Board Incentives and Board Independence in Dynamic Agency

Svetlana Katolnik, Sandra K. Kukec and Jens Robert Schöndube*

Leibniz Universität Hannover

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Abstract

Efficiency of the board structure is usually perceived as linked to a higher degree of monitoring. If monitoring improves performance measurement signals, on which a manager is compensated, it can be considered desirable from the manager's point of view. As a result, having a low degree of board independence (many insiders on the board) may incentivize the board to improve its monitoring technology. However, from a dynamic perspective board monitoring is not always desirable, since it can destroy the ex ante efficient trade-off between risk and incentives under the presence of renegotiation possibility. This provides predictions for an optimal board composition seen from a dynamic perspective.

Keywords: Corporate governance, Board composition, Inside directors, Board incentives

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*Leibniz Universität Hannover, Institute of Managerial Accounting, Königsworther Platz 1, D-30167 Hannover. Electronic addresses: katolnik@controlling.uni-hannover.de, kukec@controlling.uni-hannover.de, schoendube@controlling.uni-hannover.de.

1 Introduction

High profile scandals, like Enron and WorldCom, were responsible for the forming of new corporate governance landscape. The most significant effect of the Sarbanes-Oxley Act of 2002 on the firm's corporate governance was the increased oversight role of the independent directors. Oversight is mostly considered beneficial because it is employed to ensure that the executives do not pursue their myopic interests, but manage the company in the best interest of the shareholders. But is this always the case? Even though high monitoring results in revealing the manager's misbehavior and compensating the manager more fairly in relation to his performance, the question remains what kind of action is incentivized from the manager by this high level of monitoring? For example, Fayele, Hoitash, and Hoitash (2013) show that the most favorable conditions for innovation occurred under a lower level of monitoring. Therefore, incentivizing the manager in a wrong way is an important negative side effect of extensive monitoring. Furthermore, independent directors are usually the ones assumed to be interested in implementing a high monitoring technology. But, wouldn't managers who exerted high effort welcome higher monitoring if it were to compensate them fairly for their work? If monitoring ex post means higher compensation to the manager for high effort then this monitoring wouldn't be desirable from the independent director's perspective. Our paper questions the usually accepted beliefs that monitoring is always beneficial and that the independent board members are more inclined than the dependent directors to exert high monitoring effort.

In this paper we focus on the implications of the board independence on the board's and managers' incentives, and, consequently, regard the welfare effects of such boards. We analyze a dynamic setting, where the board's tasks of compensating, advising and monitoring are intertwined, and show that the optimal level of board independence depends on whether the players can or cannot commit not to renegotiate the contract. We provide predictions for an optimal board composition from a dynamic perspective and show that a low level of board independence is desirable when there is no option of renegotiation. Given the renegotiation option, higher board independence becomes more desirable, because an independent board can better channel the manager's incentives in both periods and consequently increase the overall surplus of the shareholders and managers.

The relationship between the board of directors and managers is dynamic, in the sense that it lasts through several periods[1] and is prone to be influenced by new

[1] Demski and Sappington (1999) state: "Executive compensation contracts are typically multi-period arrangements where the executive is responsible for taking multiple actions at different points in time, and where these actions are also captured by performance measures at different points in time". For these reasons we consider long term contracts, eve though our setting could also be applied to short term contracts.

information during this time span. Consider a high level manager that is hired to work in a company on a long term project. The firm's final outcome is only observable at a later date and is therefore not contractible. At the end of each year the financial accounting produces a report, which is an indicator of the firm's true profit and which is determined by the manager's effort. It is easily seen, in such a multi-period setting that due to the misalignment of interests, either the firm's shareholders or the managers will not be satisfied with the initial contract, after some information about the manager has been made available. In other words, it will be costly for them to commit to the contract ex post. This new information leaves room for renegotiation.

