Show me the Information: Board Independence and D&O Insurance

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Abstract

Outside directors and D&O insurance are both considered means of corporate governance. The empirical studies, however, generate mixed results as to how these different oversight mechanisms contribute to firm performance. This paper endogenizes D&O insurance in firm value maximization decisions, and incorporates D&O insurance coverage into the board's monitoring cost function. Such an approach enables us to find whether D&O insurance helps reduce the marginal cost of monitoring, and it plays a key role in understanding the board's incentives and their optimal level of monitoring efforts. By modeling and studying two oversight mechanisms together, we contribute to the corporate governance literature in several ways. First, we address the interactions of board independence and D&O insurance. Second, we characterize the importance of information transparency in determining the optimal D&O insurance coverage. Third, we enrich discussions on board independence and show that a high level of information transparency helps an independent board achieve a higher level of monitoring efforts.

Keywords: Information Transparency, Peer Monitoring, Board Independence, Directors and Officers' Liability Insurance

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1. Introduction

> *In the current environment, companies have a strong incentive to adopt rigorous governance procedures because those that fail to do so will be unable to attract top quality directors and will pay a risk premium in terms of both director compensation and possibly officer and director liability insurance.* (*Cynthia A. Glassman, SEC Commissioner, in a speech delivered to the National Economists' Club, April 7, 2003*)

In the traditional principal-agent models, if the agents are risk-neutral, the optimal contract design is to let the agents bear all risks, so as to avoid the moral hazard problem resulting from ex post information asymmetry. On the public policy and regulatory side, the corporate scandals in the past few years have triggered newer corporate governance rules and regulations, strengthening the functions of the corporate board of directors. Directors participate in board meetings to monitor the management team.[1] In the meantime, legislation and court decisions have also placed more emphasis on investor protection. In the case of company failures or drastic share price decreases, directors can face legal actions brought by disappointed investors. In the finance and economics literature, theoretical analyses of these issues are still rare.

We develop an analytical model in which shareholders delegate board members to monitor the CEO. The key decision variables in the shareholders' maximization problem are the board compensation and D&O insurance. The most unique part of the model is the emphasis on information transparency in corporate governance. For shareholders, the private benefit the CEO could obtain at the project selection stage cannot be ruled out by contract design. Such an agency problem can lead to a lower firm value. Thus, shareholders will delegate independent directors to participate in board meetings to exercise the peer monitoring function, in the hopes of solving the agency issue.

There have been a growing number of studies focusing on issues related to boards of directors, but they are mostly empirical. Few of them provide analytical insights. Of these, Kumar and Sivaramakrishnan (2008) and Laux (2010) are most closely related to our model.[2] Kumar and Sivaramakrishnan (2008) discuss board independence and its effects on compensation and levels of monitoring. In Laux (2010), the board

[1] Outside directors can also play an advisory role; see more discussions in Adams and Ferreira (2007).
[2] Other related theory papers on the board of directors include Hermalin and Weisbach (1998), Harris and Raviv (2008), Raheja(2005), etc.

determines CEO compensation according to firm performance. When there are higher director liabilities, the direct effect is for them to increase monitoring efforts. But in the meantime, in order to reduce the CEO's manipulation of a firm's accounting results, the board can try to increase the fixed salary and reduce the equity compensation, thus reducing the board's monitoring efforts. This is the indirect effect. In some situations, higher director liabilities yield a greater indirect effect than direct effect, leading to a lower level of board oversight.

Our model consists of shareholders, the CEO, and the board. Shareholders determine the board's compensation and make the D&O insurance purchase decisions. The CEO is the decision-maker as to what type of projects to undertake, from which he can potentially get private benefits. Only the board, with their professional capability, can observe such choices through board meetings. The CEO tends to choose high-risk projects with possible private benefits, but these can lead to a lower expected firm value. A more independent board is more concerned with the interests of the shareholder. A less independent board will move closer to the CEO's interests. In other words, Kumar and Sivaramakrishnan (2008) suggest the board's objective function is weighted expected value, with independence as the weight. The board will choose the optimal monitoring level with such a weighted function.

After a firm purchases D&O insurance, what effects will such insurance have on board oversight? To the best of our knowledge, the question has not yet been addressed analytically in the literature. Our model fills the gap. We will look at the issue from the perspective of information transparency and the director's out-of-pocket damage payments.

According to the in-depth surveys conducted by and reported in Baker and Griffith (2007) with D&O professionals (underwriters, actuaries, brokers, risk managers, lawyers, claims managers, etc.), when D&O insurers make the decision to accept an insurance application, they look to three principal sources of information about the prospective insured. First, they elicit basic information from the written application, including the experience of covered officers and directors, and the claims history of the corporation, plans for acquisitions or securities issuances, and whether any prospective insured has "prior knowledge" of acts or omissions likely to give rise to a claim. Second, D&O insurers use a wide variety of publicly available data sources including SEC filings, Bloomberg reports, analyst ratings, corporate governance reviews, and industry-specific forensic accounting studies. Third, they hold a series of “underwriting meetings” with the prospective insured’s senior managers and officers to get access to private information which may not be publicly available.

Historically, the out-of-pocket payment actually made by directors, if any, has not been significant. But it is no longer the case after the WorldCom and Enron settlements (Klausner et al. 2005). Naturally, nonexecutive directors would request companies to obtain some coverage of Directors and Officers Liability (D&O) insurance for potential litigation risks before they agree to act as board members. Higher coverage limits can be used as an incentive to attract good quality outside directors, improve board independence, and thus show a higher degree of corporate governance. In such a context, D&O insurance and board independence can be seen as ***complements***, as one reinforces the other. However, the fact that outside directors are covered by insurance may make them less diligent than if their own assets were at risk for their (actual or alleged) negligent wrongdoings. In addition, assuming that D&O insurers conduct the appropriate level of due diligence, buying D&O insurance can also lead to a lower level of reliance on the number of outside directors. In such a context, D&O insurance and board independence become ***substitutes*** for each other.

This paper aims to discuss the effects of D&O insurance and board independence on the board’s monitoring role. We will also investigate the interactions between D&O insurance and board independence. The core issues in the paper include peer monitoring and D&O insurance. Shareholders hire outside professionals as their representation to sit on the board of directors and monitor the management team. Such a concept of peer monitoring originally comes from Varian (1990).[3] To the best of our knowledge, there is little discussion on peer monitoring in the corporate board literature. The main reason is due to the fact that traditional principal-agent models believe contract design can solve peer monitoring problems. In Kumar and Sivaramakrishnan (2008), the board’s primary role is to discover the capital productivity type, thereby reducing information asymmetry before contracting. But in our paper, the agency problem can still be resolved by contract design. Outside directors monitor the management team mainly after contracting to see if the CEO chooses a project that will give him a private benefit.

Gutiérrez (2003) analyzes the incentive issue of corporate directors’ fiduciary duties

[3] Through participating in the board, outside directors observe the CEO’s private information, which is observable but unverifiable. Then, outside directors determine their actions, which, combined with the CEO’s action, affects the realized outcome and returns. This implicit peer monitoring differs from Banerjee, Besley and Guinnane (1994), in which a penalty is imposed directly. But the implications are similar.

and provides a justification of the widespread use of D&O liability insurance and limited-liability provisions in the US. The reason is that when damage awards are high enough, the system allows for a more efficient litigation strategy to be *ex post* rational for the shareholders.

Earlier literature (Mayers and Smith, 1982; Holderness, 1990) suggest insurers providing D&O insurance play an important monitoring role, as they scrutinize corporate policyholders and thus monitor their management. However, the effect of use of D&O insurance on corporate governance may not be that apparent, as empirical studies reveal mixed results. Using Canadian data, Core (2000) finds that insurance premiums are higher when insiders have more voting control, when inside ownership is lower, and when boards are less independent. Cao and Narayanamoorthy (2005) report that D&O liability insurance premiums decline with increased board independence. Gillan and Panasian (2008) find that the propensity of firms to purchase insurance increases with board independence.

In contrast, Chalmers, Dann, and Harford (2002), find no association between insurance coverage or premiums and board independence for their US IPO sample. Similarly, Boyer (2003, 2007) reports no significant association between D&O insurance limits or deductibles and board composition for Canadian firms during the 1993-1998 period.

