board case* and by $\left[\left(u_{m,d}^{h^*}, u_{m,d}^{l^*}\right), \left(u_{b,c}^{h^*}, f_{b,c}^{l^*}\right)\right]$

in the *contracting board case*. The following proposition characterizes the optimal compensation components in each case.

Proposition 4.12. *The optimal compensation structure in each case can be described by the following compensation components.*

1. *speculation case:*

$$\left[u_{m,s}^{l^*}, u_{b,s}^{h^*}, f_{b,s}^{l^*}\right] = \left[\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}, \frac{\gamma_b \gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2)u_{m,s}^{h^*}}, \left(\frac{1}{3} + \frac{\theta_l^2 u_{m,s}^{h^*}}{\gamma_m} + \Delta_s\right) u_{b,s}^{h^*} + \frac{\gamma_b}{1-p}\right],$$

where $u_{m,s}^{h^*}$ solves

$$\frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\left(\frac{1}{3} + \Delta_s\right) + \frac{2\theta_h^2 u_{m,s}^{h^*}}{\gamma_m}\right] + \left(\frac{1}{3} + \Delta_s\right)\frac{\gamma_b \gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2)(u_{m,s}^{h^*})^2} = 0$$

2. *disciplinary board case:*

$$\left[u_{m,d}^{l^*}, u_{b,d}^{h^*}, f_{b,d}^{l^*}\right] = \left[\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}, \frac{\gamma_b \gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2)u_{m,d}^{h^*}}, \left(\frac{1}{2} + \frac{\theta_l^2 u_{m,d}^{h^*}}{\gamma_m}\right) u_{b,d}^{h^*} + \frac{\gamma_b}{1-p}\right],$$

where $u_{m,d}^{h^*}$ solves

$$\frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\frac{1}{3} + \frac{2\theta_h^2 u_{m,d}^{h^*}}{\gamma_m}\right] + \frac{\gamma_b \gamma_m}{2p(1-p)(\theta_h^2 - \theta_l^2)(u_{m,d}^{h^*})^2} = 0$$

3. *contracting board case:*

$$\left[u_{m,c}^{l^*}, u_{b,c}^{h^*}, f_{b,c}^{l^*}\right] = \left[\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}, \frac{\gamma_b \gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2)u_{m,c}^{h^*}}, \left(\frac{1}{3} + \frac{\theta_l^2 u_{m,c}^{h^*}}{\gamma_m}\right) u_{b,c}^{h^*} + \frac{\gamma_b}{1-p}\right],$$

where $u_{m,c}^{h^*}$ solves

$$\frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\frac{1}{2} + \frac{2\theta_h^2 u_{m,c}^{h^*}}{\gamma_m}\right] + \frac{\gamma_b \gamma_m}{3p(1-p)(\theta_h^2 - \theta_l^2)(u_{m,c}^{h^*})^2} = 0.$$

Proposition 4.12 shows that there are common features of the optimal managerial and board compensation structure that appear in all three cases. First, for any given parameter values, $u_m^{l^*}$ is the same in all three cases. Second, the board and managerial compensation $(u_b^{h^*}, u_m^{h^*})$ exhibit substitutability, i.e., the increase in $u_m^{h^*}$ leads to the decrease in $u_b^{h^*}$. Finally, awarding higher $u_b^{h^*}$ to the board also increases the board's fixed wage $f_b^{l^*}$.

On the other hand, proposition 4.12 also shows that for given parameter values, the three cases differ in the size of optimal compensation components $u_b^{h^*}$, $f_b^{l^*}$ and $u_m^{h^*}$. In particular, the following proposition compares the size of the compensation components in each case.

Proposition 4.13. *For any parameter values,*

1. *Board compensation feature* $u_{b,c}^{h^*} > u_{b,s}^{h^*} > u_{b,d}^{h^*}$ *and* $f_{b,d}^{l^*} > f_{b,s}^{l^*} > f_{b,c}^{l^*}$
2. *Managerial compensation feature* $u_{m,d}^{h^*} > u_{m,s}^{h^*} > u_{m,c}^{h^*} > u_{m,d}^{l^*} (= u_{m,s}^{l^*} = u_{m,c}^{l^*})$.

Proposition 4.13 states that the performance-based managerial compensation $u_m^{h^*}$ is the highest in the *disciplinary board case* and the lowest in the *contracting board case*. In contrast, the performance-based board compensation $u_b^{h^*}$ is the highest in the *contracting board case* and the lowest in the *disciplinary board case*. This result is intuitive. As implied by proposition 4.10, shareholders must award non-convex compensation to the manager or the board in order to induce the managerial choice of $\Delta^h = \Delta_0$. Compensation for r^m, however, creates inefficiencies since it does not affect the board's incentive to monitor θ or the managerial incentive to put effort. In the *disciplinary board case*, the non-convexity of board compensation $\sigma_b^{h^*}$ limits the size of $u_{b,d}^{h^*}$ but instead shareholders can induce higher managerial effort than in the other two cases since the managerial risk choice is controlled by the board. On the other hand, in the *contracting board case* the non-convexity of managerial compensation $\sigma_{m,c}^{h^*}$ limits the size of $u_{m,c}^{h^*}$.

Proposition 4.13 also shows that fixed wage to the board $f_b^{l^*}$ is the highest in the *disciplinary board case* and the lowest in the *contracting board case*. In the *disciplinary board case*, the expected value of board compensation $\sigma_b^{h^*}$ is greater than the corresponding board compensation of other cases since it compensates for r^m and thus shareholders need to award higher fixed wage in order to induce the board to monitor and truthfully report about θ. Finally, proposition 4.13 states that in all three cases, the managerial compensation features $u_m^{h^*} > u_m^{l^*}$, i.e., the manager receives higher performance-based compensation when the board reports $\hat{\theta}_b = \theta_h^b$ than when it reports θ_l^b. Intuitively, shareholders delegate the managerial compensation to the board in order to use the board's private information about θ and to induce higher managerial effort when $\theta = \theta_h$.

So far, I have characterized the possible forms of optimal compensation contracts. In section 5, I search the optimal managerial and board compensation by comparing shareholder values in *uninformed board case* and the three cases that arises in *informed board case* and then analyze how the key parameters affect the compensation structure.

5 Optimal compensation structure

Shareholder value in each case can be written as follows:

Uninformed board case:

$$V_0 + \frac{V_\theta}{\gamma_m}\left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6V_\theta}\right)^2, \tag{29}$$

Speculation case:

$$V_0 - \left(\frac{1}{3} + \Delta_s\right)\frac{2\gamma_b}{D_\theta u_{m,s}^{h^*}} + \frac{p\theta_h^2 (u_{m,s}^{h^*})^2}{\gamma_m} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)\gamma_b + \frac{(1-p)\theta_l^2}{\gamma_m}\left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}\right)^2, \tag{30}$$

Disciplinary board case:

$$V_0 - \frac{\gamma_b}{D_\theta u_{m,d}^{h^*}} + \frac{p\theta_h^2 (u_{m,d}^{h^*})^2}{\gamma_m} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)\gamma_b + \frac{(1-p)\theta_l^2}{\gamma_m}\left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}\right)^2, \tag{31}$$

Contracting board case:

$$V_0 - \frac{2\gamma_b}{3D_\theta u_{m,c}^{h^*}} + \frac{p\theta_h^2 (u_{m,c}^{h^*})^2}{\gamma_m} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)\gamma_b + \frac{(1-p)\theta_l^2}{\gamma_m}\left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}\right)^2, \tag{32}$$

where $(u_{m,s}^{h^*}, u_{m,c}^{h^*}, u_{m,c}^{h^*})$ are as in proposition 4.12, $V_0 = \frac{1}{3}(r^u + r^m + r^d)$, $D_\theta \equiv \frac{p(1-p)(\theta_h^2 - \theta_l^2)}{\gamma_m}$ and $V_\theta \equiv (p\theta_h^2 + (1-p)\theta_l^2)$. The globally optimal mechanism corresponds to the case in which shareholders value is maximized. In the rest of this section, I first perform comparative statics with respect to some key parameters and then I discuss the results, and in particular, develop testable hypotheses relative to the optimal managerial and board compensation structure.

5.1 Comparative statics

For comparative statics, I consider four key parameters, namely, (i) Δ_s which measures the effect of managerial risk-seeking activities on the firm's cash flow risks, (ii) γ_b which measures the board monitoring costs, (iii) D_θ which measures the variability in the project quality θ and (iv) $D_r \equiv r^u - r^d$ which measures the size of value enhancement by managerial effort. The following proposition shows that each of key parameters $(\Delta_s, \gamma_b, D_\theta, D_r)$ monotonically affects the shareholder value in the *uninformed board case* relative to *the informed board case*.

Proposition 5.1. *Other things equal, (i) higher* Δ_s*, (ii) higher* γ_b *(iii) lower* D_θ *and (iv) lower* D_r *make the optimal mechanism belong to the uninformed board case.*

Proposition 5.1 is intuitive. When managerial risk choice substantially affects the firm's cash flow risks (i.e., Δ_s is larger), shareholders are willing to make the board compensation flat as in the *uninformed board case* in order to the board monitoring on managerial risk choice. On the other hand, when the board monitoring on θ is too costly (i.e., γ_b is too high), shareholders do not afford to induce the board to monitor θ before designing the managerial compensation. Finally, when the variability in project quality (D_θ) and the firm value enhancement by managerial effort (i.e., D_r) are sufficiently small, shareholders' benefit from incorporating the board information on θ into the design of managerial compensation cannot offset the costs that shareholders incur to induce the board monitoring.

In the rest of this section, I focus on the three cases in which the board monitors θ since the key implications on the joint compensation structure arise in these cases.[27] In contrast to the *disciplinary board case* and the *contracting board case*, the *speculation case* is subject to two inefficiencies emerging from the manager's choice of Δ_s. The risky choice increases the manager's expected compensation without creating incentive for managerial effort and it also increases the expected board's compensation without affecting the board's incentive to monitor θ. Intuitively, these inefficiencies increase in the size of Δ_s. Thus,

[27] This also reflects the realistic feature that the board takes the full responsibility for the design of managerial compensation in practice.

Proposition 5.2. *For each parameter values, there exists* $\bar{\Delta}_s > 0$ *such that speculation case becomes equilibrium if and only if* $\Delta_s \leq \bar{\Delta}_s$*.*

On the other hand, the inefficiencies that arise in the other two cases are associated with the non-convexity of board compensation or managerial compensation. Specifically, in the *disciplinary board case*, the board compensation $\sigma_b^{h^*}$ pays for r^m without providing the board with incentive to monitor θ but instead the corresponding managerial compensation $\sigma_m^{h^*}$ awards higher performance-based compensation and, thus, induces higher managerial effort choice. In the *contracting board case*, by contrast, the managerial compensation $\sigma_m^{h^*}$ needs to be non-convex and, thus, awards relatively lower performance-based compensation which leads to lower managerial effort choice. The following proposition shows how these inefficiencies that emerge from the three *informed board* cases are affected by the key parameters in this analysis:

Proposition 5.3. *For each parameter values, there exists* $\bar{\gamma}_b \geq 0$*,* $\bar{D}_\theta \geq 0$ *and* $\bar{D}_r \geq 0$ *such that the globally optimal mechanism belongs to the disciplinary board case when, other things equal, (i)* $\gamma_b < \bar{\gamma}_b$*, (ii)* $D_\theta > \bar{D}_\theta$ *and (iii)* $r^u - r^d > \bar{D}_r$ *is higher.*

In the *disciplinary board regime*, awarding performance-based compensation to the board is costly and therefore shareholders can induce the board to monitor θ only when the monitoring cost γ_b is sufficiently low. On the other hand, when the variability in the project quality is large (i.e., D_θ is higher), the board requires lower level of performance-based compensation to monitor θ. When the board does not monitor θ before choosing the managerial compensation, it may receive performance-based compensation for unproductive projects or fixed wage for productive projects. The larger variability in the project quality, however, significantly reduce the expected value of board compensation misaligned with the project type and thus induces the board to monitor the type even at lower level of performance-based compensation. Finally, when D_r is high, the managerial effort increases the firm value more efficiently and thus the optimal compensation structure belongs to *disciplinary board case* in which the managerial compensation features the highest level of performance-based compensation.

5.2 Discussion

The previous analysis provides a number of insights relative to the optimal managerial and board compensation. First, it shows that in the *informed board* case (i.e., when board are active monitors), managerial and board compensation are closely aligned. Specifically, high pay-for-performance compensation is awarded to both managers and boards in firms with high-quality projects (i.e., $\theta = \theta_h$) and low-pay-for-performance compensation is awarded when the project quality is low (i.e., $\theta = \theta_l$).

The analysis also shows that when managers are able to engage in intense risk-seeking, the potential collusion of managers and boards affects the optimal board-manager compensation structure. Consistent with this insight, proposition 5.2 suggests that in firms with high managerial risk-seeking ability, the optimal compensation structure either strengthens the board's incentives to monitor managerial risk-seeking by awarding lower performance-based board compensation (i.e., the *disciplinary board case*) or reduces the manager's incentive to engage in risk-seeking activities by awarding lower managerial pay-for-performance compensation (i.e., the *contracting board case*). Furthermore, proposition 5.3 states the conditions in which the optimal compensation structure reduces managerial risk-seeking incentives by inducing the board to monitor managerial activities rather than by lowering managerial performance-based compensation. Specifically, when the board has lower monitoring costs (i.e., lower γ_b) or faces a larger variability in project quality (i.e., higher D_θ), the board's monitoring incentives can still be provided by low pay-for-performance board compensation.