Since the shareholders cannot directly control the manager, they hire a board of directors to perform the following three tasks: compensating the agent, advising the agent and monitoring the agent. Conventional wisdom says that monitoring the agent is necessary in order to make sure that the manager works hard and that better monitoring technology is always preferable from the owners' perspective, because it increases the shareholder's profit. Since the shareholders delegate the task of monitoring the managers to the board of directors, the board is then considered more efficient if it implements a better monitoring technology. We incorporate all three tasks of the board into our model. Through monitoring, the board increases the precision of the performance signal and through advising the senior management the board, on the one hand, improves the performance signal and, on the other hand, improves the firm's terminal value. We show that high monitoring and advising technology is desirable in a setting where contracting only occurs at the beginning and all players can commit to this contract. Surprisingly, when the commitment is not possible, then lower monitoring technology is often the preferable option, because such technology is not only able to lower the second period incentives, which may be too high under a renegotiation option, but also to increase the joint surplus of the owners and managers.

Our model extends the results of the one period model from Drymiotes (2007) in two aspects. Firstly, in addition to following the idea that the board's activity has a risk effect (decreases the variance of the monitored signal) we also assume that the board's activity has a productivity measurement effect and increases the mean of the performance measure, as well as, the mean of the firm's outcome. Secondly, following the dynamic approach, we consider the influence of renegotiation on optimal contracting and board composition. Drymiotes (2007) regards the insiders on the board of directors as a commitment device that the board exerts high effort ex post. The reason for this is that not only do monitoring and advising increase the performance measure and thus the manager's compensation, but they also decrease the firm's expected value. Hence, a sufficient number of insiders on the board is needed to enable efficient monitoring. We show that in a dynamic setting, where renegotiation is a viable option, the insiders on the board may become wasteful, because they are now more motivated to increase the manager's compensation and thus induce an inefficiently high level of monitoring, which distorts the manager's incentives in both periods and in effect reduces the joint overall surplus of the shareholders and managers.

The trend in board structure is that the proportion of outside directors on the board has steadily increased over time (Linck, Netter, and Yang (2008), Lehn, Patro, and Zhao (2009)). Our paper indicates that the lack of commitment not to renegotiate a long term contract, or the prevalence of short term contracts, drives the optimal board structure towards a more independent board.[2] One of the examples of increasing board independence is the case of General Electric, which increased the number of its independent board members from only 6 in 1998 to 11 in 2006, while the board size of 15 remained unchanged. Our results are also in line with the results from Laux (2008), who predicts a trend towards greater board independence, even though his focus is addressed towards CEO turnover, severance packages and stock option grants.

Within the corporate governance research, one stream of literature stresses the importance of the board of directors' structure. The composition of the members and how the board is formed influences its actions substantially.[3] Governance practices allow the monitored entity (manager) to become a part of the governance mechanism, like CEOs sitting on the board or even acting as chairmen of the board. Directors on the board, who collectively perform the board's tasks, can be of two types: independent members (outsiders) and management-dependent members (insiders) (Drymiotes (2007), Drymiotes (2011), Harris and Raviv (2008), Hermalin (2005), and Raheja (2005)). We consider the inside directors as the ones that are in any way dependent on the firm's managers.

Interestingly, and in line with our results, there is mixed evidence about the usefulness of the insiders on the board.[4] On the one hand, there is the notion that only a fully independent board can perform the monitoring role in the best

[2]Armstrong, Guay, and Weber (2010) state the following explanations for such a trend in the board structure: it's a result of a regulatory pressure or regulatory actions; other economic forces removed frictions that prevented shareholders from setting the desired structure of the board; the transparency has declined over time and there was a need for outside directors to improve monitoring and reduce information asymmetry.

[3]For detailed reviews and basic model presentations of corporate governance and boards of directors see: Adams, Hermalin, and Weisbach (2010), Shleifer and Vishny (1997), Bushman and Smith (2001), Hermalin and Weisbach (2003), Denis and McConnell (2003), Armstrong, Guay, and Weber (2010), Tirole (2001) and Gillan (2006)

[4]The empirical literature mostly assumes that the board's size or composition are a good proxy for the degree of the board's independence (Boone, Field, Karpoff, and Raheja (2007), Bushman, Chen, Engel, and Smith (2004), Coles, Daniel, and Naveen (2008) and Linck, Netter, and Yang (2008)).