Because of the mixed results, we believe the role of D&O insurance deserves more investigation. Specifically, how do D&O insurance and board composition affect each other simultaneously? Does D&O insurance compliment or substitute outside directors? We contribute to the literature by modeling the D&O insurance coverage into the board's monitoring cost function. This model setup helps us respond to some unanswered questions in the literature.

The remainder of the paper is organized as follows. Section II presents the model, and provides discussions of the subgame perfect equilibrium. Section III offers several comparative statics results. In Section IV, we inspect the effects of exogenous factors on the model, including D&O insurance premium rates, litigation risk, and information cost. Section V concludes the paper.

2. The Model

The theoretical framework of our model is based on four basic ideas: first, contract design can hardly change the CEO's behavior; second, board members oversee the CEO through peer monitoring; third, D&O insurance improves information transparency; fourth, corporate governance reform is not completely effective.[4]

According to traditional contract theory, information asymmetry after contracting can be eliminated via contract design. However, in the case of business operations, the subtlety of CEO decision-making is difficult to observe and verify. Even when tiny hints are observable, the potential free-rider issue can arise as a large and fragmented ownership structure will make shareholders unwilling to spend resources to verify information. As a consequence, companies have to delegate professionals and experts to take part in the board to exercise various oversight functions.

This paper focuses on peer monitoring among boards of directors. To describe the level of monitoring efforts, we follow a similar approach to previous studies that theorize the board's monitoring role through interfering with the CEO's project choice.[5] As elaborated by Adams and Ferreira (2007), the CEO does not like board interference both because their interests are not always aligned with each other and because the CEO enjoys private benefits of controlling project choice.

Adams and Ferreira contend that private benefits of control may arise for two reasons. First, the CEO may attribute a psychic value to being in control, in which case he dislikes board interference per se. Second, the board interference may weaken the CEO's authority, causing him to lose the respect of his subordinates; it may also diminish his value in the CEO market.[6]

If the oversight role by the board induces the CEO to make decisions that are more in line with shareholders' interests, which thus enhance firm value, it is of interest to ask what factors will affect the level of the board's monitoring efforts. Specifically, we will look at the role of directors' fiduciary duties, and whether the insurance

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[4] For instance, the Sarbanes-Oxley Act (SOX) requires that public companies disclose whether they have a financial expert on their audit committee. Yet, it is controversial whether SOX should define financial experts narrowly to include primarily accounting financial experts as initially proposed. The empirical work by Defond, Hann, and Hu (2005) found that there was a positive market reaction to the appointment of accounting financial experts assigned to audit committees, but no reaction to non-accounting financial experts assigned to audit committees.

[5] See, for example Burkart, Gromb, and Panunzi (1997) or Adams and Ferreira (2007).

[6] Many studies on corporate governance have discussed how the CEO loses private benefits of control due to monitoring by the board; see, for example, Dyck and Zingales(2004)；Adams and Ferreira (2007) also explain how the CEO may incur significant costs due to board interference.

protection changes a director's incentives. On the one hand, the availability of recovery from D&O policies may weaken director's diligence incentives, as the potential legal liability due to their professional negligence decreases. On the other hand, the insurance purchase may empower directors because the firm's D&O insurance submission and underwriting meetings with the insurer help promote corporate governance issues.

As mentioned earlier, Baker and Griffith (2007) outline three principal sources of information that D&O insurers collect from the prospective insured: information from the application submission, from public sources, and from private meetings. All sources of the information presented in the D&O underwriting process help insurers determine the insured's risk level and enhance loss control. Intuitively, as higher insurance coverage exposes the insurers to higher potential D&O claim liability, we expect that higher insurance limits increase the level of account-specific underwriting and due diligence audits from the insurer. This in turn helps directors (particularly outside directors) to acquire information and reduce the monitoring costs. As a result, we expect an inverse relationship between D&O insurance coverage and directors' monitoring costs due to a higher degree of information transparency.

2.1 Model Descriptions

How D&O insurance affects the board of directors' monitoring efforts is the primary focus of this paper. We believe that the role of information transparency is critical in the interaction between the two governance mechanisms: board oversight and D&O insurance. Through a theoretical analysis of the interaction and discussions of its impact on corporate governance, we are able to contribute to the literature and respond to some questions that remain unanswered. Because corporate governance reform emphasizes board independence, our model will also look at this issue.

We first describe the behavioral setup of the actors in the model. The time line is as shown in Figure 1. At stage $t=1$, shareholders (and the CEO) select a board of directors, and negotiate a reward contract Z, $Z = Z(\beta, K)$, where β represents the equity ratio awarded to the board, $0 < \beta < 1$, and K represents the D&O insurance coverage. In general, the compensation to business managers consists of cash salary and equity shares. The optimal incentive mechanism is to award equity exclusively.[7] As the main focus of this paper is directors' incentives and their monitoring efforts, we consider only the equity compensation to directors. This way we can simplify the

[7] This concept is originally from Holmstrom (1979).

analyses without altering the main conclusion. In addition, we assume that shareholders and the CEO jointly make board appointment decisions so as to avoid potential insufficient monitoring due to the CEO's involvement in director selection.[8]

At $t=2$, the CEO makes the project selection and the board determines the degree of monitoring, m. We follow Adams and Ferreira (2007) in assuming the existence of two types of projects: high risk and low risk. The probability of failure of the high risk project is p_H, but the CEO will get a private benefit, B, from such choice. The probability of failure of the low risk project is p_L, from which the CEO will not obtain any private benefit. The nature of the risks require that $0 \le p_L < p_H \le 1$. As shareholders cannot observe and verify the CEO's actions, they rely on peer monitoring from directors to oversee the CEO. If the board's monitoring efforts are substantial, the CEO will choose the low risk project that shareholders prefer; however, if the board's monitoring is sloppy, the CEO will tend to choose the high risk project which does not serve the best interests of shareholders, and he will obtain sufficiently large private benefits from such a choice.[9]

The composition of the board will affect its oversight efforts. Practically, the more independent the board is, the more likely it will better serve the interests of shareholders. A less independent board is more likely to act along with the CEO. We assume the board is a group decision-making body, with an objective function similar to that proposed in Kumar and Sivaramakrishnan (2008). A variable I represents the independence of the board, where $I \in [0,1]$. When I is closer to 1, indicating a more independent board, the board of directors considers more firm value maximization issues. Wwhen I is closer to 0, indicating a less independent board, directors' objective are more in line with those of the CEO.

At stage $t=3$, the project outcome is realized which generates the firm value R if it is a success, otherwise the value is zero. Finally, at stage $t=4$, if the project fails, not only there is no value realized, the board can potentially face a dire situation with the

[8] Shivdasani and Yermack (1999) analyze the outcomes of CEO involvement in board selection. They find firms with higher CEO involvement will appoint less independent outside directors and more gray directors. The stock market reaction suggests that shareholders are not in favor such involvement. Also, the authors observe a recent trend of companies removing CEOs from involvement in director selection.

[9] The concept is originally from Aghion and Bolton (1992). In our model, when the board does not exercise high monitoring efforts, the high risk project which is not preferred by shareholders will be chosen. In this case, the CEO achieves substantial control and earns private benefits. By contrast, when the monitoring effort is substantial, shareholders will prefer and choose a low risk project. In such a case, the CEO only has nominal control of project selection, as the board will request the low risk project to be selected.

probability q that the court reaches a verdict asking them to compensate D to shareholders[10].

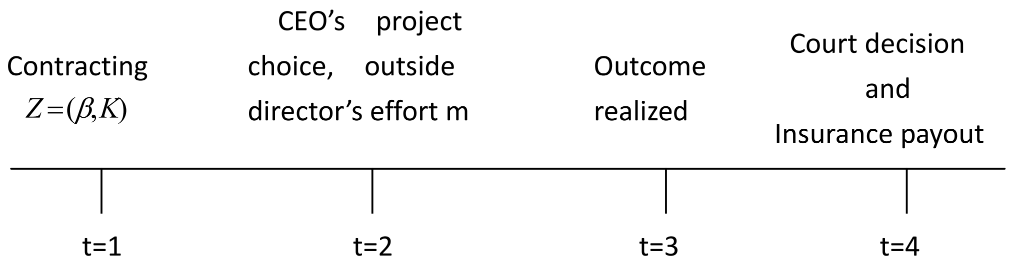

Figure1. Timeline

To focus on the board's monitoring efforts, we simplify the CEO's role in our model. First of all, before the firm contract with the board at stage t = 1, the CEO holds a reward contract with an equity ratio α, $0<\alpha<1$. This reward contract has to satisfy the CEO's individual rationality constraint and incentive compatibility constraint. In addition, we standardize the probability of project failure. When the CEO selects the project, if it is a low risk project, the probability of failure p_L equals zero. If it is a high risk one, the probability of failure p_H equals p, where $0<p<1$.