From these insights, three empirical hypotheses can be derived concerning the structure of the managerial and board compensation. In particular, controlling for all other factors, firms are more likely to award their managers higher pay-for-performance compensation while simultaneously awarding their boards lower pay-for-performance compensation when: (i) managers can engage in risk-seeking activities more easily, (ii) boards can monitor managers at a lower cost and (iii) boards face a larger variability in project quality.

6 Empirical analysis

6.1 Data and sample construction

For the period 1996-2005 I collect information on CEO and board characteristics.[28] In particular, I gather information on CEO compensation, tenure and duality (i.e., whether or not the CEO also serves as the chairman of the board) from Execucomp. Regarding boards, I collect information about their compensation from Execucomp and about board structure (i.e., whether or not their directors are classified as independent) from RiskMetrics.[29] Following previous studies (e.g., Yermack 2004 and Ryan and Wiggins 2004) the empirical analysis exclusively considers outside directors' compensation which is consistent with the previously described implications and con-

[28]From 2006 on Execucomp fails to provide information on board compensation.

[29]RiskMetrics classifies directors into three categories, namely, *insiders*, *linked directors* and *outsiders*. Following Ryan and Wiggins [2004] and Linck et al. [2008], I define an independent board as a board which has a majority of outside directors.

sistent with the fact that outside directors are in practice responsible for managerial monitoring.[30]

I obtain financial information and data on the number of business segments from Compustat. After excluding utilities (SIC 4900-4999), the sample consists of 6496 non-financial firm years and 1003 financial firm years (SIC 6000-6999). Furthermore, as described below, for some of my tests I collect information on outside directors' blockholding ownership from the database provided by Dlugosz et al. [2006] which corrects the errors contained in Compact Disclosure during the period 1996-2001. The use of this corrected board ownership data makes it possible to investigate the effect of directors' blockholding ownership on CEO and directors compensation but this data requires a restricted sample period. To minimize this data limitation, in the following analysis I compare: (i) results from the extended sample period (1996-2005) without considering directors' blockholding ownership and (ii) results from the shorter sample period (1996-2001) including the corrected information on directors' blockholding ownership.[31] Variables are reported in real terms (i.e., adjusted for inflation using 2000 as a base year).

[30] For instance, the NYSE and NASDAQ exchanges require the listed firms to form audit committees (which are in charge of overseeing risk-management policies) and compensation committees (which are in charge of designing managerial compensation) entirely with outside directors.

[31] Among the firm-years that exist in Execucomp, RiskMetrics and Compustat during 1996-2001, 498 non-financial firm-years and 91 financial firm-years are not available in the blockholding ownership database. After excluding these firm-years, the shorter sample consists of 3323 firm-years of 925 non-financial firms and 509 firm-years of 144 financial firms.

6.2 Determinants of compensation structure

6.2.1 Managerial risk-seeking ability

I use R&D expenditures as a proxy for managerial risk-seeking ability. Since R&D investments tend to generate uncertain future cash flows and create information asymmetry between managers and shareholders (e.g., Hall and Lerner 2010), I postulate that R&D investments provide managers with opportunities to engage in risk-seeking activities. Specifically, for firm i and year t, I construct a dummy variable, $R\&D\_4yr_{i,t}$, which equals 1 for firm-years which have continuously recognized R&D expenses from $t-3$ to t and equals 0 otherwise.[32]

Since a key implication of my model is that managerial risk-seeking ability affects a firm's optimal compensation structure, I perform a second set of tests that compare the compensation practices of firms in the banking sector with firms outside banking.[33] These tests are built on the insight of previous studies (e.g., Laeven and Levine 2009) which suggest that in the banking sector it is hard to disentangle productive risky investments (e.g., profitable risky loans) from unproductive managerial risk-seeking activities (e.g., pure financial speculation). In other words since bank managers can easily engage in risk-seeking activities, the shareholders find it optimal to resort to a joint compensation structure in which managerial or board pay-for-performance compensation is reduced. In what follows, I define banking firms following the Fama-French 48 industry classification codes (i.e., the classification code equals 44).[34]

[32] In (unreported) robustness checks I consider a number of variations on the R&D expenditure proxy (i.e., different periods or R&D levels) and find similar results.

[33] While most studies on compensation exclude financial firms, I find it useful to include them in my empirical analysis in order to examine the effect of managerial risk-seeking abilities on the compensation structure. Nevertheless, to avoid potential distortions that arise from including financial firms, I present separate results for the sample of non-financial and financial firms below.

[34] In the Fama-French 48 classification code 44 includes some non-banking financial firms (in SIC 6199) and code 47 includes a few investment banks (in SIC 6211). Excluding these firms, however,

6.2.2 Board monitoring costs

I postulate that the presence of at least one blockholder on the board is akin to a situation of low board-monitoring costs (and thus intense managerial monitoring). Specifically, since blockholding directors are exposed to financial losses in the case of bad firm performance, I expect that, as with low board-monitoring costs, the presence of blockholding directors leads to intense managerial monitoring even when no explicit pay-for-performance board compensation is used.

Following the literature (e.g., Dlugosz et al. 2006 and Villalonga and Amit 2006), I define blockholders as shareholders who own at least 5% of outstanding shares, and for firm i and year t, I construct a dummy variable $DIRBLK_{i,t}$ which equals 1 for firm-years which have at least one non-officer blockholder in the board and equals 0 otherwise.

6.2.3 Variability in the quality of projects

I consider two proxies for variability in project quality: the number of business segments and the firm's size. In the model, a larger variability in project quality refers to the case in which the board faces a higher *ex-ante* uncertainty relative to the optimal level of managerial pay-for-performance compensation. The link between larger variability in project quality and multi-segment (or larger) firms follows since these firms tend to operate in complex business environments which make board monitoring particularly useful in the design of adequate managerial compensation.[35] Empirically the proxies considered in this analysis are $Segments_{i,t}$ and $ln(sale)_{i,t}$ which correspond to the number of segments and the natural log of sales for firm i and year t,

does not significantly affect the results.

[35]In line with this insight, Fama and Jensen [1983] proposes board monitoring as a key governance mechanism for firms that operate in highly complex environments.

respectively.[36]

6.2.4 Control variables

As controls I include a number of determinants of pay-for-performance compensation proposed by previous studies (e.g., Yermack 1995, Guay 1999 and Coles et al. 2006). First I consider the effect of a firm's past performance (i.e., past return on firm assets and past stock returns).[37] Specifically, I include lagged return on assets and annual stock returns (i.e., $ROA_{i,t-1}$ and $Return_{i,t-1}$ for firm i and year t).[38] Second, I include the KZ index modified by Baker et al. [2003], the market-to-book value ratio, and the presence of long-term debt indicator (i.e., $KZ4_{i,t}$, $MB_{i,t}$ and $LTD_{i,t}$, respectively) as proxies for the level of a firm's financial constraints.[39] Yermack [1995] reports that to defer the cash payout financially constrained firms tend to award managers stock options (which, as described below, I use as a measure for pay-for-performance compensation) in lieu of cash compensation.

Third, I control for tax effects on compensation by including an operating loss dummy variable $Loss_{i,t}$. Intuitively, firms that have net operating loss carryforwards expect higher future tax returns and thus desire to defer the compensation expense by awarding stock options. Fourth, I control for a firm's past stock return volatilities, namely $Vol_{i,t}$, since, as suggested by Kadan and Swinkels [2008], firms that have

[36]Relative to other studies (e.g., Core and Guay 2001) which have considered the relationship between the firm size and the compensation structure, my model analysis predicts that the firm size has contrasting effects on CEO and directors compensation structures.

[37]Previous studies suggest contrasting predictions relative to the effect of the past performance on the level of pay-for-performance compensation. See, e.g., Core and Guay [2001] for the details.

[38]I consider both one-year and two-year lagged annual stock returns but excluding two-year lagged stock returns does not change the results.

[39]In unreported robustness checks I also consider cash flow shortfalls (i.e., [common and preferred dividends+cash flow used in investing activities-cash flow from operations]/total assets) which is also widely used as a proxy for the degree of financial constraints (e.g., Yermack 1995).

experienced high stock return volatilities may not be willing to grant high pay-for-performance compensation that provides additional risk-taking incentives.[40]

In addition, I consider CEO and board characteristics relative to the CEO's influence on the board in order to capture situations in which CEOs can influence boards to design CEO pay with cash compensation rather than pay-for-performance compensation (Chhaochharia and Grinstein 2009). To control for the effects of CEO-board relationship on compensation, I include the board independence indicator, the logarithm of the CEO's tenure and the CEO-chairman duality indicator (i.e., $IND_{i,t}$, $Ln(tenure)_{i,t}$ and $Dual_{i,t}$, respectively).[41] Finally, I consider a new CEO indicator $NCEO_{i,t}$ to control for the possible effects related to changes in compensation practices for incoming CEOs.[42] The details of each variable are available in Table 1.

6.3 Pay-for-performance compensation measures

I use stock option grants as the pay-for-performance compensation measures and main dependent variables in the analysis (e.g., Yermack 1995, Guay 1999 and Coles et al. 2006). Specifically, for each firm i and year t, I calculate the option-to-total compensation ratio $CEO\_r_{i,t}$ (resp. $BRD\_r_{i,t}$) in order to measure the extent to which CEOs' (resp. directors') pay is linked to the firms' performance. In addition, I consider a dummy variable $CEO\_p_{i,t}$ (resp. $BRD\_p_{i,t}$) which indicates whether or

[40]In the analysis of the joint compensation structure for the CEO and directors, it is particularly important to control for the stock return volatilities which affect a firm's stock option valuation and thus may generate a mechanical relationship between CEO and directors pay-for-performance compensation measures.

[41]To mitigate the endogeneity of board indpendence, I also consider only the post-SOX period (2002-2005) in which almost all firms have independent board structures and find consistent results.

[42]See Fee and Hadlock [2003] for evidence of these effects.

not a stock option plan is awarded to the CEO (resp. directors). More formally,

$$CEO\_r_{i,t}\,(BRD\_r_{i,t}) \equiv \frac{\text{Black-Scholes value of option grants to CEO (directors)}}{\text{Total compensation to CEO (directors)}},$$

$$CEO\_p_{i,t}\left(BRD\_p_{i,t}\right) \equiv \begin{cases} 1 & \text{if stock options are awarded to CEO (directors)} \\ 0 & \text{otherwise.} \end{cases}$$

Furthermore I consider three measures of the joint compensation structure of the CEO and directors (i.e., the association between the magnitudes of CEO and director pay-for-performance compensation for each firm-year). Specifically, for firm i and year t, three categorical variables $CEOBRD\_r_{i,t}$, $CEOBRD\_p_{i,t}$ and $CEOBRD\_indr_{i,t}$ classify firm-years into the following four categories:

(1) *LL*: firm-years in which both the CEO and directors are awarded low pay-for-performance compensation

(2) *LH*: firm-years in which the CEO is awarded low pay-for-performance and directors are awarded high pay-for-performance

(3) *HL*: firm-years in which the CEO is awarded high pay-for-performance and directors are awarded low pay-for-performance

(4) *HH*: firm-years in which both the CEO and directors are awarded high pay-for-performance compensation.

More specifically, $CEOBRD\_r_{i,t}$ classifies firm-years by comparing their option-to-total compensation ratios (i.e., $\mathrm{CEO\_r_{i,t}}$ and $\mathrm{BRD\_r_{i,t}}$) with the corresponding median for each year. In addition, to control for industry characteristics, $CEOBRD\_indr_{i,t}$ classifies firm-years by comparing the option-to-total compensation ratios with the corresponding industry-year medians. Finally, $CEOBRD\_p_{i,t}$ classifies firm-years by the presence of option award plans for the CEO and directors.[43]

6.4 Descriptive statistics

Table 2 presents summary statistics of CEO and board compensation in non-financial firms (Panel A) and financial firms (Panel B). In non-financial firms the average directors compensation is $0.21 million and the average CEO compensation is $5.46 million. While CEO pay is substantially larger than director pay, both CEOs and directors receive stock options as the main form of equity-based compensation. In particular, directors (resp. CEOs) receive stock options in approximately 72% (resp. 80%) of firm-years and on average the value of options granted accounts for 45% (resp. 39%) of total pay for directors (resp. CEOs).[44] Panel A also shows that R&D firms (i.e., $R\&D\_4yr_{i,t} = 1$) grant stock options more intensively to both CEOs and directors. On average the value of options granted accounts for nearly 49% (resp. 43%) of directors (resp. CEO) pay in R&D firms relative to 40% (resp. 34%) in other firms.

A comparison between Panel A (non-financial firms) and Panel B (financial firms) shows that the level of directors pay is similar in both types of firms but CEO pay is much higher in financial firms. In addition financial firms award directors fewer stock options than non-financial firms. Within the sample outside directors receive stock options in only 60% of financial firm-years and on average the value of options granted

[43] A formal definition of each variable is available in Table 1.

[44] These results are in line with previous studies about directors compensation (e.g., Ryan and Wiggins 2004 and Yermack 2004).

accounts for 36% of the total directors pay. Among financial firms, banks grant even fewer option awards to outside directors. Banks grant stock options in only 54% of firm-years and the value of options granted constitutes only 31% of directors' total pay.

Table 3 describes the measures of the joint compensation structure in non-financial firms (Panel A) and financial firms (Panel B). Panel A shows that in non-financial firms the magnitudes of CEO and director pay-for-performance compensation are positively correlated. In 60% of non-financial firm-years both the CEO's and directors' option-to-total compensation ratios are simultaneously below or above the corresponding industry-year medians (i.e., $CEOBRD\_indr_{i,t} = LL$ or HH). Panel A also indicates that R&D firms are more likely to award high pay-for-performance compensation either simultaneously to both the CEO and directors or to the CEO alone. In particular, R&D firms exhibit a 5% (resp. 2%) higher probability that both the CEO's and directors' (resp. only the CEO's) option-to-total compensation ratios are above the industry-year median.