interest of the owners, since the insiders on the board are only a hindrance to the board's monitoring function (Kumar and Sivaramakrishnan (2008), Linck, Netter, and Yang (2008) and Yermack (2004)). On the other hand, less independent boards with insiders on the board can be preferable since CEOs are more willing to disclose private information to them (Adams and Ferreira, 2007), can help evaluate investment opportunities better (Raheja, 2005), make it less costly for firms to extract private information from the CEO (Laux, 2008) or ensure the CEO's alignment with the interests of the firm (Almazan and Suarez, 2003).[5]

Additionally, our paper builds on the work of Hermalin and Weisbach (1998) who simultaneously look at the endogenous decisions of board structure and monitoring action. We, on the other hand, abstract from the questions about CEO replacement and focus on the contracting perspective, as well as, consider the influence of renegotiation. They model a bargaining game between the board and the manager where the shareholders play no active role in the model. In contrast, our model holds for both instances of endogenous board structure, namely, endogenously chosen boards by the shareholders or boards as a product of a bargaining process between the shareholders and the CEOs.

Our model allows for contract renegotiation after the first period effort has been exerted, and after the first period performance measure has been observed. We follow the renegotiation literature and models from Fudenberg and Tirole (1990) and Gigler and Hemmer (2004). Furthermore, our model is also influenced by the work of Christensen, Feltham, and Şabac (2005) and Schöndube-Pirchegger and Schöndube (2012) who, the same as we, consider two-period LEN models under renegotiation. The general idea of the renegotiation models is that after the agent has taken his action, the principal proposes another take-it-or-leave-it contract. The possibility to renegotiate destroys the ex ante efficient trade-off between risk and incentives.[6] To the best of our knowledge the only paper that deals with renegotiation in the corporate governance environment is the Laux (2008) paper.[7] Contrary to our model, Laux (2008) focuses on the agent's dismissal and severance pay, and shows that board dependence can be a substitute for commitment.

To show our results we use a two-period principal-agent framework, where the shareholder's role in contracting (incentivizing), monitoring and advising the agent is delegated to the board of directors. Firstly, we look at the situation where the board and the manager can commit to a two period contract. In this case, the optimal

[5]Klein (1998) finds positive association between the firm's performance and percentage of insiders on the board, while Bhagat and Black (2002) find no evidence that firms with more independent boards are more profitable.

[6]For other papers that consider lack of commitment after the agent's effort has been exerted please consult Demski and Frimor (1999) and Christensen, Demski, and Frimor (2002).

[7]Laux (2008) also follows the models of Hermalin (2005) and Hermalin and Weisbach (1998).

incentives can only be achieved if the board implements an efficient monitoring technology and a sufficiently dependent board is necessary for that. This is because monitoring increases the performance measure and manager's compensation, which consequently decreases the expected value to the shareholders. Secondly, we turn to a scenario closer to the real life contract where a possibility of contract renegotiation exists after some new information has been observed. Under this scenario a sufficiently independent board acts potentially as a commitment device to lower the second period incentives and to increase the joint surplus of the owners and managers. Less monitoring could now be beneficial, which is only feasible with a sufficiently independent board that is ex post not interested in monitoring. Consequently, our paper shows that board monitoring and insiders on the board cannot strictly be considered as good or bad, as sometimes regarded in the literature. Having an independent board that implements an inefficient monitoring technology might be the optimal choice if the renegotiation option influences a misbalance and increases the second period incentives. Otherwise, the insiders on the board are beneficial and increase the joint surplus.

The rest of the paper is organized as follows. Section 2 presents the basic model. Section 3 discusses the main findings of the paper and Section 4 concludes the paper.

2 The Model

We consider a two-period Linear-Exponential-Normal (LEN) agency framework. There are three types of players: the firm's owners, F, the firm's management, M, and the board of directors, B. The owners' role in contracting, monitoring and advising the management is delegated to the board of directors. Board members may be outside directors that represent the owners' interests, and inside directors who are managers of the firm.[8] The firm's terminal value,

$$x = a_1 + a_2 + \lambda\, b + \varepsilon_x, \tag{1}$$

is an additive function of the manager's unobservable effort, $a_t \in \mathbb{R}$, in the two periods, $t = 1, 2$, the board's monitoring action $b \in \{b^L, b^H\}$, and a noise component, ε_x, that follows a zero-mean normal distribution, $\varepsilon_x \sim \mathcal{N}(0,\, \sigma_x^2)$. The parameter $\lambda \geq 0$ reflects the marginal effect on profit x arising from an increase in the level b of board monitoring. For simplicity, b can be either high or low, $b^H > b^L$, such that b^L can be normalized to zero without loss of generality. We assume that x is non-contractible information since it is realized too late to be used for contracting.