In addition, because we are not analyzing the impacts of investor lawsuits,[11] we make several simplifications on this part. We assume the insurance market is competitive, so the D&O insurance premium rate, r, is determined by the condition of zero insurer profit.[12] At the contracting stage, if the shareholders decide to carry the coverage limit K, then the firm needs to pay a D&O insurance premium G:

$$G = rK \tag{1}$$

If the court rules in favor of the plaintiff, shareholders get D from the defendant officers and directors. Of this, K will be reimbursed by the D&O insurer, leaving out-of-pocket payout $(D-K)$ from the (alleged) negligent CEO and the board.

2.2 Subgame Perfect Equilibrium

[10] In most firms, the CEO is usually a member of the board. To simplify analyses, we separate the role of the CEO and the board.
[11] Gutiérrez (2003) provides a more detailed analysis of directors' fiduciary duties and investor lawsuits.
[12] Many factors can affect the D&O insurance premium rate. In our model extension, we will consider the relationship between board independence and the premium rate. In practice, a more independent board can lead to a less expensive premium rate.

Given that the CEO owns α ratio of shares, after the optimal contract $Z = Z(\beta, K)$ is signed at $t = 1$, the firm's expected value is:

$$V_i = (1 - p_i)R + p_i qD - G \text{ , } i = H, L \tag{2}$$

Given $p_H = p$ and $p_L = 0$, we can find

$$V_L - V_H = p(R - qD).$$

If the CEO takes out the high risk project at $t = 2$, his (her) expected value is U_{CEO}^{H}

$$U_{CEO}^{H} = \alpha V_H + B = \alpha[(1 - p)R + pqD - G] + B \tag{3}$$

Similarly, if s/he goes with the low risk option, the expected value is U_{CEO}^{L} :

$$U_{CEO}^{L} = \alpha V_L = \alpha[R - G] \tag{4}$$

To the CEO, if s/he can freely select the project without the board's interference, he will choose the high-risk option to receive a private benefit. This implies $U_{CEO}^{H} > U_{CEO}^{L}$. From equations (3) and (4), we can obtain the following inequality:

$$B > \alpha p(R - qD) \tag{5}$$

The equation (5) indicates a condition for the CEO to opt for the high risk project. Ceteris paribus, only when the private benefit is large enough will the CEO consider the high risk option. In the meantime, we characterize the board's utility function U_D as:

$$\begin{aligned} U_D = \{m[I\beta V_L + (1 - I)U_L] + (1 - m)[I\beta V_H + (1 - I)U_H]\} \\ - TC(m, \mathrm{K}) - (1 - \mathrm{m})\, pq \times \max\{D - K, 0\} \end{aligned} \tag{6}$$

Equation (6) includes several important terms that shape decisions by outside directors. The first term reflects the expected value considering board independence, the second term is the board's monitoring cost, and the last term describes the expected damage amount if the project fails and the court rules in favor of the shareholders. To avoid the complicated situations resulting from various outcomes of investor litigation, we simply assume that the probability of directors and officers losing a shareholder lawsuit is q, which is mainly affected by legislation and the legal environment, and is independent of the board's monitoring efforts.

It is worth particular note that the board's monitoring cost $TC(m,K)$ is a function of the monitoring effort m , $m \in [0,1]$, and the D&O insurance coverage, K. In order to simplify the analysis, we assume

$$TC(m,K) = \frac{1}{2} \cdot c(K) \cdot m^2, \quad c(K) = ce^{-\lambda K} \tag{7}$$

Equation (7) provides the board's monitoring cost function $TC(m,K)$. There are two key aspects of the function. First, $\frac{\partial^2 TC(m,K)}{\partial m^2} = c(K) > 0$, $TC(m,K)$ is a convex function of monitoring effort m. Second, the D&O insurance coverage K will affect the marginal cost of the board's monitoring, that is:

$$\frac{\partial(\frac{\partial TC(m,K)}{\partial m})}{\partial K} = -\lambda ce^{-\lambda K} \cdot m < 0$$

As discussed earlier, the higher D&O insurance coverage will lead to higher degree of information transparency requested from the insurer who bears most, if not all, the costs of project failure and shareholder lawsuit. The above formula implies that the higher the D&O insurance coverage, the higher the information transparency and the lower the monitoring costs. Therefore, we model the monitoring cost function as in equation (7), suggesting that given the same level of monitoring efforts, the higher D&O insurance coverage K will lead to lower marginal cost of monitoring efforts. How effective such a decrease is depends on what we call the degree of information transparency λ.

Lemma 1: Given the range of the degree of information transparency $\lambda \in [0, \infty]$, there exists a λ_1, such that

(a) If $0 < \lambda < \lambda_1$, then $\frac{\partial m^*(\beta, K)}{\partial K} < 0$; similarly, if $\lambda_1 < \lambda$, then $\frac{\partial m^*(\beta, K)}{\partial K} > 0$.

(b) $\frac{\partial m^*(\beta, K)}{\partial \beta} > 0$

Proof:

We rearrange equation (6).[13] Differentiate it with respect to m, and we can get the first-order condition

$$\frac{dU_D}{dm} = [I\beta + (1-I)\alpha]p(R-qD) - (1-I)B - ce^{-\lambda K}m + pq(D-K) = 0$$

The second-order condition is satisfied because $\frac{d^2U_D}{dm^2} = -ce^{-\lambda K} < 0$, so we can obtain the only optimal solution $m^*(\beta, K)$. Rearranging terms in the first-order condition, we can obtain the optimal monitoring effort, which is:

$$m^*(\beta, K) = c^{-1}e^{\lambda K}\{[I\beta + (1-I)\alpha]p(R-qD) - (1-I)B + pq(D-K)\} \tag{8}$$

Next, in order to analyze how the contracting terms affect the optimal monitoring effort m^*, we differentiate $m^*(\beta, K)$ with respect to β:

$$\frac{\partial m^*(\beta, K)}{\partial \beta} = c^{-1}e^{\lambda K}Ip(R-qD) \tag{9}$$

As $R - qD > 0$, we can get that $\frac{\partial m^*(\beta, K)}{\partial \beta} > 0$. Next, we differentiate $m^*(\alpha, \beta, K)$ with respect to K:

$$\frac{\partial m^*(\beta, K)}{\partial K} = \lambda m^* - c^{-1}e^{\lambda K}pq \tag{10}$$

Let $f(\lambda) = \frac{\partial m^*(\beta, K)}{\partial K} = \lambda m^* - c^{-1}e^{\lambda K}pq$. When $\lambda \in [0, \infty)$, $f'(\lambda) = (1+\lambda K)m^* - Kc^{-1}e^{\lambda K}pq$. It is possible to find in this range a λ_0 such that $f'(\lambda_0) = 0$. That is, $\lambda_0 = \frac{pq}{[I\beta + (1-I)\alpha]p(R-qD) - (1-I)B + pq(D-K)} - \frac{1}{K}$. In the range of $\lambda \in [0, \lambda_0)$, $f'(\lambda) < 0$; in the range of $\lambda \in (\lambda_0, \infty]$, $f'(\lambda) > 0$. Therefore, with appropriate selected values of m^*, β, K, p, and q, $f'(\lambda) > 0$ when $\lambda \in [\lambda_0, \infty]$.

[13] We assume $D - K \geq 0$. That is, D&O insurance coverage limit, *K*, is not greater than the court ruling, *D*, which means some out-of-pocket payout from directors and officers is required.

At $\lambda = 0$, $f(0) = -c^{-1}pq < 0$. When λ increases from zero (but below λ_0), $f(\lambda) < 0$ as $f'(\lambda) < 0$. At $\lambda = \lambda_0$, $f(\lambda_0) = -\frac{m^*}{K} < 0$. When λ increases from λ_0, because $f'(\lambda) > 0$, and $\lim_{\lambda \to \infty} f(\lambda) = \infty$, we can find a unique λ_1 ($\lambda_0 < \lambda_1 < \infty$) such that $f(\lambda_1) = 0$. When $\lambda > \lambda_1$, $f(\lambda) = \frac{\partial m^*(\beta, K)}{\partial K} > 0$; when $\lambda_0 < \lambda < \lambda_1$, $f(\lambda) = \frac{\partial m^*(\beta, K)}{\partial K} < 0$.