A comparison between Panel A (non-financial firms) and Panel B (financial firms) shows that financial firms tend to grant high pay-for-performance to the CEO and low pay-for-performance to directors rather than simultaneously awarding high pay-for-performance to both. Specifically, financial firms (resp. non-financial firms) award stock options only to the CEO (i.e., $CEOBRD\_p_{i,t} = HL$) in 31% (resp. 21%) of firm-years. Among financial firms, banks are more likely to award high pay-for-performance to the CEO and low pay-for-performance to directors. In particular, banks award stock options to the CEO alone in 38% of firm-years.

Table 4 summarizes the proxies for determinants of the compensation structure in non-financial firms (Panel A) and financial firms (Panel B). Panel A shows that

R&D firms are less likely to have non-officer blockholding directors and tend to have more business segments and smaller firm size. Specifically, R&D firms have at least one non-officer blockholding director in 6% of firm-years while other firms have such a director in 11% of firm years. R&D firms also show more operating loss, more growth opportunities and higher stock return volatilities. Regarding the measures of the board-manager relationship, R&D firms are more likely to have independent boards. In 80% of firm-years, R&D firms maintain the board with a majority of independent directors while other firms do so in only 69% of firm-years..

Relative to non-financial firms (Panel A), financial firms (Panel B) tend to have a larger firm size, more reliance on long-run debt and fewer growth opportunities. In terms of the board-manager relationship, financial firms are more likely to have the CEO-Chair duality and independent boards. In addition Panel B shows that banks are more financially constrained and have fewer growth opportunities than other financial firms. Banks are also more likely to have independent boards. In 88% of firm-years banks maintain their boards with a majority of outside directors.

7 Results

7.1 CEO and directors pay-for-performance compensation

I start by individually estimating the regressions of CEO and directors compensation on the determinants of compensation structure (i.e., managerial risk-seeking abilities, board monitoring costs and the variability in project quality).[45] According to the model CEO and directors compensation structures are jointly determined and thus

[45] To adjust the standard errors for the correlation between managerial and board pay-for-performance measures in each firm-year, I use the seemingly unrelated regression (SUR).

running each regression of CEO and directors compensation potentially suffers from simultaneity bias. However, the estimates from each regression provide descriptive information about the effects of the determinants of compensation structures and also can be compared to previous studies which examine CEO and directors compensation independently.[46]

7.1.1 Non-financial firms

Table 5 presents the regression results for non-financial firms. Specifically, the regressions reported in columns (1)-(4) differ in their sample periods and dependent variables. More specifically, columns (1) and (2) present the results from the extended sample period (i.e., 1996-2005 without directors' blockholding ownership) and (3) and (4) report the results from the shorter sample (i.e., 1996-2001 including directors' blockholding ownership). Furthermore, the dependent variables are (CEO_p and BRD_p) in columns (1) and (3) while (CEO_r and BRD_r) in (2) and (4).

The results show that lower magnitudes of pay-for-performance compensation tend to be awarded to directors in R&D firms, in firms with at least one non-officer blockholding director, in more diversified firms and in larger firms. Specifically, column (3) reports that, all else being equal, the probability of awarding stock option grants to directors are about 5% (resp. 6.2%) lower in R&D firms (resp. firms that have non-officer blockholders in the board). Furthermore, each additional segment (resp. 1% increase in sales) is associated with 1.5% (resp. 2.9%) lower odds of awarding options to directors. These results suggest that, as predicted by the model analysis, lower magnitudes of pay-for-performance compensation for directors are associated

[46] See, e.g., Yermack 1995, Guay 1999 and Coles et al. 2006 for research on CEO compensation and Yermack [2004] and Ryan and Wiggins [2004] for studies on directors compensation.

with higher managerial risk-seeking ability, lower board monitoring costs and larger variability in (potential) project quality.

Table 5 also shows that R&D firms, more diversified firms and larger firms tend to award higher pay-for-performance compensation to the CEO while firms with at least one non-officer blockholding director tend to grant lower pay-for-performance compensation to the CEO. In particular, column (4) shows that, all else being equal, the CEO's option-to-total compensation ratio is around 4.8% higher in R&D firms and 3.7% lower in firms which have at least one non-officer blockholding director. Column (4) also reports that a 1% increase in sales is associated with a 3.1% higher option-to-total compensation ratio. The effect of the number of segments on this ratio is positive but statistically insignificant.[47] These results imply that higher managerial risk-seeking ability and larger variability in project quality are associated with higher pay-for-performance compensation for CEOs.

7.1.2 Financial firms

Table 6 reports the results for financial firms. As in Table 5, columns (1) and (2) present the results from the extended sample period (1996-2005 without directors' blockholding ownership) and by contrast columns (3) and (4) report the results from the shorter sample (i.e., 1996-2001 including directors' blockholding ownership). The dependent variables are (*CEO_p* and *BRD_p*) in the regressions reported in columns (1) and (3) and (*CEO_r* and *BRD_r*) in columns (2) and (4). To compare the compensation structure of banks with other financial firms I include the bank indicator and exclude the industry-fixed effects.[48]

[47] As shown in column (3) of Table 5, the positive relationship between the number of segments and the odds of awarding the CEO stock option grants is statistically significant.

[48] I also exclude $R\&D\_4yr_{i,t-1}$ and $Segments_{i,t-1}$ which have very small variation within financial firms but considering the two variables does not substantially change the coefficient estimates of

Table 6 shows that banking firms award lower pay-for-performance compensation to outside directors. In particular, column (3) reports that banks show a nearly 16% lower probability of awarding stock options to directors. Consistent with the results from non-financial firms, firms with non-officer blockholding directors or that have larger sales tend to award lower pay-for-performance compensation to directors. Column (3) shows that the firms with at least one non-officer blockholding director have a 21.3% lower probability of awarding stock options to directors and a 1% increase in sales lowers this probability by 5.4%.

In contrast, banks and other firms do not exhibit a significant difference in the level of pay-for-performance compensation for CEOs. Furthermore, the relationship between the presence of non-officer blockholding directors and the magnitude of CEO pay-for-performance compensation is also statistically insignificant. In line with the result from non-financial firms, however, larger firms tend to award higher pay-for-performance compensation to the CEO. Overall, the findings suggest that banks in which CEOs can easily engage in risk-seeking activities tend to grant lower pay-for-performance compensation to directors.

7.2 CEO-directors joint compensation structure

I now consider the determinants of the joint compensation structure and more specifically the determinants of the association between the magnitudes of the CEO's and the directors' pay-for-performance compensation. To do so I estimate a multinomial logit model with *CEOBRD_r*, *CEOBRD_p* and *CEOBRD_indr* as dependent variables. As before, I consider separate models for non-financial and financial firms.

other variables.

7.2.1 Non-financial firms

Table 7 presents the results for non-financial firms. Rather than reporting coefficient estimates, Table 7 reports average partial effects which better illustrate the economic magnitude as well as the statistical significance.[49] Panel A reports the results from the extended sample period (i.e., 1996-2005 without directors' blockholding ownership) and Panel B reports the results from the shorter sample period (i.e., 1996-2001 including directors' blockholding ownership, $DIRBLK_{i,t}$). Standard errors are adjusted for clusters within an industry and include all control variables considered in Table 5.

Panel B shows three main results. First, R&D firms are more likely to offer high pay-for-performance compensation to CEOs and low pay-for-performance compensation to directors. In Panel B, R&D firms show 7.3% higher odds that the CEO's (resp. directors') option-to-total compensation ratio is above (resp. below) the industry-year median (i.e., *CEOBRD_indr=HL*). Consistent with these findings, R&D firms show a 6.6% higher probability of awarding options only to the CEO (i.e., *CEOBRD_p=HL*).

Second, Panel B shows that firms which have non-officer blockholding directors are less likely to award high pay-for-performance compensation to the CEO and to the directors simultaneously. Instead, these firms award high pay-for-performance to the CEO and low pay-for-performance to directors. Specifically, these firms show a nearly 8% higher probability that the CEO's (resp. directors') option-to-total compensation ratio is above (resp. below) year median (i.e., *CEOBRD_r=HL*) and a 12.2% lower probability that both the CEO's and the directors' option-to-total compensation ratios are above the year medians (i.e., *CEOBRD_r=HH*). Consistently, the probability of awarding options to CEOs and directors simultaneously (i.e., *CEOBRD_p=HH*)

[49]Partial effects of control variables are unreported but available from the author upon request.

are 7.5 % lower in these firms.

Finally, Panel B also reports that larger or more diversified firms also tend to award higher pay-for-performance CEO compensation and lower pay-for-performance director compensation. Specifically each additional segment (resp. 1% increase in sales) is associated with 1.8% (resp. 3.2%) higher odds that both the CEOs' and the directors' option-to-total compensation ratios are simultaneously above the industry-medians (i.e., *CEOBRD_indr=HL*).

In general, these findings are in line with my model analysis which predicts that the *disciplinary board case* is more likely to occur in firms in which (i) managerial risk-seeking activities are more likely to occur (ii) board monitoring costs are likely to be lower and (iii) projects can exhibit a large variability in quality. In the *disciplinary board case*, consistent with the reported evidence, directors are awarded low pay-for-performance compensation while CEOs receive simultaneous high pay-for-performance compensation.

7.2.2 Financial firms

Table 8 reports the results for financial firms which, as shown in Section 7.1.2, compare the effects on banks with other financial firms.[50] Panels A and B report the results from the extended sample period (i.e., 1996-2005 without directors' blockholding ownership) and from the shorter sample period (i.e., 1996-2001 including directors' blockholding ownership), respectively. Standard errors are adjusted for clusters within an industry only in Panel A but are unadjusted in Panel B because of the insufficient number of observations.

Relative to other financial firms, banks show a 17% higher probability of awarding

[50] As before, I exclude $R\&D\_4yr_{i,t-1}$ and $Segments_{i,t-1}$ from independent variables.

stock options to the CEO alone (i.e., *CEOBRD_p=HL*) and a 14.1% lower probability of awarding options to the CEO and directors simultaneously (i.e., *CEOBRD_p=HH*). However, this difference between banks and other firms is not significantly observed in other joint compensation measures.[51]

In line with the results from non-financial firms, larger firms and firms with non-officer blockholding directors are less likely to award high pay-for-performance compensation to both the CEO and the directors but rather they award high pay-for-performance compensation to the CEO and low pay-for-performance compensation to directors simultaneously. Specifically, the presence of non-officer blockholding directors (resp. 1% increase in sales) is associated with 21.3% (resp. 5.1%) higher odds of awarding stock options to the CEO alone and 21.8% (resp. 4.2%) lower odds of awarding options to the CEO and directors simultaneously. Overall, these results confirm previous findings that higher managerial risk-seeking ability, lower board monitoring costs and larger variability in project quality lead to the simultaneous award of high pay-for-performance compensation to CEOs and low pay-for-performance compensation to directors.

8 Concluding remarks

This paper considers the optimal managerial and board compensation in a setting in which both managers and boards are subject to agency problems and shareholders delegate to boards the task of designing managerial compensation and the task of monitoring managerial risk-seeking activities. The model shows that while high pay-for-performance board compensation provides incentives for the board to properly

[51] Banks show higher odds that *CEOBRD_indr=HH* but, as displayed in Table 3, the median of directors' option-to-total compensation ratio in the banking sector is fairly low.

design managerial compensation, it also diminishes the board's incentive to discourage non-productive managerial risk-shifting activities. This analysis implies that the optimal board compensation structure is determined by the trade-off between the magnitudes of these two countervailing effects. The analysis also derives implications for the optimal joint compensation structure for managers and boards.

The analysis suggests that the three determinants that shape the optimal compensation structure for managers and boards are (i) managerial risk-seeking ability, (ii) the magnitude of board monitoring costs and (iii) the variability in (potential) project quality. The analysis predicts that, all else being equal, high pay-for-performance compensation for managers and low pay-for-performance compensation for boards are awarded by firms in which the managerial risk-seeking ability is higher, the board monitoring costs are lower and the projects exhibit lower variability in quality.

In the second part of the study I take these predictions into the data. Empirically, I find that high managerial pay-for-performance compensation tends to be awarded jointly with low board pay-for-performance in (i) R&D firms or banks in which managers can easily engage in risk-seeking activities (ii) firms in which the board contains non-officer blockholders who are likely to provide high-intensity monitoring and (iii) larger or more diversified firms which feature a wider variability in project quality.

The analysis of the joint compensation structure for managers and boards provides some novel findings and suggests several avenues for future research. However, the study abstracts from issues related to the dynamics of board composition and other governance mechanisms which can affect the relationship between CEO and board compensation. Fascinating but challenging tasks to include board dynamics and to examine the joint compensation structure in the presence of a richer set of governance mechanisms are left for future research.

References

R. B. Adams and D. Ferreira. Do directors perform for pay? *Journal of Accounting and Economics*, 46(1):154–171, September 2008.

R. B. Adams, B. E. Hermalin, and M. S. Weisbach. The role of boards of directors in corporate governance: A conceptual framework and survey. *Journal of Economic Literature*, 48(1):58–107, March 2010.

A. Almazan and B. Suarez. Entrenchment and severance pay in optimal governance structures. *Journal of Finance*, 58(2):519–548, April 2003.

M. Baker, J. C. Stein, and J. Wurgler. When does the market matter? stock prices and the investment of equity-dependent firms. *Quarterly Journal of Economics*, 118(3):969–1005, August 2003.