[8] For simplicity, we will use the wording "manager" and refer to it as a group of managers.

Instead, to motivate the manager to take the desired actions, an incentive contract can be based on the publicly observable performance measure y_t,

$$y_t = \gamma_t\, a_t + b + \varepsilon_t, \qquad t = 1, 2, \tag{2}$$

which is a noisy signal of the manager's effort, a_t, and of the board's monitoring action, b. The constant measures the sensitivity of the performance signal y_t to effort a_t. Thus, γ_t determines the extent of the agency problem with respect to a_t: being compensated on the basis of y_t, the manager does not perfectly internalize the effect of his efforts on firm value x. We consider a linear relationship, $y_t'(a_t) = \gamma_t$, and focus on short-term effort effects, $y_2'(a_1) = 0$. That is, γ_t can be interpreted as a measurement bias that is based on the firm's accounting practices in different periods of time. The additive noise ε_t is a correlated random variable with a zero-mean normal distribution, $\varepsilon_t \sim \mathcal{N}(0, (1-b)\,\sigma^2)$ and $Cov(\varepsilon_1, \varepsilon_2) = \rho\,(1-b)\,\sigma^2$, where $\rho \in [-1, 1]$. To ensure that the noise terms are well-defined, i.e. $Var(\varepsilon_t) > 0$, we require that $b^H \in (0, 1)$. In line with the related literature, we assume that the distribution of ε_t is independent of γ_t and a_t. The error terms ε_x and ε_t are supposed to be stochastically independent.

We model the board's monitoring technology similar to Drymiotes (2007): a high level b^H of monitoring raises overall productivity, but also increases the performance measures in both periods and enhances their information content regarding the manager's effort. Thus, the board's action captures two dimensions of performance (measurement) improvement: advising the manager (increasing the mean of x and y_t) and monitoring the manager (reducing the variance of y_t). For example, the board may improve the existing monitoring techniques, increase the accuracy of the auditing technology, or implement new accounting-reporting processes. This technology specification incorporates choices or decisions that impact the firm's performance-reporting processes, used to evaluate and compensate the manager, but also the level of the firm's returns. For concreteness, while the manager's short-term action has a *productivity* and a *compensation* effect, the board's long-term action, in addition, has a *compensation risk* effect. To simplify the analysis, we assume that the board does not suffer any costs to its work. However, there will be a moral hazard problem with respect to b in our model, even if it is a costless activity, since the firm is not able to commit to a specific monitoring technology ex ante.[9] The manager's personal disutility from performing $\boldsymbol{a} = (a_1, a_2)'$ is $C(\boldsymbol{a}) = \boldsymbol{a}'\boldsymbol{a}/2$.

The compensation of the manager is determined by a long-term linear incentive contract w. This contract is a take-it-or-leave-it offer by the board that covers both periods and is potentially subject to renegotiation,

$$w = f + v_1\, y_1 + v_2\, y_2, \tag{3}$$

[9] Intuitively, with costly board monitoring, the marginal benefit of performing the efficient level b^H of monitoring technology declines. In equilibrium, this will generally lead to less monitoring, irrespective of the composition of the board.

with f as the fixed payment and v_t as the variable incentive coefficient such that the manager's bonus payment is linear in his period-t performance y_t. The manager is risk-averse with exponential utility $U^M = -\mathrm{e}^{-r\,(w-C(\boldsymbol{a}))}$, where $r > 0$ is the Arrow-Pratt measure of risk aversion. Thus, inverting the expected utility in its certainty equivalent, the manager's preferences can be represented by

$$CE[U^M] = E[w] - C(\boldsymbol{a}) - \frac{r}{2}\,Var(w). \tag{4}$$

The certainty equivalent consists of the expected wage payment, less the costs of effort and a risk premium, with the manager's wage risk given by $Var(w) = (1-b)\,(v_1^2 + v_2^2 + 2\,\rho\,v_1\,v_2)\,\sigma^2$ under the linear contract. As usual, the firm is assumed to be risk neutral; her expected utility increases in expected firm value and decreases in the manager's expected compensation,

$$E[U^F] = E[x] - E[w]. \tag{5}$$

Without loss of generality, the manager's reservation wage is normalized to zero. The firm will abstain from running the business if her expected utility is negative. However, as the board negotiates the contract, we have to impose a participation constraint for the firm as well, $E[U^F] \geq 0$. For simplicity, there is no discounting.