With the proof in the previous paragraph and equation (10), we can easily obtain

$$\lambda_0 = \frac{pq}{[I\beta + (1-I)\alpha]p(R-qD) - (1-I)B + pq(D-K)} - \frac{1}{K}$$

and

$$\lambda_1 = \frac{pq}{[I\beta + (1-I)\alpha]p(R-qD) - (1-I)B + pq(D-K)}$$

Q.E.D.

This algebra proves the existence of two values λ_0 and λ_1, $0 < \lambda_0 < \lambda_1 < \infty$. (i) When $0 < \lambda < \lambda_1$, $\frac{\partial m^*(\beta, K)}{\partial K} < 0$; (ii) When $\lambda_1 < \lambda$, $\frac{\partial m^*(\beta, K)}{\partial K} > 0$. The result of Lemma 1(a) comes from the cost-benefit analysis of purchasing D&O insurance. When the information transparency parameter is low ($\lambda < \lambda_1$), an additional unit of insurance coverage leads to larger reduced expected liability payments than reduced marginal monitoring costs, so the optimal monitoring effort will be lower. If the information transparency parameter is high enough ($\lambda > \lambda_1$), an additional unit of insurance coverage leads to reduced marginal monitoring costs than larger reduced expected liability payments, so the optimal monitoring effort will increase. The result of Lemma 1(b) reflects the common economic intuition: when the board is given higher equity rewards, its monitoring efforts will increase, ceteris paribus.

Lemma 1 shows that the contract decided at the first stage will have an impact on the board's optimal monitoring effort. It is of interest to note that the impact from D&O insurance coverage on monitoring depends on the degree of information transparency. At different levels of information transparency parameters, more insurance can lead to either higher or lower monitoring efforts. Now we will use the result of Lemma 1 to analyze the equilibrium of the model.

Proposition 1: There exists an unique Subgame Perfect Equilibrium (SPE) , $\{(\beta^*, K^*), m^*(\beta^*, K^*)\}$, where (a) an interior solution β^*, $0 < \beta^* < 1$, always exists; (b) there exist λ_1 and λ_2 such that $K^* = 0$ when $0 < \lambda < \lambda_1$, and $K^* > 0$ when $\lambda_1 < \lambda < \lambda_2$. $\lambda_2 = \bar{\lambda}$ is the upper limit of the information transparency.

Proof:

The objective function for shareholders is to seek maximization of expected value EV_S, that is

$$(\beta, K) \in \arg Max \ EV_S = (1-\beta)\{m^*(\beta, K)V_L + [1 - m^*(\beta, K)]V_H\}$$

Differentiate EV_S with respect to β and K, and we get

$$\frac{\partial EV_s(\beta, K)}{\partial \beta} = -\{m^*(\beta, K)V_L + [1 - m^*(\beta, K)]V_H\}$$
$$+ (1-\beta)(V_L - V_H)\frac{\partial m^*(\beta, K)}{\partial \beta} \le 0 \qquad (FOC_\beta)$$

and

$$\frac{\partial EV_s(\beta, K)}{\partial K} = (1-\beta)[(V_L - V_H)\frac{\partial m^*(\beta, K)}{\partial K} - (1 - m^*)r] \le 0 \qquad (FOC_K)$$

Lemma 1(b) shows that $\frac{\partial m^*(\beta, K)}{\partial \beta} > 0$, hence, we can find a β^* between 0 and 1 so that the equality of (FOC_β) holds, indicating the existence of an interior solution β^*. In addition, Lemma 1(a) implies $\frac{\partial m^*(\beta, K)}{\partial K} > 0$ when $\lambda > \lambda_1$, so we can find a K^* larger than zero such that the equality of (FOC_K) holds, indicating the existence of an interior solution K^*. On the other hand, when $\lambda < \lambda_1$, $\frac{\partial m^*(\beta, K)}{\partial K} < 0$. So, (FOC_K) is less than zero, only the corner solution $K^* = 0$

exists.

To prove the uniqueness of the optimal solutions, we need to check the second-order condition. Differentiate EV_S with respect to β and K twice, and we obtain:

$$\frac{\partial^2 EV_s(\beta,K)}{\partial\beta^2} = -2(V_L - V_H)\frac{\partial m^*(\beta,K)}{\partial\beta}$$

$$\frac{\partial^2 EV_s(\beta,K)}{\partial K^2} = (1-\beta)[(V_L - V_H)\frac{\partial^2 m^*}{\partial K^2} + r\frac{\partial m^*}{\partial K}]$$

$$\frac{\partial^2 EV_s(\beta,K)}{\partial\beta\partial K} = \frac{\partial^2 EV_s(\beta,K)}{\partial K\partial\beta}$$

$$= -[(V_L - V_H)\frac{\partial m^*}{\partial K} - (1-m^*)r] + (1-\beta)(V_L - V_H)\frac{\partial^2 m^*}{\partial\beta\partial K} + (1-\beta)r\frac{\partial m*}{\partial K}$$

As both (FOC_β) and (FOC_K) hold, we now discuss the existence of the second-order condition. First, from the result of Lemma 1(b), it can be proved that $\frac{\partial^2 EV_s(\beta,K)}{\partial\beta^2} < 0$; moreover, with equations (8) and (10), we can derive

$$\frac{\partial^2 EV_s(\beta,K)}{\partial K^2} = (1-\beta)\{[\lambda p(R-qD)+r]\frac{\partial m^*}{\partial K} - \lambda c^{-1}e^{\lambda K}pq\}$$

$$= (1-\beta)[\lambda p(R-qD)+r][\frac{\partial m^*}{\partial K} - \frac{\lambda c^{-1}e^{\lambda K}pq}{\lambda p(R-qD)+r}]$$

We know from Lemma 1 (a) that there exists a cut-off value λ_1, and $\frac{\partial m^*}{\partial K} > 0$ when $\lambda > \lambda_1$. Besides, the value of $\frac{\partial m^*}{\partial K}$ will increase as λ increases. Therefore, there exists a turning point λ_2 such that $\frac{\partial^2 EV_s(\beta,K)}{\partial K^2} = 0$. The second derivative $\frac{\partial^2 EV_s(\beta,K)}{\partial K^2} < 0$ when $\lambda_1 < \lambda < \lambda_2$. Now, λ_2 has to satisfy the equation

$$\lambda\{[I\beta + (1-I)\alpha]p(R-qD) - (1-I)B + pq(D-K)\} - pq - \frac{\lambda pq}{\lambda p(R-qD)+r} = 0.$$

In addition, with the functions obtained earlier, we can get

$$\Delta = \frac{\partial^2 EV_s(\beta, K)}{\partial \beta^2} \times \frac{\partial^2 EV_s(\beta, K)}{\partial K^2} - \frac{\partial^2 EV_s(\beta, K)}{\partial \beta \partial K} \times \frac{\partial^2 EV_s(\beta, K)}{\partial K \partial \beta} < 0,$$

the Hessian matrix is negative definite, so the uniqueness of optimal (β^*, K^*) can be proved.

Q.E.D.

From proposition 1, we can infer several implications that are in line with economic intuition. To elaborate, we now rewrite (FOC_β) and (FOC_K):

$$-\{m^*(\beta, K)V_L + [1 - m^*(\beta, K)]V_H\} + (1-\beta)(V_L - V_H)\frac{\partial m^*(\beta, K)}{\partial \beta} = 0 \qquad (11)$$

$$(1-\beta)[(V_L - V_H)\frac{\partial m^*(\beta, K)}{\partial K} - (1-m^*)r] \le 0 \qquad (12)$$

Equation (11) is the formula for the optimal equity compensation to the board. For shareholders, higher equity compensation to the board leads to higher monitoring levels, thereby increasing the firm value. As a result, shareholders are willing to give up certain a percentage of shares, up to the point that one additional relinquishment of shares will not be compensated by gains in firm value based on their share holdings. Such a trade-off suggests the existence of an optimal interior solution. Furthermore, Equation (12) is the formula for the optimal insurance coverage. If purchasing more insurance does not effectively enhance information transparency, i.e., when $\lambda < \lambda_1$, more insurance spending cannot lead to a higher degree of optimal monitoring, so the best move is not to insure, suggesting a corner solution. In contrast, if purchasing more insurance does effectively enhance information transparency, i.e., when $\lambda_1 < \lambda < \lambda_2$, more insurance spending can lead to higher degree of optimal monitoring, thereby improving firm value. In such a case, there exists an interior solution of optimal insurance coverage, depending on the trade-off of the benefit of higher firm value and the cost of higher insurance spending. Lastly, if purchasing more insurance enhances information transparency at a tremendous speed, i.e., $\lambda_2 < \lambda$, then it would lead to infinite insurance coverage. This is not the case we observe in the real world. Hence, we can practically consider λ_2 as the upper limit for the information transparency parameter.