S. Baliga and T. Sjöström. Decentralization and collusion. *Journal of Economic Theory*, 83(2):196–232, December 1998.

L. A. Bebchuk and J. M. Fried. *Pay-without-Performance: The Unfulfilled Promise of Executive Compensation*. Harvard University Press, Cambridge, MA, 2004.

S. Chava and A. Purnanandam. CEOs versus CFOs: Incentives and corporate policies. *Journal of Financial Economics*, 97(2):263–278, August 2010.

V. Chhaochharia and Y. Grinstein. CEO compensation and board structure. *Journal of Finance*, 64(1):231–261, February 2009.

J. L. Coles, N. D. Daniel, and L. Naveen. Managerial incentives and risk-taking. *Journal of Financial Economics*, 79(2):431–468, February 2006.

J. E. Core and W. R. Guay. Stock option plans for non-executive employees. *Journal of Financial Economics*, 61(2):253–287, August 2001.

J. Dlugosz, R. Fahlenbrach, P. Gompers, and A. Metrick. Large blocks of stock: prevalence, size, and measurement. *Journal of Corproate Finance*, 12(3):594–618, June 2006.

E. Fama and M. Jensen. Separation of ownership and control. *Journal of Law and Economics*, 26(2):301–325, June 1983.

A. Faure-Grimaud, J. J. Laffont, and D. Martimort. Collusion, delegation and supervision with soft information. *Review of Economic Studies*, 70(2):253–279, April 2003.

E. Fee and C. Hadlock. Raids, rewards, and reputations in the market for managerial talent. *Review of Financial Studies*, 16(4):1315–1357, October 2003.

E. M. Fich and A. Shivdasani. The impact of stock-option compensation for outside directors on firm value. *Journal of Business*, 78(6):2229–2254, November 2005.

C. Frydman and D. Jenter. CEO compensation. *Annual Review of Financial Economics*, 2(1):75–102, December 2010.

C. C. Géczy, B. A. Minton, and C. M. Schrand. Taking a view: Corporate speculation, governance, and compensation. *Journal of Finance*, 62(5):2405–2443, October 2007.

S. J. Grossman and O. D. Hart. An analysis of the principal-agent problem. *Econometrica*, 51(1):7–46, January 1983.

W. R. Guay. The sensitivity of CEO wealth to equity risk: an analysis of the magnitude and determinants. *Journal of Financial Economics*, 53(1):43–71, July 1999.

B. H. Hall and J. Lerner. The financing of R&D and innovation. In B. H. Hall and N. Rosenberg, editors, *Handbook of Economics of Technical Change*. Elsevier, New York, 2010.

R. M. Hayes, M. Lemmon, and M. Qiu. Stock options and managerial incentives for risk taking: Evidence from FAS 123r. *Journal of Financial Economics*, 105(1): 174–190, July 2012.

M. C. Jensen and W. H. Meckling. Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, 3(4):305–360, October 1976.

O. Kadan and J. Swinkels. Stocks or options? moral hazard, firm viability, and the design of compensation contracts. *Review of Financial Studies*, 21(1):451–482, January 2008.

L. Laeven and R. Levine. Bank governance, regulation and risk taking. *Journal of Financial Economics*, 93(2):259–275, August 2009.

J. S. Linck, J. M. Netter, and Y. T. The determinants of board structure. *Journal of Financial Economics*, 87(2):308–328, February 2008.

R. B. Myerson. Optimal coordination mechanisms in generalized principal-agent problems. *Journal of Mathematical Economics*, 10(1):67–81, June 1982.

H. E. Ryan and R. A. Wiggins. Who is in whose pocket? director compensation, board independence, and barriers to effective monitoring. *Journal of Financial Economics*, 73(3):497–524, September 2004.

J. Tirole. Hierarchies and bureaucracies: on the role of collusion in organizations. *Journal of Law, Economics and organization*, 2(2):181–214, Fall 1986.

B. Villalonga and R. Amit. How do family ownership, control and management affect firm value? *Journal of Financial Economics*, 80(2):385–417, May 2006.

D. Yermack. Do corporations award ceo stock options effectively? *Journal of Financial Economics*, 39(2-3):237–269, October-November 1995.

D. Yermack. Remuneration, retention, and reputation incentives for outside directors. *Journal of Finance*, 59(5):2281–2308, October 2004.

Table 1: Definition of variables

This table presents the definition of compensation variables and control variables. For the fair value of equity grants to managers, I use the corresponding measures provided by Execucomp. To value the equity grants to outside directors, I follow Ryan and Wiggins [2004]. The details are available in section B. For financial and accounting variables, I describe the definition by using the compustat data items. The independent directors are identified by teh classification of Riskmetrics database. For each firm year, I identify the chairperson from Riskmetrics database while find the CEO from Execucomp. In particualr, the appointment and resignation date of CEOs are provided by Execucomp.

Variable	Definition
CEO(BRD)_total$_{i,t}$	Total compensation to the CEO (outside director) in firm i and year t
CEO(BRD)_option$_{i,t}$	Black-Scholes value of option grants to the CEO (outside director)
CEO(BRD)_p$_{i,t}$	Indicator (1,0) of option grants to the CEO (outside director)
CEO(BRD)_r$_{i,t}$	CEO_option$_{i,t}$/CEO_total$_{i,t}$ (BRD_option$_{i,t}$/BRD_total$_{i,t}$)
CEO(BRD)_stk$_{i,t}$	Dollar amount of stock grants to the CEO (outside director)
CEO(BRD)_stkp$_{i,t}$	Indicator (1,0) of stock grants to the CEO (outside director)
CEO(BRD)_stkr$_{i,t}$	CEO_stk/CEO_total (BRD_stk/BRD_total)
ROA$_{i,t}$	Return on Asset reported in Execucomp
Loss$_{i,t}$	Net operating loss dummy (=1 if oibdp$_{i,t}$ ¡ 0)
LTD$_{i,t}$	long term debt dummy (=1 if dltt$_{i,t}$¿0)
kz4$_{i,t}$	-1.002*kz_cf$_{i,t}$-39.368*kz_div$_{i,t}$-1.315*kz_c$_{i,t}$+3.139*kz_lev$_{i,t}$
kz_cf$_{i,t}$	(dp$_{i,t}$+ib$_{i,t}$)/at$_{i,t}$
kz_div$_{i,t}$	(dvp$_{i,t}$+dvc$_{i,t}$)/at$_{i,t}$
kz_c$_{i,t}$	che/at$_{i,t}$
kz_lev$_{i,t}$	(dltt$_{i,t}$+dlc$_{i,t}$)/(dltt$_{i,t}$+dlc$_{i,t}$+seq$_{i,t}$)
Return	1-year stock return
MB	(prcc_f$_{i,t}$*csho$_{i,t}$+at$_{i,t}$-ceq$_{i,t}$-txdb$_{i,t}$)/at$_{i,t}$
R&D	3-year moving average of (xrd$_{i,t}$/at$_{i,t}$)
Vol	Stock return volatility reported in Execucomp
IND	Board independence dummy (=1 if the board holds a majority of independent directors)
Tenure	the CEO's tenure
NCEO	New CEO dummy (=1 for the first year of the CEO)
Dual	CEO-Chair dummy (=1 if the CEO is the chairman of the board)
CEO_m$_t$ (BRD_$_t$)	the year-median of CEO_r$_{i,t}$ (BRD_r$_{i,t}$)
CEO_indm$_t$ (BRD_indm$_t$)	the Fama-French 48 industry-year median of CEO_r$_{i,t}$ (BRD_r$_{i,t}$)
CEOBRD_r$_{i,t}$	$\begin{cases} LL & \text{if } CEO\_r_{i,t} \leq CEO\_m_t \text{ and } BRD\_r_{i,t} \leq BRD\_m_t \\ LH & \text{if } CEO\_r_{i,t} \leq CEO\_m_t \text{ and } BRD\_r_{i,t} > BRD\_m_t \\ HL & \text{if } CEO\_r_{i,t} > CEO\_m_t \text{ and } BRD\_r_{i,t} \leq BRD\_m_t \\ HH & \text{otherwise.} \end{cases}$
CEOBRD_p$_{i,t}$	$\begin{cases} \text{LL} & \text{if CEO\_p}_{i,t} = \text{BRD\_p}_{i,t} = 0 \\ \text{LH} & \text{if CEO\_p}_{i,t} = 0 \text{ and BRD\_p}_{i,t} = 1 \\ \text{HL} & \text{if CEO\_p}_{i,t} = 1 \text{ and BRD\_p}_{i,t} = 0 \\ \text{HH} & \text{otherwise,} \end{cases}$
CEOBRD_indr$_{i,t}$	$\begin{cases} \text{LL} & \text{if CEO\_r}_{i,t} \leq \text{CEO\_indm}_t \text{ and BRD\_r}_{i,t} \leq \text{BRD\_indm}_t \\ \text{LH} & \text{if CEO\_r}_{i,t} \leq \text{CEO\_indm}_t \text{ and BRD\_r}_{i,t} > \text{BRD\_indm}_t \\ \text{HL} & \text{if CEO\_r}_{i,t} > \text{CEO\_indm}_t \text{ and BRD\_r}_{i,t} \leq \text{BRD\_indm}_t \\ \text{HH} & \text{otherwise,} \end{cases}$

Table 2: Summary statistics: Compensation

This table presents the summary statistics about compensation for CEO and outside directors between 1997 and 2005. The sample consists of 7442 non-financial firm years and 1003 financial firm years. The utilities (sic 4900-4999) are excluded from the sample. Compensation information is obtained from Execucomp database. Panel A reports the compensation of non-financial firms and also separately presents the compensation of R&D firms and other non-financial firms. Financial firms are defined as the firms whose standard industrical classsification is between 6000 and 6999. R&D firms are defined as the firms which recognize the R&D expenditure for the past four consecutive years. The last two columns in Panel A presents the mean difference between long R&D firms and other non-financial firms and the unpaired t-statistics (computed for unequal variance and unequal observations) which tests for the null hypothesis that the mean difference is zero. Panel B reports the compensation of financial firms and also separately presents the compensation of banks and non-bank financial firms. Banks are defined as the firms whose Fama-French 48 industrial classification code is 44. As in Panel A, the last two columns of Panel B presents the mean difference between banks and other financial firms and the corresponding t-statistics. The details about compensation variables are available in Table 1.

Panel A: Non-financial firms

	All firms			R&D firms			Other firms			Diff.	
	mean	sd	median	mean	sd	median	mean	sd	median	mean	t
CEO_total	5459.28	13924.72	2817.74	5907.44	17190.07	3082.68	4966.35	9040.80	2550.79	941.09	2.99
CEO_option	2900.99	10232.15	962.32	3353.52	12244.21	1219.14	2403.26	7383.16	691.56	950.26	4.10
CEO_p	0.80	0.40	1	0.84	0.37	1	0.76	0.42	1	0.07	7.91
CEO_r	0.39	0.29	0.38	0.43	0.29	0.44	0.34	0.27	0.32	0.09	14.43
CEO_stk	621.75	8260.83	0	637.58	11226.93	0	604.33	2163.79	0	33.25	0.18
CEO_stkp	0.27	0.44	0	0.24	0.43	0	0.31	0.46	0	-0.06	-6.21
CEO_stkr	0.07	0.15	0	0.06	0.14	0	0.08	0.15	0	-0.02	-5.55
BRD_total	206.66	574.38	96.75	267.87	740.97	108.77	139.34	283.43	83.84	128.53	10.05
BRD_option	155.11	575.87	36.84	214.42	743.76	45.32	89.87	282.69	27.37	124.55	9.71
BRD_p	0.72	0.45	1	0.74	0.44	1	0.69	0.46	1	0.05	4.87
BRD_r	0.45	0.36	0.47	0.49	0.37	0.53	0.40	0.34	0.40	0.08	10.12
BRD_stk	19.68	51.94	0	21.44	60.21	0	17.75	40.89	0	3.68	3.11
BRD_stkp	0.40	0.49	0	0.41	0.49	0	0.40	0.49	0	0.01	0.95
BRD_stkr	0.16	0.24	0	0.16	0.24	0	0.16	0.24	0	0.00	0.60
Obs.	7442			3898			3544				

Panel B: Financial firms

	All firms			Banks			Other firms			Diff.	
	mean	sd	median	mean	sd	median	mean	sd	median	mean	t
CEO_total	7428.81	11135.43	4035.32	7314.28	13436.57	3385.14	7552.12	7958.75	4878.86	-237.84	-0.34
CEO_option	3360.48	8535.52	1302.05	3541.59	10935.49	1116.86	3165.49	4755.60	1622.97	376.11	0.71
CEO_p	0.83	0.37	1	0.86	0.35	1	0.80	0.40	1	0.06	2.46
CEO_r	0.36	0.26	0.34	0.35	0.25	0.33	0.36	0.27	0.36	-0.01	-0.31
CEO_stk	1014.61	2826.64	0	948.14	2847.14	0	1086.17	2805.59	0	-138.04	-0.77
CEO_stkp	0.39	0.49	0	0.39	0.49	0	0.38	0.49	0	0.01	0.31
CEO_stkr	0.10	0.17	0	0.10	0.16	0	0.11	0.17	0	-0.01	-0.73
BRD_total	223.56	2248.00	91.08	111.02	177.88	64.81	344.72	3231.56	125.10	-233.70	-1.59
BRD_option	158.84	2247.40	21.96	57.08	171.02	10.75	268.39	3231.89	46.05	-211.31	-1.44
BRD_p	0.60	0.49	1	0.54	0.50	1	0.67	0.47	1	-0.13	-4.31
BRD_r	0.36	0.35	0.36	0.31	0.33	0.26	0.42	0.36	0.44	-0.12	-5.47
BRD_stk	32.32	85.12	0	21.81	61.57	0	43.63	103.61	0	-21.82	-4.02
BRD_stkp	0.43	0.49	0	0.38	0.49	0	0.48	0.50	0	-0.11	-3.39
BRD_stkr	0.20	0.28	0	0.16	0.25	0	0.24	0.30	0	-0.07	-4.18
Obs.	1003			520			483				

Table 3: Summary statistics: CEO-directors joint compensation structure

This table presents the summary statistics about categorical variables constrctured by compensation for CEO and outside directors. The details about categorical compensation variables are available in Table 1. The sample consists of 7442 non-financial firm years and 1003 financial firm years between 1997 and 2002. Compensation information is obtained from Execucomp database. Panel A reports the summary statistics about categorical variables of non-financial firms and also separately presents the summary statistics of R&D firms and other non-financial firms. Financial firms are defined as the firms whose standard industrical classsification is between 6000 and 6999. R&D firms are defined as the firms which recognize the R&D expenditure for the past four consecutive years. The last two columns in Panel A presents the mean difference between long R&D firms and other non-financial firms and the corresponding t-statistics (computed for unequal variance and unequal observations) of the null hypothesis that the mean difference is zero. Panel B reports the compensation of financial firms and also separately presents the compensation of banks and non-bank financial firms. Banks are defined as the firms whose Fama-French 48 industrial classification code is 44. As in Panel A, the last two columns of Panel B presents the mean difference between banks and other financial firms and the corresponding t-statistics.