The collective preferences of the board can be modeled by a convex combination of the manager's and the firm's objective functions,

$$\delta\,CE[U^M] + (1-\delta)\,E[U^F], \tag{6}$$

with $\delta \in [0,1]$ as a measure of the board's independence.[10] According to the US regulatory requirements, δ is supposed to be publicly observable.[11] The bargaining process is not modeled explicitly, (6) only assumes that either insiders or outsiders may control the board. We formalize the idea that the board has no personal benefits or costs. Rather, the board's wage contract and the decision to monitor depend on the preferences of its members. These preferences are combined in such a way that it is possible to comprehend the board's actions in terms of a single objective function. Thereby, $\delta = 0$ captures the special case of a perfectly independent board (outsider-controlled board), while $\delta = 1$ indicates a fully dependent board (insider-controlled board). Since board structure changes only at rare intervals, we assume that δ is not revised in the second period.

[10]The board's objective function is defined as in Drymiotes (2007). A related approach that explicitly includes the costs related to board monitoring has been used by Hermalin and Weisbach (1998).

[11]Regulation S-K Item 470(a) states that firms must disclose whether each director is independent or not.

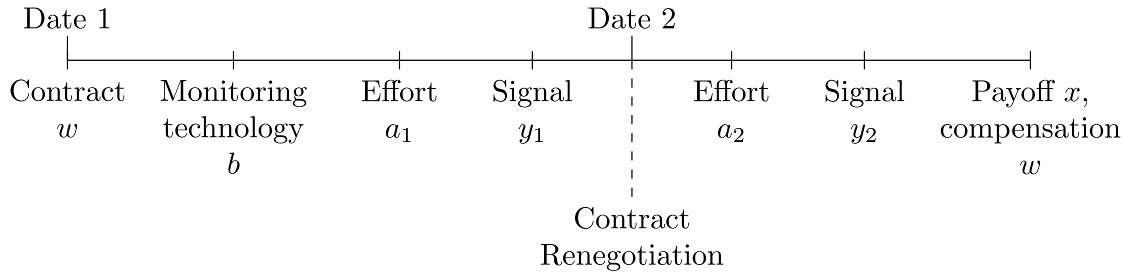

Figure 1: Model Timeline

The aggregate expected surplus of the agency, denoted $E[Z]$, is simply the difference of the expected firm profits over the manager's effort costs and his risk premium,

$$E[Z] = CE[U^M] + E[U^F] = E[x] - C(\boldsymbol{a}) - \frac{r}{2} Var(w). \tag{7}$$

It can be considered as an efficiency measure in our model. However, the board's preferences do not coincide with the firm's objective function. Hence, in contrast to the standard agency problem, $E[Z]$ cannot be regarded as a measure for the firm's expected wealth in our model. The timing of the model is shown in Figure 1.

3 Equilibrium Analysis

This section describes the board's optimal contract offer and the firm's double-sided moral hazard problem on the board's and the manager's side. Recall that the board has to decide on its monitoring technology before the manager's efforts have been taken. Hence, its optimal action depends on the anticipated effort strategy of the manager. The manager's effort incentives are determined by the wage contract that is offered by the board. This contract is based on the realization of the performance signals and, therefore, is also a function of the board's monitoring technology, $w(b, y_1, y_2)$. Since the board's action is unobservable, the manager must consider what the board would do after the contract had been signed. On the other hand, the board must account for the manager's optimal efforts when proposing a contract to him, and for the constraints on the firm and on the manager. We analyze the interaction of these incentives and characterize equilibria in subgame perfect strategies.