The result of our model's equilibrium has a very important practical implication. Whether D&O insurance contributes positively to firm values depends on the crucial factor of information transparency. Only a large transparency parameter can effectively reduce the board's marginal monitoring cost, thereby increasing the level of board oversight. In other words, simply because a firm purchases D&O insurance does not mean it will generate a higher value for the firm. It may not be the case that every firm needs D&O insurance. When the insured firm's information transparency is low, our model suggests zero optimal D&O insurance coverage. For this type of firm, if shareholders want to purchase D&O insurance for reasons of corporate governance, not only does it not lead to lower marginal monitoring costs, but it also increases the company's expenses of paying premiums, which in turn reduce the board's monitoring level and firm value.

Accordingly, our model provides an alternative explanation to the managerial opportunism hypothesis. The empirical results in Chalmers et al. (2002) show a significant negative relation between the three-year post- IPO stock price performance and the insurance coverage purchase. The authors' interpretation is that, like insider securities transactions, D&O insurance decisions reveal opportunistic behavior by managers. Our model suggests an explanation that is of more economics and less value-judgmental. For firms with lower information transparency, more D&O insurance simply reduces more expected liability payments than marginal monitoring costs, thereby inducing lower monitoring efforts from the board and accordingly reducing the firm value.

3. Equilibrium Analysis

The implementation of SOX legislation makes the role of the directors the focus of many discussions. The focus is whether directors can act independently to assist shareholders to monitor CEOs. One SOX requirement is for firms to increase the percentage of independent directors on the board to enhance its function. In this section, we will look at board independence and its relationship to the optimal monitoring level. Intuitively, higher board independence implies a higher level of monitoring per se. However, other than the direct effect, board independence can affect the monitoring level indirectly, through its interaction with board compensation and D&O insurance. The interactions between board independence, board compensation, and D&O insurance will be the primary focus of this section.

In Proposition 1, we prove the existence of a *Subgame Perfect Equilibrium* $\{(\beta^*, K^*), m^*(\beta^*, K^*)\}$, which satisfies equations (8), (11), and (12). Next, we will ask the question: Do directors with a higher degree of independence achieve better monitoring effects?

Once the equilibrium is reached, equation (8) can be rewritten as

$$m^*(\beta^*(I), K^*(I), I) = c^{-1} e^{\lambda K^*(I)} \{[I\beta^*(I) + (1-I)\alpha](V_L - V_H) - (1-I)B\} \qquad (8)_{SPE}$$

It can be seen from equation $(8)_{SPE}$ that board independence, ***I***, affects optimal monitoring efforts through three channels. The immediate effect is the intuition that higher board independence leads to higher level of monitoring per se; the second is the indirect effect through board compensation β^*; and the third is the indirect effect through insurance coverage K^*.

Next, we will discuss these indirect impacts. Part I will focus on the impact of board independence on optimal board compensation β^*, and Part II will explore the impact of board independence on optimal D&O insurance coverage K^*.

Proposition 2: *If* $\lambda_1 < \lambda < \lambda_2$, *higher board independence implies higher optimal board compensation,* $\dfrac{d\beta^*}{dI} > 0$**,** *and higher optimal D&O insurance coverage ,* $\dfrac{dK^*}{dI} > 0$. *However, if* $\lambda < \lambda_1$, *the optimal D&O insurance coverage is zero,* $K^* = 0$, *and higher board independence only implies higher optimal board compensation,* $\dfrac{d\beta^*}{dI} > 0$.

Proof:

Part I:

Differentiate eq. (FOC_β) 及 eq. (FOC_K) with respect to β^*, K^*, and I :

$$\frac{\partial^2 EV_s}{\partial \beta^2} d\beta^* + \frac{\partial^2 EV_s}{\partial \beta \partial K} dK^* + \frac{\partial^2 EV_s}{\partial \beta \partial I} dI = 0$$

$$\frac{\partial^2 EV_s}{\partial K \partial \beta} d\beta^* + \frac{\partial^2 EV_s}{\partial K^2} dK^* + \frac{\partial^2 EV_s}{\partial K \partial I} dI = 0$$

Rearranging the terms yields the following matrix:

$$\begin{bmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{bmatrix} \begin{bmatrix} \frac{d\beta^*}{dI} \\ \frac{dK^*}{dI} \end{bmatrix} = \begin{bmatrix} \frac{\partial^2 EV_s}{\partial \beta \partial I} \\ \frac{\partial^2 EV_s}{\partial K \partial I} \end{bmatrix}$$

With the inverse matrix, we get:

$$\frac{d\beta^*}{dI} = \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix}^{-1} \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta \partial I} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial I} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix} \tag{13}$$

By the second-order condition for maximization, the matrix in the denominator of this expression in negative semi-definite, which is

$$\Delta = \frac{\partial^2 EV_s}{\partial \beta^2} \times \frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial \beta \partial K} \times \frac{\partial^2 EV_s}{\partial K \partial \beta} < 0 .$$

The values in the determinant of Equation (13) can be discussed in three parts. First, from the second-order condition of Proposition 1, we learn that:

$$\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial \beta^2} = -2(V_L - V_H)\frac{\partial m^*}{\partial \beta} = -2(V_L - V_H)^2 Ic^{-1}e^{\lambda K^*} < 0$$

and

$$\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial K^2} = (1-\beta)[(V_L - V_H)\frac{\partial^2 m^*}{\partial K^2} + r\frac{\partial m^*}{\partial K}]$$

$$= (1-\beta)[(V_L - V_H)(\lambda^2 m^* - 2\lambda pqc^{-1}e^{\lambda K^*}) + r\lambda m^* - rpqc^{-1}e^{\lambda K^*}]$$

$$= (1-\beta)\{[\lambda^2(V_L - V_H) + r\lambda]m^* - [2\lambda(V_L - V_H) + r]pqc^{-1}e^{\lambda K^*} < 0 .$$

(from the proof and Proposition 1)

Second, (FOC_K) implies $(V_L - V_H)\frac{\partial m^*}{\partial K} - (1-m^*)r \le 0$, and from equation (9), we know $\frac{\partial^2 m^*}{\partial\beta\partial K} = \lambda c^{-1} e^{\lambda K} I(V_L - V_H) > 0$, therefore

$$\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial\beta\partial K} = -[(V_L - V_H)\frac{\partial m^*}{\partial K} - (1 - m^*)r] + (1-\beta)(V_L - V_H)\frac{\partial^2 m^*}{\partial\beta\partial K} + (1-\beta)r\frac{\partial m^*}{\partial K} > 0.$$

Third, our model assumes that the CEO's project selection depends on the board's monitoring. If there is no monitoring, the CEO will definitely choose the high risk project. The private benefit to the CEO generated from the high risk project plays an important role in the following discussion. Additionally, our model does not discuss the CEO's compensation α, which in general should be higher than the board's compensation, that is, $\alpha > \beta$.