Panel A: Non-financial firms

	All firms			R&D firms			Other firms			Diff.	
	mean	sd	median	mean	sd	median	mean	sd	median	mean	t
CEOBRD_r=LL	0.27	0.45	0	0.22	0.42	0	0.33	0.47	0	-0.11	-10.27
CEOBRD_r=LH	0.17	0.38	0	0.16	0.37	0	0.19	0.39	0	-0.03	-3.13
CEOBRD_r=HL	0.22	0.42	0	0.23	0.42	0	0.21	0.41	0	0.02	2.20
CEOBRD_r=HH	0.33	0.47	0	0.39	0.49	0	0.27	0.45	0	0.11	10.38
CEOBRD_p=LL	0.07	0.26	0	0.05	0.22	0	0.10	0.30	0	-0.05	-8.46
CEOBRD_p=LH	0.12	0.33	0	0.11	0.32	0	0.14	0.34	0	-0.02	-2.80
CEOBRD_p=HL	0.21	0.41	0	0.21	0.41	0	0.21	0.41	0	0.00	0.08
CEOBRD_p=HH	0.59	0.49	1	0.63	0.48	1	0.56	0.50	1	0.07	6.36
CEOBRD_indr=LL	0.30	0.46	0	0.28	0.45	0	0.33	0.47	0	-0.05	-4.85
CEOBRD_indr=LH	0.17	0.38	0	0.16	0.37	0	0.19	0.39	0	-0.02	-2.37
CEOBRD_indr=HL	0.23	0.42	0	0.24	0.43	0	0.22	0.41	0	0.02	2.54
CEOBRD_indr=HH	0.29	0.45	0	0.31	0.46	0	0.27	0.44	0	0.05	4.56
Obs.	7442			3898			3544				

Panel B: Financial firms

	All firms			Banks			Other firms			Diff.	
	mean	sd	median	mean	sd	median	mean	sd	median	mean	t
CEOBRD_r=LL	0.29	0.45	0	0.34	0.48	0	0.23	0.42	0	0.11	3.88
CEOBRD_r=LH	0.17	0.38	0	0.14	0.34	0	0.21	0.41	0	-0.07	-3.04
CEOBRD_r=HL	0.30	0.46	0	0.32	0.47	0	0.27	0.44	0	0.05	1.88
CEOBRD_r=HH	0.24	0.43	0	0.20	0.40	0	0.29	0.45	0	-0.09	-3.39
CEOBRD_p=LL	0.09	0.28	0	0.08	0.27	0	0.10	0.30	0	-0.02	-1.14
CEOBRD_p=LH	0.08	0.27	0	0.06	0.24	0	0.10	0.30	0	-0.04	-2.20
CEOBRD_p=HL	0.31	0.46	0	0.38	0.49	0	0.23	0.42	0	0.15	5.32
CEOBRD_p=HH	0.52	0.50	1	0.48	0.50	0	0.57	0.50	1	-0.09	-3.00
CEOBRD_indr=LL	0.24	0.43	0	0.26	0.44	0	0.23	0.42	0	0.03	1.18
CEOBRD_indr=LH	0.21	0.40	0	0.20	0.40	0	0.22	0.41	0	-0.02	-0.67
CEOBRD_indr=HL	0.24	0.43	0	0.25	0.43	0	0.23	0.42	0	0.02	0.83
CEOBRD_indr=HH	0.31	0.46	0	0.29	0.46	0	0.33	0.47	0	-0.04	-1.26
Obs.	1003			520			483				

Table 4: Summary statistics: Independent variables

This table presents the summary statistics about the firm characteristics of the sample, which consists of 7442 non-financial firm years and 1003 financial firm years between 1996 and 2004. Among them, 6496 non-financial firm years are available in segments database while 3731 non-financial and 509 financial firm years are available in blockholding ownership database which covers between 1996 and 2001. The utilities (sic 4900-4999) are excluded from the sample. I obtain financial and accounting information from Compustat database, board structure from Riskmetrics database, blockholding ownership from the data provided by Dlugosz et al. [2006], and business segment information from the Compustat segment database. Panel A reports the characteristics of non-financial firms and also separately presents the characteristics of R&D firms and other non-financial firms. Financial firms are defined as the firms whose standard industrical classsification is between 6000 and 6999. R&D firms are defined as the firms which recognize the R&D expenditure for the past four consecutive years. The last two columns in Panel A presents the mean difference between R&D firms and other firms and the unpaired t-statistics (computed for unequal variance and unequal observations) which tests for the null hypothesis that the mean difference is zero. Panel B reports the characteristics of financial firms and also separately presents the characteristics of banks and non-bank financial firms. Banks are defined as the firms whose Fama-French 48 industrial classification code is 44. As in Panel A, the last two columns of Panel B presents the mean difference between banks and other financial firms and the corresponding t-statistics. The details about all variables are available in Table 1.

Panel A: Non-financial firms

	All firms				R&D firms				Other firms				Diff.	
	mean	sd	median	Obs.	mean	sd	median	Obs.	mean	sd	median	Obs.	mean	t
DIRBLK	0.08	0.27	0	3731	0.06	0.23	0	2002	0.11	0.31	0	1729	-0.05	-5.86
Segments	1.72	1.04	1	6496	1.83	1.13	1	3494	1.60	0.90	1	3002	0.22	8.89
ln(sale)	7.40	1.50	7.29	7442	7.26	1.62	7.16	3898	7.54	1.36	7.41	3544	-0.28	-8.20
ROA	0.04	0.14	0.05	7442	0.03	0.17	0.05	3898	0.05	0.08	0.05	3544	-0.02	-7.09
Loss	0.04	0.20	0	7442	0.06	0.25	0	3898	0.01	0.12	0	3544	0.05	11.20
KZ4	0.22	1.17	0.28	7442	0.05	1.14	0.04	3898	0.41	1.17	0.53	3544	-0.37	-13.69
LTD	0.87	0.34	1	7442	0.84	0.37	1	3898	0.90	0.29	1	3544	-0.06	-8.42
Return	0.04	0.46	0.08	7442	0.03	0.49	0.08	3898	0.06	0.43	0.09	3544	-0.03	-2.52
MB	2.17	1.61	1.66	7442	2.43	1.86	1.83	3898	1.88	1.22	1.51	3544	0.56	15.41
R&D	0.03	0.06	0.01	7442	0.06	0.07	0.04	3898	0.00	0.01	0.00	3544	0.06	58.74
Vol	0.44	0.19	0.39	7442	0.47	0.21	0.41	3898	0.41	0.16	0.38	3544	0.06	12.42
Ln(tenure)	1.77	0.87	1.79	7442	1.71	0.87	1.61	3898	1.82	0.87	1.79	3544	-0.11	-5.44
NCEO	0.08	0.27	0	7442	0.09	0.28	0	3898	0.08	0.27	0	3544	0.01	1.73
Dual	0.66	0.47	1	7442	0.67	0.47	1	3898	0.65	0.48	1	3544	0.02	1.64
IND	0.75	0.43	1	7442	0.80	0.40	1	3898	0.69	0.46	1	3544	0.12	11.66

Panel B: Financial firms

	All firms				Banks				Other firms				Diff.	
	mean	sd	median	Obs.	mean	sd	median	Obs.	mean	sd	median	Obs.	mean	t
DIRBLK	0.08	0.27	0	509	0.09	0.29	0	278	0.06	0.23	0	231	0.04	1.61
ln(sale)	7.84	1.52	7.66	1003	7.72	1.56	7.52	520	7.98	1.46	7.79	483	-0.26	-2.76
ROA	0.03	0.05	0.01	1003	0.01	0.01	0.01	520	0.04	0.07	0.03	483	-0.03	-8.86
Loss	0.01	0.12	0	1003	0.00	0.00	0	520	0.03	0.17	0	483	-0.03	-3.93
KZ4	1.08	1.14	1.28	1003	1.80	0.64	1.91	520	0.31	1.06	0.38	483	1.48	26.63
LTD	0.93	0.26	1	1003	0.97	0.16	1	520	0.88	0.32	1	483	0.09	5.58
Return	0.10	0.36	0.12	1003	0.10	0.36	0.11	520	0.11	0.37	0.14	483	-0.02	-0.82
MB	1.45	1.08	1.13	1003	1.18	0.50	1.11	520	1.73	1.41	1.19	483	-0.55	-8.20
R&D	0.00	0.02	0.00	1003	0.00	0.00	0.00	520	0.00	0.02	0.00	483	0.00	-4.08
Vol	0.34	0.14	0.30	1003	0.30	0.12	0.28	502	0.37	0.15	0.34	483	-0.07	-7.94
Ln(tenure)	1.81	0.88	1.95	1003	1.84	0.85	1.95	520	1.77	0.90	1.79	483	0.07	1.19
NCEO	0.07	0.26	0	1003	0.07	0.25	0	520	0.08	0.27	0	483	-0.02	-0.93
Dual	0.70	0.46	1	1003	0.75	0.43	1	520	0.65	0.48	1	483	0.10	3.46
IND	0.79	0.41	1	1003	0.88	0.33	1	520	0.70	0.46	1	483	0.18	7.03

Table 5: CEO and directors pay-for-performance compensation and determinants of compensation structure: Non-financial firms

This table reports the coefficient estimates from seemingly unrelated regressions (SUR) in a sample of 6496 (or 3323 with DIRBLK) non-financial firm years. In model (1) and (3), the dependent variables are CEO_p and BRD_p, which are indicators for the firm years awarding stock option grants to the CEO and outside directors, respectively. In model (2) and (4), the dependent variables are CEO_r and BRD_r, which refer to (the value of stock options granted to the CEO/total compensation for CEO) and (the value of stock options granted to outside directors/total compensation for outside directors), respectively. The independent variables include R&D_4yr=1 if the firm has continuously recognized R&D expenditure for the past 4 years, 0 otherwise; DIRBLK=1 if a blockholder (who owns more than 5% of the outstanding common shares) sits on the board as an outside director, 0 otherwise; Segments= the number of business segments; and ln(Sale)= the natural logarithm of sales. The details about other control variables are available in Table 1. Independent variables, except for NCEO, are lagged by one year. All specifications include the year dummy and the industry dummy variables (created by Fama-Frech 48 industrial classification code). The standard errors computed in SUR is robust for correlation between equations. In parentheses, t-statistics are reported.