Hence,

$$\begin{aligned}\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial\beta\partial I} &= -(V_L - V_H)c^{-1}e^{\lambda K}[(\beta-\alpha)p(R-qD)+B] \\ &\quad + (1-\beta)(V_L - V_H)p(R-qD)e^{\lambda K} \\ &= [2(1-\beta)(V_L - V_H) - B](V_L - V_H)c^{-1}e^{\lambda K}\end{aligned}$$

and

$$\begin{aligned}\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial K\partial I} &= (1-\beta)(V_L - V_H)c^{-1}\lambda e^{\lambda K}[(\beta-\alpha)p(R-qD)+B] \\ &= (1-\beta)(V_L - V_H)c^{-1}\lambda e^{\lambda K}[-(\alpha-\beta)(V_L - V_H)+B] > 0 \\ &\quad \text{(by eq.(5) } B > \alpha p(R-qD)\text{)}\end{aligned}$$

Plugging the above terms into eq. (13), it can be found that:

$$\frac{d\beta^*}{dI} = \frac{1}{\Delta}\left(\frac{\partial^2 EV_s}{\partial\beta\partial I}\times\frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial\beta\partial K}\times\frac{\partial^2 EV_s}{\partial K\partial I}\right)$$

where $\Delta = \frac{\partial^2 EV_s}{\partial\beta^2}\times\frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial\beta\partial K}\times\frac{\partial^2 EV_s}{\partial K\partial\beta} < 0$

When $B = \alpha(V_L - V_H) + \varepsilon$, where ε is a small positive value, the cross derivative $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial\beta\partial I} > 0$, therefore, $\frac{d\beta^*}{dI} > 0$. However when $B = 2(1-\beta)(V_L - V_H)$, the cross derivative $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial\beta\partial I} = 0$, which also makes $\frac{d\beta^*}{dI} > 0$. In addition, we can observe that $\frac{d\beta^*}{dI}$ increases as B increases, which proves that $\frac{d\beta^*}{dI} > 0$.

Part II:

With an approach similar to that used in Part I, we obtain the following equation:

$$\frac{dK^*}{dI} = \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix}^{-1} \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial I} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K \partial I} \end{vmatrix} \tag{14}$$

Given $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial \beta^2} < 0$, $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial K \partial I} > 0$, and

$$\frac{\partial^2 EV_s(\beta, K)}{\partial K \partial \beta} = -[(V_L - V_H)\frac{\partial m^*}{\partial K} - (1-m^*)r] + (1-\beta)(V_L - V_H)\frac{\partial^2 m^*}{\partial \beta \partial K}$$

$$+ (1-\beta)r\frac{\partial m *}{\partial K} > 0$$

so

$$\frac{dK^*}{dI} = \frac{1}{\Delta}(\frac{\partial^2 EV_s}{\partial \beta^2} \times \frac{\partial^2 EV_s}{\partial K \partial I} - \frac{\partial^2 EV_s}{\partial \beta \partial I} \times \frac{\partial^2 EV_s}{\partial K \partial \beta})$$

where $\Delta = \frac{\partial^2 EV_s}{\partial \beta^2} \times \frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial \beta \partial K} \times \frac{\partial^2 EV_s}{\partial K \partial \beta} < 0$

When $B = \alpha p(R - qD) + \varepsilon$, the cross derivative $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial \beta \partial I} < 0$, which implies that $\frac{dK^*}{dI} > 0$; when $B = 2(1-\beta)(V_L - V_H)$, the cross derivative $\frac{\partial^2 EV_s(\beta^*, K^*)}{\partial \beta \partial I} = 0$, which also implies that $\frac{dK^*}{dI} > 0$. Also, the value of $\frac{dK^*}{dI}$ increases as B increases, like when B approaches to infinity. Thus, $\frac{dK^*}{dI} > 0$.

Q.E.D

To encourage the board to act independently and to assist shareholders to monitor the management team, it is common for firms to use higher rewards for the board to induce more monitoring. This result is consistent with the findings of Kumar and Sivaramakrishnan (2008). However, we also want to emphasize the function of D&O insurance. We can consider the private benefit associated with a high risk project as an "implicit cost" to shareholders and directors. In our model, we assume the private benefit is high enough, as in equation (5), which satisfies the CEO's subjective incentive compatibility constraint. The increased marginal return from higher board independence is less than the marginal implicit cost, yielding an overall negative payoff. Therefore, the demand for insurance increases with higher board independence, so as the optimal D&O insurance coverage.

As discussed previously, firms use board compensation and D&O insurance in the hope of inducing better monitoring efforts. However, if we desire a higher level of board independence, does that imply the purchase of more D&O insurance coverage? Our answer is yes. As the purpose of insurance is the protection of potential legal liability, if higher board independence implies a negative overall marginal gain, the demand for insurance will be strengthened, and optimal insurance coverage will be higher. Several corporate scandals in recent years are largely due to senior executives' misconduct as they sought huge personal interests. The role of high private benefits in our model reflects the possibility that executives may deviate from their fiduciary duties. If shareholders want to increase board independence, our model suggests that they also need to increase D&O insurance coverage. We now turn to the effects of board independence on monitoring levels.

Proposition 3**:** *When the information transparency parameter is within the range of* $\lambda_1 < \lambda < \lambda_2$*, D&O insurance purchase will increase the board's monitoring level. Subsequently, higher board independence will lead to greater monitoring efforts. However, when* $\lambda < \lambda_1$*, the D&O insurance purchase will increase the board's monitoring level, and higher board independence will lead to less monitoring efforts. In such a situation, the best strategy is to purchase zero D&O insurance.*

To examine how board independence affects monitoring levels, we need to utilize the results we have obtained from previous sections. First of all, the proofs from Proposition 2 indicate that $\frac{d\beta^*}{dI} > 0$ and $\frac{dK^*}{dI} > 0$. Moreover, with Lemma 1 and Proposition 1, we learn that at equilibrium $\{(\beta^*, K^*), m^*(\beta^*, K^*)\}$, the condition for an interior solution of (β^*, K^*) is that the information transparency parameter has to be in the range of $\lambda_1 < \lambda < \lambda_2$. Under such information transparency, $\frac{\partial m^*}{\partial K^*} > 0$ and $\frac{\partial m^*}{\partial \beta^*} > 0$. Lastly, we know from the equation $(8)_{SPE}$ that,

$$\frac{dm^*(\beta^*(I),K^*(I),I)}{dI}=\frac{\partial m^*}{\partial I}+\frac{\partial m^*}{\partial \beta^*}\frac{d\beta^*}{dI}+\frac{\partial m^*}{\partial K^*}\frac{dK^*}{dI} \qquad (15)$$

The effects of board independence changes on the optimal monitoring level are three-fold. The first term in the righthand side of equation (15) is the direct effect, the second term is the effect via board compensation, and the third term is the effect via D&O insurance. The direct effect is positive, as shown below,

$$\frac{\partial m^*}{\partial I}=c^{-1}e^{\lambda K^*}[(\beta-\alpha)(V_L-V_H)+B]>0,$$

which indicates that a higher level of board independence increases optimal monitoring efforts, provided other variables, including β^* and K^*, hold constant. However, board independence also affects β^* and K^*, which in turn will affect the optimal monitoring level. Holding other variables constant, as board independence increases, shareholders will offer higher compensation to the board, which gives them a higher motivation to monitor the CEO. This reinforces the monitoring efforts. However, when the private benefit to the CEO is high enough, the directors with equity shares in the firm will have a stronger demand for insurance, which again enhances monitoring efforts. This shows that D&O insurance improves board oversight and indeed promotes corporate governance.

However, if the information transparency parameter is low, $\lambda<\lambda_1$, as a more independent board will request more insurance, which points to lower optimal monitoring level. For these types of firms, the best strategy is not to insure at all.

Proposition 4: (*Firm Value Maximization*) *From the perspective of shareholders, there exists an interval of information transparency* $\lambda_1<\lambda<\lambda_2$, at which *shareholders will be willing to purchase D&O insurance. In such a situation, the optimal insurance coverage shows a substitute relationship with optimal board compensation.*

Proof:

As $EV_S(\beta^*,K^*)=m^*(\beta^*,K^*)V_L+[1-m^*(\beta^*,K^*)]V_H$, we learn that

$dEV_s(\beta^*, K^*) = (1-\beta^*)(V_L - V_H)[\frac{\partial m^*}{\partial \beta^*} d\beta^* + \frac{\partial m^*}{\partial K^*} dK^*] = 0$, plugging eq. (9) and eq. (10) into the formula gets:

$$\frac{d\beta^*}{dK^*}_{|EV_s = \overline{V}} = -\frac{\frac{\partial m^*}{\partial K^*}}{\frac{\partial m^*}{\partial \beta^*}}$$

By lemma 1, the denominator and the numerator are both positive ($\frac{\partial m^*}{\partial K^*} > 0$ and $\frac{\partial m^*}{\partial \beta^*} > 0$), provided the information transparency $\lambda_1 < \lambda < \lambda_2$. Therefore, it can be proved that $\frac{d\beta^*}{dK^*}_{|EV_s = \overline{V}} < 0$.