	(1)		(2)		(3)		(4)	
	CEO_p	BRD_p	CEO_r	BRD_r	CEO_p	BRD_p	CEO_r	BRD_r
R&D_4yr (t-1)	0.0511***	-0.0312**	0.0477***	0.0179	0.0282	-0.0501**	0.0478***	0.0194
	(3.52)	(-1.98)	(4.85)	(1.60)	(1.51)	(-2.32)	(3.54)	(1.29)
DIRBLK					-0.0298	-0.0617**	-0.0372**	-0.0363*
					(-1.29)	(-2.30)	(-2.23)	(-1.96)
Segments	-0.00814	-0.0173***	-0.0108***	-0.0245***	0.0136**	-0.0152*	0.00548	-0.0174***
	(-1.49)	(-2.93)	(-2.92)	(-5.81)	(1.98)	(-1.91)	(1.10)	(-3.14)
ln(Sale) (t-1)	0.0140***	-0.0280***	0.0301***	-0.0249***	0.00831	-0.0285***	0.0311***	-0.0186***
	(3.22)	(-5.94)	(10.24)	(-7.41)	(1.47)	(-4.36)	(7.62)	(-4.11)
ROA (t-1)	0.0622	0.0594	0.0931***	0.111***	0.0152	0.102	0.106***	0.147***
	(1.47)	(1.30)	(3.26)	(3.39)	(0.27)	(1.56)	(2.59)	(3.22)
Loss (t-1)	0.0258	0.00296	0.00527	0.0194	-0.0340	0.0162	-0.00512	0.0476
	(0.91)	(0.10)	(0.27)	(0.88)	(-0.87)	(0.36)	(-0.18)	(1.51)
KZ4 (t-1)	-0.00462	0.0211***	-0.000695	0.0136***	-0.00302	0.0346***	0.00466	0.0215***
	(-0.89)	(3.75)	(-0.20)	(3.39)	(-0.46)	(4.51)	(0.97)	(4.04)
LTD (t-1)	0.0617***	-0.0361**	0.00907	-0.0450***	0.0566**	-0.0751***	-0.00902	-0.0832***
	(3.74)	(-2.02)	(0.81)	(-3.53)	(2.47)	(-2.83)	(-0.55)	(-4.52)
Return (t-1)	-0.0300**	-0.0137	-0.0134*	0.0216**	0.000762	0.00152	0.00212	0.0365***
	(-2.51)	(-1.06)	(-1.65)	(2.33)	(0.05)	(0.09)	(0.20)	(3.12)
Return (t)	0.0201*	-0.00148	-0.00299	-0.00526	0.0302**	-0.0125	0.000970	-0.00938
	(1.83)	(-0.12)	(-0.40)	(-0.62)	(2.34)	(-0.84)	(0.10)	(-0.90)
MB (t-1)	0.00908**	0.0191***	0.0307***	0.0382***	0.0110**	0.0143***	0.0320***	0.0339***
	(2.45)	(4.77)	(12.28)	(13.37)	(2.42)	(2.73)	(9.76)	(9.30)
Vol (t-1)	0.0408	0.261***	0.335***	0.439***	0.103**	0.300***	0.386***	0.537***
	(1.12)	(6.60)	(13.52)	(15.54)	(2.04)	(5.14)	(10.59)	(13.25)
IND (t-1)	0.0830***	0.0703***	0.0338***	0.00531	0.0786***	0.104***	0.0294***	0.0167
	(7.20)	(5.63)	(4.34)	(0.60)	(5.39)	(6.18)	(2.79)	(1.43)
Tenure (t-1)	-0.0499***	-0.0282***	-0.0229***	0.00953*	-0.0363***	-0.0212**	-0.0185***	0.0184**
	(-7.09)	(-3.71)	(-4.81)	(1.76)	(-4.05)	(-2.04)	(-2.86)	(2.55)
NCEO (t)	0.0173	-0.0532**	0.0720***	-0.00133	0.0390	-0.0209	0.0806***	0.0269
	(0.83)	(-2.36)	(5.12)	(-0.08)	(1.53)	(-0.71)	(4.38)	(1.31)
Dual (t-1)	0.0131	0.00486	0.0138*	-0.0152*	-0.000423	0.000390	0.00814	-0.0164
	(1.19)	(0.41)	(1.87)	(-1.79)	(-0.03)	(0.02)	(0.79)	(-1.42)
Constant	0.341***	0.803***	-0.202***	0.416***	0.228**	0.700***	-0.323***	0.224***
	(4.84)	(10.53)	(-4.24)	(7.65)	(2.37)	(6.43)	(-4.75)	(2.96)
Year FE	Y		Y		Y		Y	
Industry FE	Y		Y		Y		Y	
N	6496		6496		3323		3323	
R-sq	0.075	0.133	0.208	0.330	0.082	0.158	0.230	0.374

***,**, and *: significance at the 1, 5, and 10 percent level, respectively.

Table 6: CEO and directors pay-for-performance compensation and determinants of compensation structure: Financial firms

This table reports the coefficient estimates from seemingly unrelated regressions (SUR) for financial firms. The analyses reported in panel A consider both non-financial and financial firms while in panel B, only financial firms are considered. In model (1) and (3) of both panels, the dependent variables are CEO_p and BRD_p, which are indicators for the firm years awarding stock option grants to the CEO and outside directors, respectively. In model (2) and (4), the dependent variables are CEO_r and BRD_r, which refer to (the value of stock options granted to the CEO/total compensation for CEO) and (the value of stock options granted to outside directors/total compensation for outside directors), respectively. The independent variables include Bank=1 if Fama-French 48 industrial code is 44, 0 otherwise; DIRBLK=1 if a blockholder (who owns more than 5% of the outstanding common shares) sits on the board as an outside director, 0 otherwise; and ln(Sale)= the natural logarithm of sales. To fully exploit the observations, DIRBLK is considered only in model (3) and (4) of each panel. The details about other control variables are available in Table 1. Independent variables are lagged by one year. All specifications include the year dummy and the industry dummy variables (created by Fama-Frech 48 industrial classification code). The standard errors computed in SUR is robust for correlation between equations. In parentheses, t-statistics are reported.

	(1)		(2)		(3)		(4)	
	CEO_p	BRD_p	CEO_r	BRD_r	CEO_p	BRD_p	CEO_r	BRD_r
Bank	0.0507	-0.0820*	0.0316	-0.0458	0.0228	-0.164***	0.0406	-0.0573
	(1.57)	(-1.95)	(1.48)	(-1.64)	(0.58)	(-2.92)	(1.30)	(-1.50)
DIRBLK					0.0121	-0.213***	0.00553	-0.0519
					(0.23)	(-2.85)	(0.13)	(-1.02)
ln(Sale) (t-1)	0.0194**	-0.0278***	0.0288***	-0.0289***	0.00825	-0.0544***	0.0286***	-0.0384***
	(2.38)	(-2.63)	(5.35)	(-4.12)	(0.75)	(-3.45)	(3.27)	(-3.58)
ROA (t-1)	-0.844***	0.0913	-0.456**	0.452*	-0.630	-0.490	-0.639*	-0.133
	(-2.97)	(0.25)	(-2.43)	(1.84)	(-1.31)	(-0.71)	(-1.68)	(-0.28)
Loss (t-1)	-0.137	0.0323	-0.0687	-0.103	0.0528	0.0276	-0.119	-0.113
	(-1.35)	(0.25)	(-1.03)	(-1.18)	(0.31)	(0.11)	(-0.89)	(-0.69)
KZ4 (t-1)	-0.0418**	0.00839	-0.0269**	0.00649	-0.0295	0.0119	-0.0382**	-0.0213
	(-2.48)	(0.38)	(-2.42)	(0.45)	(-1.39)	(0.39)	(-2.27)	(-1.03)
LTD (t-1)	-0.0197	-0.173***	-0.00725	-0.116***	-0.0550	-0.212***	0.0108	-0.138**
	(-0.41)	(-2.76)	(-0.23)	(-2.80)	(-0.97)	(-2.61)	(0.24)	(-2.50)
Return (t-1)	0.0481	0.0532	0.0540**	0.102***	0.0344	0.105	0.0677*	0.161***
	(1.19)	(1.01)	(2.03)	(2.94)	(0.69)	(1.48)	(1.71)	(3.32)
Return (t)	0.0681*	0.0497	0.00942	0.0262	0.0774*	0.0733	0.0228	0.0500
	(1.89)	(1.06)	(0.40)	(0.84)	(1.88)	(1.25)	(0.70)	(1.25)
MB (t-1)	-0.0313**	0.0186	0.00253	0.0293**	-0.0484**	0.0247	-0.00786	0.0264
	(-2.17)	(0.99)	(0.27)	(2.36)	(-2.48)	(0.89)	(-0.51)	(1.39)
Vol (t-1)	-0.128	0.573***	0.324***	0.679***	-0.210	0.834***	0.410***	0.924***
	(-1.34)	(4.63)	(5.16)	(8.28)	(-1.51)	(4.20)	(3.72)	(6.84)
IND (t-1)	0.0618**	-0.000135	0.0599***	-0.0345	0.0385	0.0521	0.0535*	0.0110
	(2.03)	(-0.00)	(2.98)	(-1.32)	(1.11)	(1.05)	(1.95)	(0.33)
Tenure (t-1)	-0.0226	-0.00882	-0.00200	0.0233	-0.0195	-0.0555*	0.0165	0.00440
	(-1.32)	(-0.40)	(-0.18)	(1.58)	(-0.95)	(-1.91)	(1.02)	(0.22)
NCEO(t)	0.0290	-0.0948	0.0479	-0.000456	-0.0563	-0.162*	0.0358	-0.0382
	(0.54)	(-1.35)	(1.34)	(-0.01)	(-0.86)	(-1.73)	(0.69)	(-0.60)
Dual (t-1)	0.0628**	-0.00133	0.0404**	-0.0339	0.0738**	0.0484	0.0577**	0.00453
	(2.25)	(-0.04)	(2.20)	(-1.41)	(2.18)	(1.00)	(2.15)	(0.14)
_cons	0.701***	0.714***	-0.0692	0.382***	0.820***	0.943***	-0.137	0.421***
	(6.91)	(5.41)	(-1.03)	(4.37)	(6.48)	(5.22)	(-1.36)	(3.42)
Year FE	Y		Y		Y		Y	
N	1003		1003		509		509	
R-sq	0.094	0.104	0.169	0.220	0.105	0.177	0.117	0.255

***,**, and *: significance at the 1, 5, and 10 percent level, respectively.

Table 7: CEO-directors joint compensation structure: Non-financial firms

Each panel of this table presents the average partial effect estimates of three multinomial logit regressions for non-financial firms. Panels A and B report the results from the extended sample period (i.e., 1996-2005 without directors' blockholding ownership) and from the shorter sample period (i.e., 1996-2001 but including directors' blockholding ownership), respectively. To highlight the economic significance, this table presents values for the average partial effects, not the standard multinomial logit coefficients. In each panel, dependent variables are categorical compensation variables: *CEOBRD_r* in the first four columns, *CEOBRD_p* in the next four columns, and *CEOBRD_indr* in the last four columns. All independent variables reported in Table 5 are considered but this table presents only partial effects of *R&D_4yr*, *DIRBLK*, *Segments* and *ln(Sales)*. The details about dependent and independent variables are available in Table 1. All specifications include one-year lagged independent variables and also control for the year dummy and the industry dummy variables (created by Fama-Frech 48 industrial classification code). The standard errors are adjusted for clustering at the industry level. In parentheses, t-statistics are reported.

Panel A: all firms

	CEOBRD_r				CEOBRD_p				CEOBRD_indr			
	LL	LH	HL	HH	LL	LH	HL	HH	LL	LH	HL	HH
R&D_4yr (t-1)	-0.0412**	-0.00547	0.0420	0.00474	-0.0276***	-0.0142	0.0568**	-0.0150	-0.0780***	-0.0270	0.0560*	0.0490
	(-2.15)	(-0.30)	(1.36)	(0.11)	(-2.61)	(-1.22)	(2.14)	(-0.47)	(-3.02)	(-1.47)	(1.79)	(1.05)
Segments (t-1)	0.0177**	-0.00142	0.00999	-0.0263**	0.00382	0.00399	0.00800	-0.0158	0.0212*	-0.0118	0.00856	-0.0180
	(2.04)	(-0.17)	(1.15)	(-2.34)	(0.63)	(0.60)	(1.00)	(-1.63)	(1.67)	(-1.30)	(0.90)	(-1.54)
ln(sales) (t-1)	-0.0166*	-0.0325***	0.0479***	0.00122	-0.0000288	-0.0150**	0.0259***	-0.0108	-0.0115	-0.0361***	0.0425***	0.00512
	(-1.65)	(-4.76)	(6.12)	(0.10)	(-0.01)	(-2.47)	(3.21)	(-0.92)	(-1.19)	(-5.05)	(5.37)	(0.47)
Controls	Y				Y				Y			
Year FE	Y				Y				Y			
Industry FE	Y				Y				Y			
N	6496				6496				6496			

Panel B: firms with DIRBLK

	CEOBRD_r				CEOBRD_p				CEOBRD_indr			
	LL	LH	HL	HH	LL	LH	HL	HH	LL	LH	HL	HH
R&D_4yr (t-1)	-0.0699**	0.0195	0.0457	0.00477	-0.0189	-0.00323	0.0657*	-0.0436	-0.0965***	-0.0143	0.0732**	0.0377
	(-2.30)	(0.78)	(1.22)	(0.13)	(-1.39)	(-0.17)	(1.90)	(-1.35)	(-2.87)	(-0.48)	(2.06)	(0.97)
DIRBLK (t-1)	0.00667	0.0354	0.0802***	-0.122***	0.00663	0.0182	0.0505	-0.0754*	-0.00447	0.0176	0.0437	-0.0569**
	(0.32)	(1.36)	(3.21)	(-4.28)	(0.53)	(0.93)	(1.17)	(-1.72)	(-0.16)	(0.58)	(1.57)	(-2.07)
Segments (t-1)	0.00315	-0.0113	0.0141	-0.00595	-0.00950**	-0.00519	0.0183**	-0.00361	-0.00300	-0.00990	0.0189**	-0.00603
	(0.29)	(-1.48)	(1.55)	(-0.53)	(-2.33)	(-0.71)	(1.96)	(-0.30)	(-0.22)	(-1.16)	(2.19)	(-0.54)
ln(sales) (t-1)	-0.0217**	-0.0298***	0.0520***	-0.000493	-0.00603	-0.00450	0.0324***	-0.0219*	-0.0286***	-0.0318***	0.0513***	0.00904
	(-1.98)	(-2.88)	(5.23)	(-0.04)	(-1.53)	(-0.54)	(3.56)	(-1.89)	(-2.72)	(-2.92)	(4.52)	(0.74)
Controls	Y				Y				Y			
Year FE	Y				Y				Y			
Industry FE	Y				Y				Y			
N	3323				3323				3323			

***,**, and *: significance at the 1, 5, and 10 percent level, respectively.

Table 8: CEO-directors joint compensation structure: Financial firms

Each panel of this table presents the average partial effect estimates of three multinomial logit regressions for financial firms. Panels A and B report the results from the extended sample period (i.e., 1996-2005 without directors' blockholding ownership) and from the shorter sample period (i.e., 1996-2001 but including directors' blockholding ownership), respectively. To highlight the economic significance, this table presents values for the average partial effects, not the standard multinomial logit coefficients. In each panel, dependent variables are categorical compensation variables: *CEOBRD_r* in the first four columns, *CEOBRD_p* in the next four columns, and *CEOBRD_indr* in the last four columns. All independent variables reported in Table 6 are considered but this table presents only partial effects of *Bank*, *DIRBLK*, and *ln(Sales)*. The details about dependent and independent variables are available in Table 1. All specifications include one-year lagged independent variables and also control for the year dummy. The standard errors are adjusted for clustering at the industry level in Panel A but not in panel B since the number of observations is not sufficient. In parentheses, t-statistics are reported.