Q.E.D.

Corporate scandals since 2002 have raised concerns about board independence and directors' "fat cat pay". While the primary focus is on firms to strengthening board independence, it is of similar importance to design adequate compensation to qualified, competent, and reputable board members. In the past, it has been widely debated whether board independence and D&O insurance have a complementary or substitute relationship. The above result has shown that for a given level of board monitoring, the optimal D&O insurance coverage is a substitute for the board's incentive pay. In such a case, there are two effects for firms that choose the optimal trade-off of D&O insurance coverage and board's compensation. On one hand, it can reduce the fat cat pay criticism; on the other hand, the firm's corporate governance image can be improved.

4. Model Extensions

In this section, we investigate the effects of several exogenous factors on the model's key variables, including D&O insurance premium rate, litigation risk, and information cost. We will discuss how these exogenous variables relate to corporate governance.

4.1 D&O Insurance Premium Rate

As with many lines of business in property-liability insurance, the D&O insurance marketplace shows an underwriting cycle (Fier et al., 2009). In the hard market, insurer capacity is limited, the coverage is tight, and the premium rate is higher. Whether the higher premium rate (r) implies higher optimal board's compensation and insurance coverage is of interest.

Proposition 5: *A higher D&O insurance premium rate (r) implies higher optimal board's compensation.* $\frac{d\beta^*}{dr} > 0$. *However, a higher D&O insurance premium rate (r) leads to lower optimal D&O insurance coverage* $\frac{dK^*}{dr} < 0$.

Proof:

(a) We use the same approach in the proof of Proposition 2.

Differentiate (FOC_β) and (FOC_K) with respect to β^* 、 K^* and r ：

$$\frac{\partial^2 EV_s}{\partial \beta^2} d\beta^* + \frac{\partial^2 EV_s}{\partial \beta \partial K} dK^* + \frac{\partial^2 EV_s}{\partial \beta \partial r} dr = 0$$

$$\frac{\partial^2 EV_s}{\partial K \partial \beta} d\beta^* + \frac{\partial^2 EV_s}{\partial K^2} dK^* + \frac{\partial^2 EV_s}{\partial K \partial r} dr = 0$$

Rearranging the terms yields the following matrix:

$$\begin{bmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{bmatrix} \begin{bmatrix} \frac{d\beta^*}{dr} \\ \frac{dK^*}{dr} \end{bmatrix} = \begin{bmatrix} \frac{\partial^2 EV_s}{\partial \beta \partial r} \\ \frac{\partial^2 EV_s}{\partial K \partial r} \end{bmatrix}$$

With the inverse matrix, we can obtain:

$$\frac{d\beta^*}{dr} = \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix}^{-1} \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta \partial r} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial r} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix}$$

$$\frac{dK^*}{dr} = \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial K} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K^2} \end{vmatrix}^{-1} \begin{vmatrix} \frac{\partial^2 EV_s}{\partial \beta^2} & \frac{\partial^2 EV_s}{\partial \beta \partial r} \\ \frac{\partial^2 EV_s}{\partial K \partial \beta} & \frac{\partial^2 EV_s}{\partial K \partial r} \end{vmatrix}$$

Given $\Delta = \frac{\partial^2 EV_s}{\partial \beta^2} \times \frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial \beta \partial K} \times \frac{\partial^2 EV_s}{\partial K \partial \beta} < 0$, we have

$$\frac{d\beta^*}{dr} = \frac{1}{\Delta}\left(\frac{\partial^2 EV_s}{\partial \beta \partial r} \times \frac{\partial^2 EV_s}{\partial K^2} - \frac{\partial^2 EV_s}{\partial \beta \partial K} \times \frac{\partial^2 EV_s}{\partial K \partial r}\right) \tag{16}$$

$$\frac{dK^*}{dr} = \frac{1}{\Delta}\left(\frac{\partial^2 EV_s}{\partial \beta^2} \times \frac{\partial^2 EV_s}{\partial K \partial r} - \frac{\partial^2 EV_s}{\partial \beta \partial r} \times \frac{\partial^2 EV_s}{\partial K \partial \beta}\right) \tag{17}$$

where

$$\frac{\partial^2 EV_s}{\partial K^2} < 0, \quad \frac{\partial^2 EV_s}{\partial \beta^2} < 0 \quad , \quad \frac{\partial^2 EV_s}{\partial K \partial \beta} = \frac{\partial^2 EV_s}{\partial \beta \partial K} > 0,$$

and $\frac{\partial^2 EV_s}{\partial \beta \partial r} = K^* > 0$, $\frac{\partial^2 EV_s}{\partial K \partial r} = -(1-\beta^*)(1-m^*) < 0$.

It is not readily apparent to determine the sign of $\frac{d\beta^*}{dr}$ and $\frac{dK^*}{dr}$ according to the above equations. However, we can gain insights from the two first-order conditions, (FOC_β) and (FOC_K). First, regarding the effect of the premium rate on optimal board compensation, we can observe directly from (FOC_β) that when r increases, holding other variables fixed, the firm needs to pay higher premiums, which lowers the firm value. Therefore, the firm will raise board compensation to balance the effect. In contrast, (FOC_K) indicates that when r increases, the firm will reduce insurance spending so as to balance the drop of the firm value. The insurance coverage will drop and indirectly cause an increase in board compensation, due to the substitute effect of K and β. Hence we can conclude that $\frac{d\beta^*}{dr} > 0$.

Similarly, regarding the effect of the premium rate on optimal insurance coverage, we can observe directly from (FOC_K) that when r increases, the firm will reduce insurance spending so as to balance the drop of the firm's value. Thus, insurance coverage will drop. However, (FOC_β) suggests that when r increases, the firm will raise β which will lead to a decrease of K. Hence we can conclude that $\frac{dK^*}{dr} < 0$.

Q.E.D.

The foregoing analysis suggests the impact of a premium rate hike on the model's equilibrium. If the *D&O insurance premium rate* (r) increase, then (1) the optimal board compensation (β^*) will increase and (2) the optimal insurance coverage (K^*) will decrease. Its impact on the board's monitoring level (and subsequently the firm value), however, it is not readily apparent. When the optimal (β^*, K^*) are both interior, higher board compensation will increase monitoring efforts, and lower insurance coverage will reduce monitoring efforts. So an increase of the D&O insurance premium rate can lead to higher, lower, or unchanged monitoring efforts, depending on the firm's information transparency parameter. Generally, when the parameter is relatively small, the impact on (1) will be higher than (2). Therefore, an increase in the D&O insurance premium rate actually raises the board's monitoring level. Yet, when the parameter is relatively large, the impact on (1) will be higher than (2). A higher D&O insurance premium rate will have a negative impact on firm value.

In reality, when insurance companies accept D&O insurance applications, the premium rate may depend on the prospective insured firm's risk characteristics and corporate governance practices. Therefore, a more independent board not only has a direct influence on (β^*, K^*), but also has an indirect impact through a lower premium rate. If the premium rate is indeed an inverse function of board independence, i.e., $\frac{dr}{dI} < 0$, then equation (15) can be rewritten as

$$\frac{dm^*[\beta^*(r(I),I),K^*(r(I),I),I)]}{dI} = \frac{\partial m^*}{\partial I} + \frac{\partial m^*}{\partial \beta^*}\frac{d\beta^*}{dI} + \frac{\partial m^*}{\partial K^*}\frac{dK^*}{dI} + \Big(\underbrace{\frac{\partial m^*}{\partial \beta^*}\frac{d\beta^*}{dr}}_{(+)} + \underbrace{\frac{\partial m^*}{\partial K^*}\frac{dK^*}{dr}}_{(-)}\Big)\frac{dr}{dI}$$

The implications of the foregoing discussion are as follows. Even though higher board independence generally increases the monitoring efforts, as shown in Proposition 4, the indirect effect via the D&O premium rate can depend on the information transparency parameter. When it is relatively small, higher board independence leads to lower premium rates and subsequently lower monitoring. [The first $(+)$ dominates the second $(-)$.] In contrast, if the information transparency parameter is relatively large, higher board independence leads to lower premium rates and subsequently higher monitoring. [The second $(-)$ dominates the first $(+)$.] This generates a subtle implication of the insurer's D&O pricing strategy. Only if the firm's information transparency parameter is relatively large can the rate deduction reflecting higher board independence enhance the board's oversight function.

4.2 Litigation Risk

In the corporate world, the legal environments and lawsuit cultures are not created equal. How does higher litigation risk, represented as q in our model, affect the optimal board's compensation and insurance coverage, and subsequently the monitoring efforts? Proposition 6 analyzes the effects from the variations in the litigation risk.

Proposition 6: *There exists a cut-off value* $\hat{D}$*, where* $\hat{D} > K^*$*. When* $D < \hat{D}$*, higher litigation risk* (q) *will lead to a lower optimal monitoring level; only when* D *is large enough will the higher litigation risk* (q) *have the potential to increase the monitoring level.*

Proof:

This part of the discussion is based on the interior solution (β^*, K^*) at equilibrium, so both (FOC_β) and (FOC_K) are binding, From equation (8) we learn

$$\frac{dm^*(\beta^*(q), K^*(q), q)}{dq} = \frac{\partial m^*}{\partial q} + \frac{\partial m^*}{\partial \beta^*}\frac{d\beta^*}{dq} + \frac{\partial m^*}{\partial K^*}\frac{dK^*}{dq}.$$

The litigation risk q affects monitoring efforts through three channels: direct effects, indirect effects through β, and indirect effects through K. Holding other factors fixed, $\frac{\partial m^*}{\partial q} = c^{-1}e^{\lambda K^*}\{[I\beta^* + (1-I)\alpha](-pD) + p(D-K^*)\}$. Therefore, there exists a cut-off value $\hat{D} = [I(1-\beta^*) + (1-I)(1-\alpha)]^{-1}K^* > K^*$. When $D = \hat{D}$, $\frac{\partial m^*}{\partial q} = 0$; when $D > \hat{D}$, $\frac{\partial m^*}{\partial q} > 0$; and $D < \hat{D}$, $\frac{\partial m^*}{\partial q} < 0$.

From (FOC_β), if q increases, $V_H = (1-p)R + pqD$ will increase accordingly. Hence, the value of $(V_L - V_H)$ will drop. To offset the impact, β^* will decrease, which suggests $\frac{d\beta^*}{dq} < 0$. On the other hand, we learn from (FOC_K) that holding everything else fixed, an increase in q will lead to a decrease in K^*, suggesting

$\frac{\partial K^*}{\partial q} < 0$.

The foregoing analysis shows that higher litigation risk leads to lower oversight. Only if $D > \hat{D}$, does the oversight have the potential to increase. Moreover, when D is sufficiently large, the direct effect could surpass the indirect effect, leading to an increased level of board oversight.

Q.E.D.

The result of Proposition 6 is intuitive. The direct effect of litigation risk on the board's oversight will turn positive only if liability damages D is larger than the cut-off value $\hat{D}$. Furthermore, if it is so large that the out-of-pocket liability payment, $(D - K^*)$, becomes significant, the positive direct effect can surpass the negative indirect effect, leading to positive effects of litigation risk on the board's oversight. Otherwise, from the board's perspective, if the out-of-pocket liability expenses are minimal or zero, the higher litigation risk has little direct impact. It will only reduce firm value and subsequently the board's incentive to monitor as their equity interest in the firm decreases.

In addition, our results are consistent with those of Laux (2010), whose model predicts that for firms in which board oversight is difficult and costly, a stricter legal environment for directors leads to a lower level of board oversight. Considering the situation when the direct effect is positive, we can observe from the partial derivative equation that a higher monitoring cost parameter will lead to a smaller positive effect, thereby lowering the likelihood that the positive direct effects surpass negative indirect effects. Hence, with a higher monitoring cost parameter, it is more likely in our model that higher litigation risk leads to a lower level of board oversight.

4.3 Information Cost

As indicated by Duchin et al. (2010), information plays a significant role in assessing a board's effectiveness. Our model can be extended to incorporate the role of information in a board's monitoring and its impact on the firm value.

Under the optimal contract $Z(\beta^*, K^*)$, we know $E[V(\beta^*, K^*)] = m^*(\beta^*, K^*)(V_L - V_H) + V_H$. If there exist two different cost structures, given the *optimal D&O insurance coverage* K^*, due to the differences in the level of acquiring information, high cost c_1 and low cost c_2, so

$$TC_1(K^*, m^*) = \frac{1}{2} c_1 e^{\lambda K^*} m^{*2} \quad \text{and} \quad TC_2(K^*, m^*) = \frac{1}{2} c_2 e^{\lambda K^*} m^{*2}$$

From eq.(6), it can be obtained

$$m_1^*(\beta^*, K^*) < m_2^*(\beta^*, K^*)$$

Thus, we can infer

$$E[V_1(\beta^*, K^*)] < E[V_2(\beta^*, K^*)]$$

This result corresponds to the recent empirical findings by Duchin et al. (2010), who find that the effectiveness of outside directors depends on the cost of acquiring information about the firm.

5. Concluding Remarks

It is commonly believed that company board members' independence is crucial to achieve effectiveness of boards of directors as a corporate governance mechanism. Yet, empirical studies (Brickley, Coles and Terry, 1994; Yermack, 1996; Agrawal and Knoeber, 1996; Black and Bhagat, 2002) on board composition and firm performance have generated ambiguous results. Bhagat and Black (1998) suggest that directors' incentives, rather than mere independence, may be the more important determinant.

In addition to outside directors, companies may also use D&O liability insurance as an alternative monitoring mechanism. However, does that insurance strengthen or weaken the outside directors' incentives? This paper provides a new insight into the questions unanswered in the literature. We find the condition in which more D&O insurance coverage can increase (decrease) outside directors' monitoring efforts.

By endogenizing D&O insurance and incorporating D&O insurance coverage into a monitoring cost function, we find the condition for a voluntary D&O insurance purchase (positive K^*). In addition, we find the condition when the D&O insurance exhibits a substitute effect with optimal board compensation. The key lies in whether

D&O insurance reduces the marginal cost of monitoring or not. Specifically, when D&O insurance does not reduce the marginal cost of monitoring, higher board independence will lead to higher optimal monitoring efforts. In contrast, if D&O insurance reduces the marginal cost of monitoring, higher board independence will lead to lower optimal monitoring efforts.

When the information transparency parameter is higher than a cut-off point, there exists an interior solution for optimal insurance coverage. Under such a situation, Proposition 4 provides the proof for a substitute relationship between board compensation and D&O insurance coverage. Seeing the trade-off relationship, we suggest that shareholders seek an optimal combination of D&O insurance coverage and board compensation. This can reduce the public's fat cat pay concerns and improve the firm's corporate governance image.

We also provide several model extensions to discuss the effects of three exogenous variables: D&O insurance premium rate, litigation risk, and the information cost. An increase in the insurance premium rate will lead to higher board compensation and lower insurance coverage. The net effect on the monitoring level thus depends on the relative strength of these two counteracting forces. Higher information transparency can have a stronger effect on insurance coverage than on board compensation; hence, a premium rate hike will lead to lower monitoring level, and vice versa.

A similar argument can be made with the litigation risk variable. The direct effect of a higher litigation risk can have a positive influence on monitoring efforts, provided the out-of-pocket damages are high enough to surpass the indirect effects through board compensation and insurance coverage. The results are also consistent with those of Laux (2010), in the sense that a higher monitoring cost parameter can lead to a smaller positive effect, thereby lowering the likelihood that the direct effects overcome negative indirect effects.

Finally, as indicated in Duchin et al. (2010), the effectiveness of outside directors depends on the cost of acquiring information about the firm. Our model can be extended to incorporate the role of information in board monitoring and its impact on firm value. Consistent with the empirical findings in their work, we find that the higher monitoring cost parameter leads to lower monitoring efforts, and consequently lower shareholder value.

To summarize, our paper contributes to the corporate governance literature in several ways. First, we model and study two oversight mechanisms together and thus address the interactions of board independence and D&O insurance. Second, we characterize the importance of an information transparency parameter in determining the optimal D&O insurance coverage. Third, we enrich discussions on board independence and show that a high level of information transparency helps an independent board achieve a higher level of monitoring efforts.

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