Panel A: All firms

	CEOBRD_r				CEOBRD_p				CEOBRD_indr			
	LL	LH	HL	HH	LL	LH	HL	HH	LL	LH	HL	HH
Bank	0.0212	-0.0374**	0.0517	-0.0355**	-0.0479**	-0.00400	0.129***	-0.0767	-0.0477*	0.0382	-0.0287	0.0381
	(0.36)	(-2.51)	(1.26)	(-2.08)	(-2.27)	(-0.21)	(2.90)	(-1.46)	(-1.68)	(0.84)	(-0.94)	(1.09)
ln(sales) (t-1)	0.000811	-0.0473**	0.0504***	-0.00390	-0.00554	-0.0146*	0.0339***	-0.0138***	-0.00363	-0.0346***	0.0306*	0.00759
	(0.04)	(-2.33)	(4.26)	(-0.31)	(-0.48)	(-1.66)	(25.86)	(-4.02)	(-1.06)	(-3.52)	(1.93)	(0.70)
Controls	Y				Y				Y			
Year FE	Y				Y				Y			
N	1003				1003				1003			

Panel B: Firms with DIRBLK

	CEOBRD_r				CEOBRD_p				CEOBRD_indr			
	LL	LH	HL	HH	LL	LH	HL	HH	LL	LH	HL	HH
Bank	0.0652	-0.0961**	-0.00772	0.0386	-0.000988	-0.0285	0.170***	-0.141**	-0.0166	0.00794	-0.0882	0.0968*
	(1.10)	(-2.52)	(-0.13)	(0.75)	(-0.03)	(-1.12)	(2.79)	(-2.30)	(-0.29)	(0.17)	(-1.59)	(1.75)
DIRBLK (t-1)	-0.198**	0.0803*	0.203***	-0.0856	-0.0113	0.0172	0.213***	-0.218***	-0.0376	0.0465	0.146**	-0.155*
	(-2.39)	(1.73)	(2.90)	(-1.11)	(-0.28)	(0.46)	(3.19)	(-2.73)	(-0.53)	(0.80)	(2.32)	(-1.82)
ln(sales) (t-1)	-0.00969	-0.0443***	0.0662***	-0.0122	0.00363	-0.0121	0.0508***	-0.0423***	0.00776	-0.0603***	0.0485***	0.00402
	(-0.65)	(-3.54)	(4.33)	(-0.83)	(0.44)	(-1.34)	(3.36)	(-2.61)	(0.54)	(-4.25)	(3.47)	(0.26)
Controls	Y				Y				Y			
Year FE	Y				Y				Y			
N	509				509				509			

***,**, and *: significance at the 1, 5, and 10 percent level, respectively.

Appendix A Proof of Propositions and Lemmas

Proof of Lemma 3.1: This is straightforward since the zero board compensation induces the board to truthfully report the manager's choice of Δ and to remain uninformed about θ.

Proof of Lemma 3.2: The first order condition of maximizing $V_m(\hat{\theta}_m, e; \theta_i, w_m^{'})$ with respect to e is

$$\theta_i(u_m(\hat{\theta}_m) - d_m(\hat{\theta}_m) - \gamma_m e = 0,$$

which proves the lemma.

Proof of Proposition 3.3: Since zero compensation induces the board to truthfully reports to shareholders about the message received from the manager $\hat{\theta}_m$ and to produce truthful evidence of the manager's choice of Δ, this case is equivalent to the case in which shareholders directly communicate and contract with the manager by observing the manager's choice of Δ but not the productivity θ. In what follows, I first show that the optimal managerial compensation contract features a pooling contract with respect to $\hat{\theta}_m$ and then characterize the optimal contractual arrangements. For simplicity, I define $\sigma_m^j \equiv w_m^{'}(\theta_j^m) = (u_m^j, m_m^j, d_m^j)$ for $j = h, l$. Suppose that $\sigma_m^h \neq \sigma_m^l$. Since shareholders observe the manager's choice of Δ, they can require the manager to make a certain choice of $\Delta^j \in \{\Delta_0, \Delta_s\}$ when the manager reports to shareholders θ_m^j. Without loss of generality, I consider the case in which $u_m^h - d_m^h > u_m^l - d_m^l$ (i.e., shareholders induce higher managerial effort when the manager reports θ_h^m) and shareholders require $\Delta^h = \Delta_0$. Lemma 3.2 suggests that for $\theta = \theta_i$ $(i = h, l)$, the manager who reports θ_j^m selects the effort level as $e_{i,j} = \frac{\theta_i(u_m^j - d_m^j)}{\gamma_m}$. Thus, when the manager observes $\theta = \theta_l$, his expected utility from reporting θ_m^h is

$$V_m^{l,h} = \frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_l^2(u_m^h - d_m^h)^2}{2\gamma_m} \tag{A-1}$$

and, thus, the manager truthfully reports θ_l^m if and only if

$$V_m^{l,l} = \frac{1}{3}(u_m^l + m_m^l + d_m^l) + \frac{\theta_l^2(u_m^l - d_m^l)^2}{2\gamma_m} + \Delta^l(u_m^l + d_m^l - 2m_m^l) \geq V_m^{l,h} \tag{A-2}$$

Note that (A-2) is binding. When shareholders offer the manager a menu of separating contracts, shareholder value can be written as:

$$
\begin{aligned}
V_s^{sep} = V_0 &+ \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} p(r^u - r^d) + \frac{\theta_l^2(u_m^l - d_m^l)}{\gamma_m}(1-p)(r^u - r^d) \\
&- p\left[\frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_h^2(u_m^h - d_m^h)^2}{\gamma_m}\right] \\
&- (1-p)\left[\frac{1}{3}(u_m^l + m_m^l + d_m^l) + \frac{\theta_l^2(u_m^l - d_m^l)^2}{\gamma_m} + \Delta^l(u_m^l + d_m^l - 2m_m^l)\right] \quad \text{(A-3)}
\end{aligned}
$$

Alternately, by offering a pooling contract $\{u_m^h, m_m^h, d_m^h\}$, shareholders obtain the expected pay-off:

$$
\begin{aligned}
V_s^h = V_0 &+ \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} p(r^u - r^d) + \frac{\theta_l^2(u_m^h - d_m^h)}{\gamma_m}(1-p)(r^u - r^d) \\
&- p\left[\frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_h^2(u_m^h - d_m^h)^2}{\gamma_m}\right] \\
&- (1-p)\left[\frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_l^2(u_m^h - d_m^h)^2}{\gamma_m}\right] \quad \text{(A-4)}
\end{aligned}
$$

Since (A-2) is binding, (A-4) can be rewritten as

$$
\begin{aligned}
V_s^h = V_0 &+ \frac{\theta_h^2(u_m^h - d_m^h)}{\gamma_m} p(r^u - r^d) + \frac{\theta_l^2(u_m^h - d_m^h)}{\gamma_m}(1-p)(r^u - r^d) \\
&- p\left[\frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_h^2(u_m^h - d_m^h)^2}{\gamma_m}\right] \\
&- (1-p)\left[\frac{1}{3}(u_m^h + m_m^h + d_m^h) + \frac{\theta_l^2(u_m^l - d_m^l)^2}{2\gamma_m} + \Delta^l(u_m^l + d_m^l - 2m_m^l)\right] \\
&- (1-p)\frac{\theta_l^2(u_m^h - d_m^h)^2}{2\gamma_m} \quad \text{(A-5)}
\end{aligned}
$$

By subtracting (A-3) from (A-5),

$$
V_s^h - V_s^{sep} = \frac{(1-p)(\lambda^h - \lambda^l)}{\gamma_m}\left[(r^u - r^d) - \frac{\lambda^h + \lambda^l}{2}\right], \quad \text{(A-6)}
$$

where $\lambda^h = \theta_l^2(u_m^h - d_m^h)$ and $\lambda^l = \theta_l^2(u_m^l - d_m^l)$

Shareholders never offer a compensation such that $\lambda^h > r^u - r^d$. Since $\lambda^h > \lambda^l$, $V_s^h > V_s^{sep}$, which implies that shareholders would rather offer $\{u_m^h, m_m^h, d_m^h\}$ as a pooling contract than offer a menu of separating contracts. To find the optimal pooling contract, I solve for the managerial compensation $\{u_m^h, m_m^h, d_m^h\}$ that maximizes (A-4).

Obviously, $m_m^h = d_m^h = 0$. The first order condition with respect to u_m^h is

$$\frac{(p\theta_h^2 + (1-p)\theta_l^2)(r^u - r^d)}{\gamma_m} - \frac{1}{3} - \frac{2(p\theta_h^2 + (1-p)\theta_l^2)u_m^h}{\gamma_m} = 0, \tag{A-7}$$

which proves the proposition.

Proof of Lemma 4.1: The lemma is proved by showing that for any board compensation $w_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r})$ that induces the board to truthfully reports its private information about θ, there exists a corresponding board compensation that has a form characterized in the lemma and induces the same board's choices and the associated managerial actions. For an arbitrary truth-telling mechanism $w_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r})$, set $\hat{\Delta}^h \in \{\hat{\Delta}_0, \hat{\Delta}_s\}$ and $\sigma_m^h = w_m(\hat{\Delta}^h)$ (resp. $\hat{\Delta}^l$ and $\sigma_m^l = w_m(\hat{\Delta}^l)$) are the board's choices of $\hat{\Delta}$ and σ_m when the board reports θ_h^b (reps. θ_l^b). Consider an alternative board compensation contract $w_b^{'}(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r})$ such that

$$w_b^{'}(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}) = \begin{cases} w_b(\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}) & \text{if } (\hat{\theta}_b, \hat{\Delta}, \sigma_m, \tilde{r}) = (\theta_h^b, \hat{\Delta}^h, \sigma_m^h, \tilde{r}) \text{ or } (\theta_l^b, \hat{\Delta}^l, \sigma_m^l, \tilde{r}) \\ (0,0,0) & \text{otherwise.} \end{cases}$$

Then, the informed board's optimal choices induced by $w_b^{'}$ and the associated managerial choices equal to the corresponding choices induced by w_b. The uninformed board's expected compensation from $w_b^{'}$ is lower than that from w_b and, thus, $w_b^{'}$ satisfies the board's monitoring incentive compatibility constraints. This proves the lemma.

Proof of Lemma 4.2 and Lemma 4.6: omitted since they are similar to the proof of lemma 4.1.
Proof of Proposition 4.3 and Proposition 4.7: omitted since they are fully discussed in the text.

Proof of Proposition 4.5 and Proposition 4.9: refer to the proof of lemma 3.2

Proof of Proposition 4.10: To prove proposition 4.10, I first prove the following lemma which characterizes the optimal form of managerial compensation:

Lemma A.1. *In the informed board case, the optimal managerial compensation features either $\sigma_m^j = (u_m^j, 0, 0)$ or $(u_m^j, \frac{u_m^j}{2}, 0)$ for $j = h, l$.*

Proof of Lemma A.1: Consider a case in which shareholders induce the informed board to offer the manager $\sigma_m^j = \{u_m^j, m_m^j, d_m^j\}$ such that $u_m^j + d_m^j > 2m_m^j$ and $m_m^j, d_m^j > 0$ when they receive the board's message θ_j^b ($j = h, l$). As implied by propositions 4.5 and 4.9, when the manager observes $\theta = \theta_i$ ($i = h, l$), σ_m^j induces managerial effort $e^{i,j} = \frac{\theta_i(u_m^j - d_m^j)}{\gamma_m}$. Corollaries 4.4 and 4.8 also imply that given σ_m^j as above, the manager chooses Δ_0 if and only if shareholders induce the board to report $\hat{\Delta}^j = \hat{\Delta}_0$ and award board compensation such that $C_b^j = u_b^j + d_b^j - 2m_b^j \leq 0$. Now consider an alternative managerial compensation contract $\sigma_m^{j'} = \{u_m^j - d_m^j, 0, 0\}$. It is apparent that the managerial actions (e, Δ) induced by $\sigma_m^{j'}$ equals the managerial actions induced by σ_m^j. Therefore, the board compensation contracts that replace σ_m^j with $\sigma_m^{j'}$ also satisfies the board's monitoring incentive compatibility constraints while it reduces the expected value of managerial compensation. Hence, shareholders would induce the board to offer the manager $\sigma_m^{j'}$ rather than σ_m^j. Similarly, the managerial compensation plan such that $u_m^j + d_m^j < 2m_m^j$ and/or $d_m^j > 0$ is dominated by an alternative compensation plan $\{u_m^j, \frac{u_m^j}{2}, 0\}$.

Next, I prove the following lemma which characterizes the optimal form of board compensation:

Lemma A.2. *The optimal board compensation features that* $\sigma_b^h = (u_b^h, 0, 0)$ *or* $(u_b^h, \frac{u_b^h}{2}, 0)$ *and* $\sigma_b^l = (f_b^l, f_b^l, f_b^l)$.

Proof of Lemma A.2: Without loss of generality, I focus on the case in which $u_m^h \geq u_m^l$ since otherwise shareholder do not induce the board to monitor θ. I first show that w_b^l should be a fixed wage. Suppose that $u_b^l > d_b^l$. Then, since $\theta_h \geq \theta_l$, $V_b^{h,l}(w_b) > V_b^{l,l}(w_b)$, where $V_b^{i,j}(w_b)$ is the informed board's expected compensation when the board observes $\theta = \theta_i$ and reports θ_j^b ($i, j \in \{h, l\}$). Now suppose that shareholders alternately offer the board a fixed wage $\sigma_b^l = \{f_b^l, f_b^l, f_b^l\}$ such that $f_b^l = V_b^{l,l}(w_b)$. Then, when the board observes $\theta = \theta_h$ and falsely reports to shareholders θ_l^b, its expected compensation also corresponds to f_b^l. Since $V_b^{h,l}(w_b) > f_b^l$, constraint (22) does not change while (23) is relaxed. Therefore, shareholders can reduce the expected value of the compensation awarded to the board who reports θ_h^b. Next, I show that $\sigma_b^h = (u_b^h, 0, 0)$ or $(u_b^h, \frac{u_b^h}{2}, 0)$. For the board compensation $\sigma_b^h = \{u_b^h, m_b^h, d_b^h\}$ such that $d_b^h > 0$, let us consider an alternative plan $\sigma_b^{h'} = \{u_b^h + k_1 d_b^h, m_b^h, 0\}$, where $k_1 = \frac{\frac{1}{3} - \frac{\theta_h^2 u_m^h}{\gamma_m} + \Delta^h}{\frac{1}{3} + \frac{\theta_h^2 u_m^h}{\gamma_m} + \Delta^h}$. If shareholders replace w_b^h with $\sigma_b^{h'}$, (22) is relaxed while (23) does not change and, thus, shareholders can obtain higher expected pay-off. Now suppose that $m_b^h > \frac{u_b^h}{2}$ and the board induces $\Delta^h = \Delta_0$. Then, shareholders can offer $\sigma_b^{h'} = \{u_b^h + k_2\epsilon, \frac{u_b^h + k_2\epsilon}{2}, 0\}$, where $k_2 = \frac{\frac{1}{3}}{\frac{1}{3} + \frac{\theta_h^2 u_m^h}{\gamma_m}}$ and $\epsilon = \frac{2m_b^h - u_b^h}{2 + k_2}$. Then, (22) is relaxed while (23) does not change and, thus, shareholders can obtain higher expected pay-off. Similarly, if the board induces $\Delta^h = \Delta_0$ and $m_b^h > 0$, shareholders can obtain higher expected pay-off by offering $w_b^{h'} = \{u_b^h + k_3 m_b^h, 0, 0\}$, where $k_3 = \frac{\frac{1}{3} - 2\Delta_s}{\frac{1}{3} + \frac{\theta_h^2 u_m^h}{\gamma_m} + \Delta_s}$.

By lemmas A.1 and A.2, I can prove proposition 4.10 by showing that (i) $\sigma_m^l = (u_m^l, 0, 0)$ and (ii) the optimal compensation structure can feature either $\sigma_m^h = (u_m^h, \frac{u_m^h}{2}, 0)$ or $\sigma_b^h = (u_b^h, \frac{u_b^h}{2}, 0)$ but not both. First, corollary 4.4 implies that the fixed board wage $\sigma_b^l = (f_b^l, f_b^l, f_b^l)$ provides the board with incentives to induce the managerial choice Δ_0 by truthfully reporting to shareholders about the managerial choice of Δ. Therefore, the optimal compensation structure features $\sigma_m^l = (u_m^l, 0, 0)$ which induces the managerial effort most efficiently. Next, corollary 4.4 also implies that to induce the managerial choice of Δ_s when the board reports θ_h^b, either $C_m^h = 0$ or $C_b^h = 0$. If $\sigma_m^h = (u_m^h, \frac{u_m^h}{2}, 0)$ (i.e., $C_m^h = 0$) and induces the managerial choice of Δ_0, the optimal board compensation features $\sigma_b^h = (u_b^h, 0, 0)$ which induces the board's monitoring on θ most efficiently. On the other hand, $\sigma_b^h = (u_b^h, \frac{u_b^h}{2}, 0)$ (i.e., $C_b^h = 0$) which provides the board's incentives to induce the managerial choice of Δ_0, the optimal managerial compensation features $\sigma_m^h = (u_m^h, 0, 0)$ which induces the managerial effort most efficiently.

Proof of Proposition 4.12: Since (26) and (25) are binding at the optimal compensation, u_b^h and f_l^b of the optimal compensation structure correspond to

$$u_b^h = \frac{\gamma_b \gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2) u_m^h} \tag{A-8}$$

$$f_b^l = \begin{cases} (\frac{1}{3} + \Delta_s + \frac{\theta_l^2 u_m^h}{\gamma_m}) u_b^h + \frac{\gamma_b}{1-p} & \text{in speculation case} \\ (\frac{1}{2} + \frac{\theta_l^2 u_m^h}{\gamma_m}) u_b^h + \frac{\gamma_b}{1-p} & \text{in disciplinary board case} \\ (\frac{1}{3} + \frac{\theta_l^2 u_m^h}{\gamma_m}) u_b^h + \frac{\gamma_b}{1-p} & \text{in contracting board case} \end{cases} \tag{A-9}$$

Therefore, by plugging the optimal forms of contracts stated in proposition 4.10,(A-8) and (A-9) into shareholders' problems specified in (24)-(28), I obtain the following first order conditions with respect to u_m^h in each case:

$$\text{SP: } \frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\left(\frac{1}{3} + \Delta_s\right) + \frac{2\theta_h^2 u_{m,sp}^h}{\gamma_m}\right] + \left(\frac{1}{3} + \Delta_s\right)\frac{\gamma_b\gamma_m}{p(1-p)(\theta_h^2 - \theta_l^2)(u_{m,sp}^h)^2} = 0 \tag{A-10}$$

$$\text{DB: } \frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\frac{1}{3} + \frac{2\theta_h^2 u_{m,db}^h}{\gamma_m}\right] + \frac{\gamma_b\gamma_m}{2p(1-p)(\theta_h^2 - \theta_l^2){u_{m,db}^h}^2} = 0 \tag{A-11}$$

$$\text{CB: } \frac{p\theta_h^2(r^u - r^d)}{\gamma_m} - p\left[\frac{1}{2} + \frac{2\theta_h^2 u_{m,cb}^h}{\gamma_m}\right] + \frac{\gamma_b\gamma_m}{3p(1-p)(\theta_h^2 - \theta_l^2){u_{m,cb}^h}^2} = 0 \tag{A-12}$$

and the first order condition with respect to u_m^l implies that the optimal compensation features $u_m^l = \frac{r^u - r^d}{2} - \frac{\gamma_m}{6\theta_l^2}$

Proof of Proposition 4.13: $u_{m,db}^h > u_{m,sp}^h > u_{m,cb}^h$ is immediate from (A-10), (A-11), and (A-12). $u_{m,db}^l = u_{m,sp}^l = u_{m,cb}^l$ is demonstrated in proposition 4.12. $u_{b,cb}^h > u_{b,sp}^h > u_{b,db}^h$ is immediate from the relation $u_{m,db}^h > u_{m,sp}^h > u_{m,cb}^h$ and (A-8). Finally, $f_{b,db}^l > f_{b,sp}^l > f_{b,cb}^l$ is obtained from (A-9) and the first order conditions, (A-10), (A-11), and (A-12).

Proof of Proposition 5.1: Shareholder values specified in (29)-(32) imply that:

1. Δ_s: Higher Δ_s decreases shareholder value only in speculation case. Thus, higher Δ_s either decreases shareholders value in informed board cases relative to the uninformed board case (when speculation case is the optimal among informed board cases) or does not affect shareholders value (when speculation case is not optimal)

2. γ_b: Higher γ_b decreases shareholder value in all three informed board cases while it does not affect shareholder value in uninformed board case

3. D_θ: Higher D_θ increases shareholder value in all three informed board cases while it does not affect shareholder value in uninformed board case

4. $r^u - r^d$: By envelop theorem, the shadow price of $r^u - r^d$ in each case is as

follows:

$$\text{Uninformed board case: } \frac{V_\theta}{\gamma_m}\left(\frac{r^u - r^d}{2} - \frac{\gamma_m}{6V_\theta}\right)$$
$$\text{Speculation case: } \frac{p\theta_h^2 u_{m,s}^h + (1-p)\theta_l^2 u_{m,s}^l}{\gamma_m}$$
$$\text{Disciplinary board case: } \frac{p\theta_h^2 u_{m,d}^h + (1-p)\theta_l^2 u_{m,d}^l}{\gamma_m}$$
$$\text{Contracting board case: } \frac{p\theta_h^2 u_{m,c}^h + (1-p)\theta_l^2 u_{m,c}^l}{\gamma_m}$$

The first order conditions (A-10)-(A-12) imply that $u_{m,d}^h > u_{m,s}^h > u_{m,c}^h > \frac{r^u-r^d}{2} - \frac{\gamma_m}{6\theta_h^2}$ and proposition 4.12 states that $u_{m,d}^l = u_{m,s}^l = u_{m,c}^l = \frac{r^u-r^d}{2} - \frac{\gamma_m}{6\theta_l^2}$. Thus, the shadow price of $r^u - r^d$ in the three informed board cases is higher than that in uninformed board case. This implies that higher Δ_s increases shareholders value in informed board cases relative to shareholder value in uninformed board case.

Proof of Proposition 5.2: This is immediate from (30)-(32) which show that Δ_s does not affect shareholder value in disciplinary board and contracting board cases while it decreases shareholder value in speculation case.

Proof of Proposition 5.3:
1. γ_b: By envelop theorem, the shadow price of γ_b in each case is as follows:

$$\text{Speculation case: } -\left(\frac{1}{3} + \Delta_s\right)\frac{2}{D_\theta u_{m,s}^h} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)$$
$$\text{Disciplinary board case: } -\frac{1}{D_\theta u_{m,d}^h} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)$$
$$\text{Contracting board case: } -\frac{2}{3D_\theta u_{m,c}^h} - \left(\frac{V_\theta}{\gamma_m D_\theta} + 1\right)$$

As demonstrated in (30)-(32), shareholder value in disciplinary board case is larger than those in other informed board cases if

$$-\frac{\gamma_b}{D_\theta u_{m,d}^h} + \frac{p\theta_h^2 {u_{m,d}^h}^2}{\gamma_m} \geq -\left(\frac{1}{3} + \Delta_s\right)\frac{2\gamma_b}{D_\theta u_{m,s}^h} + \frac{p\theta_h^2 {u_{m,s}^h}^2}{\gamma_m} \tag{A-13}$$

and

$$-\frac{\gamma_b}{D_\theta u^h_{m,d}} + \frac{p\theta_h^2 {u^h_{m,d}}^2}{\gamma_m} \geq -\frac{2\gamma_b}{3D_\theta u^h_{m,c}} + \frac{p\theta_h^2 {u^h_{m,c}}^2}{\gamma_m} \tag{A-14}$$

As stated in proposition 4.13, $u^h_{m,d} > u^h_{m,s} > u^h_{m,c}$ and therefore when shareholders obtain the same value in all three cases,

$$\frac{1}{D_\theta u^h_{m,d}} > \left(\frac{1}{3} + \Delta_s\right) \frac{2}{D_\theta u^h_{m,s}} > \frac{2}{3D_\theta u^h_{m,c}}.$$

This implies that higher γ_b decreases shareholders value most in disciplinary board case. Thus, the optimal compensation is more likely to belong to disciplinary board case as γ_b decreases. Thus, the result is proved.
2. D_θ: omitted since it is very similar to the proof relative to γ_b.
3. $r_u - r_d$: By envelop theorem, the shadow price of $r_u - r_d$ in each regime is as follows.

$$\text{Speculation case: } \frac{p\theta_h^2 u^h_{m,s} + (1-p)\theta_l^2 u^l_m}{\gamma_m}$$

$$\text{Disciplinary board case: } \frac{p\theta_h^2 u^h_{m,d} + (1-p)\theta_l^2 u^l_m}{\gamma_m}$$

$$\text{Contracting board case: } \frac{p\theta_h^2 u^h_{m,c} + (1-p)\theta_l^2 u^l_m}{\gamma_m}$$

Since $u^h_{m,d} > u^h_{m,s} > u^h_{m,c}$ and $u^l_{m,d} = u^l_{m,s} = u^l_{m,c}$, higher $r_u - r_d$ increases shareholder value in disciplinary board case relative to other cases.

B Construction of pay-for-performance compensation measures

Relative to CEO compensation, Execucomp provides the dollar amount of total compensation and Black-Scholes value of option grants and, thus, the construction of pay-for-performance compensation measures is straightforward. Relative to outside director compensation, however, it provides four the annual cash retainer, the fee paid for attending board meetings, the number of stock grants and the number of stock option grants. Thus, to construct the pay-for-performance director compensation measure, I should compute fair values of stock and stock option grants. Following Ryan and Wiggins [2004], I define (i) the fair value of stock grants as the number of stock grants times the closing price of the previous fiscal year and (ii) the fair value of option grants as Black-Scholes value of a 10-year at-the-money option whose strike price equals the closing price of the previous fiscal year, volatility equals the standard deviation of stock returns over the last 60 month and dividend yield equals the average dividend yields over the last 3 years. Stock return volatilities and dividend yields are provided by Execucomp. In particular, the database separates the annual equity grants awarded on a regular schedule and one-time grants made on an irregular schedule. To examine the total compensation package, I consider both types of grants in the analysis.