3.1 Manager's Effort Incentives

For a given incentive scheme w, the manager chooses a vector $\boldsymbol{a}$ of efforts to maximize his certainty equivalent $CE[U^M]$ in (4). The corresponding first-order incentive compatibility constraint can be written as

$$a_t = \gamma_t \, v_t, \qquad t = 1, 2. \tag{8}$$

For evaluating the efficiency of the equilibrium actions, it is constructive to briefly discuss the first-best solution to the manager's problem. Here, the essential implication is that the joint expected surplus $E[Z]$ of the firm and the manager in (7) is maximized. Taking the first-order condition with respect to $\boldsymbol{a}$ yields

$$a^{FB} = 1, \tag{9}$$

where the superscript FB stands for first best. Intuitively, the welfare-optimal effort is equal to the *firm's* marginal benefit of effort. Against this benchmark, efficiency can be achieved under second-best effort when $v_t = 1/\gamma_t$, hence when the incentive weight v_t exactly offsets the difference in the marginal benefits of effort between the firm and the manager.

3.2 Board's Monitoring Technology

We can now go back to computing the incentives of the board. For a given wage contract w, and based on the manager's optimal effort strategy $\boldsymbol{a}$, the board prefers to perform $b^* = b^H$ instead of performing $b^* = b^L = 0$ (with the asterisk used throughout to denote equilibrium values), if $\delta \, CE[U^M(b^H)] + (1 - \delta) \, E[U^F(b^H)] \geq \delta \, CE[U^M(0)] + (1 - \delta) \, E[U^F(0)]$. We obtain the following result.

Proposition 1 *(i) For $v_1 + v_2 \geq \lambda$, an effective monitoring technology will only be implemented in equilibrium, $b^* = b^H$, if the fraction of inside board members is sufficiently large, that is, if $\delta \geq \hat{\delta} \in [0, 1]$, with*

$$\hat{\delta} = \frac{2 \, (v_1 + v_2 - \lambda)}{4 \, (v_1 + v_2) - 2 \, \lambda + r \, (v_1^2 + v_2^2 + 2 \, \rho \, v_1 \, v_2) \, \sigma^2}. \tag{10}$$

(ii) For $v_1 + v_2 < \lambda$, $b^* = b^H$ will always be implemented.

(i) It is evident from (3) that for $v_1 + v_2 \geq \lambda$, a sufficiently independent board may have no incentives to take a positive action after the contract has been accepted by the manager. The basic rationale stems from the fact that advising by the board increases the performance measures and thus also the compensation to be paid to the manager, but has only moderate effects on the firm value (low λ). The manager appreciates this compensation effect: the advise from the board increases his expected wage by $b^H \, (v_1 + v_2)$, without interfering with his actions; so the advisory expertise of the board is complementary to that of the manager. Because the manager is risk-averse, he also favors monitoring by the board. Intuitively, monitoring improves the risk-return profile of the performance signals and thus, reduces the manager's disutility from risk-taking by $r\, b^H\,(v_1^2 + v_2^2 + 2\,\rho\, v_1\, v_2)\,\sigma^2/2$. Therefore, if compensation is the only effect present, $\lambda = 0$ and $r \to 0$ (and/or $\sigma \to 0$), then the high action $b = b^H$ will only be enforced in equilibrium if the majority of board members are insiders, $\hat{\hat{\delta}} \to 1/2$. In contrast, if the risk premium becomes infinitely large, $r \to \infty$ (and/or $\sigma \to \infty$), then the critical fraction of inside directors tends to zero, $\hat{\hat{\delta}} \to 0$. Hence, the efficient monitoring mechanism will always be implemented. Similarly, a strongly positive correlation ρ of the error terms exposes the manager to greater compensation risk, implying that $\hat{\hat{\delta}}$ decreases in ρ. Consequently, the more important is the variance effect on the manager's wage (thus, the larger are r, ρ, σ), the more likely the board will play an active role in monitoring and advising the management. (ii) For $v_1 + v_2 < \lambda$, board monitoring has a relatively large impact on firm value, so it is favored by both insiders and outsiders. Therefore, the efficient action $b = b^H$ will always be implemented.

3.3 Compensation Contracts and Renegotiation

3.3.1 Full Commitment

Having determined the manager's and the board's incentives, we can now solve the outcome of the bargaining stage. We begin the analysis by exploring a setting in which the board and the manager can precommit to fulfilling a two-period contract that is not renegotiated or modified subsequently. The manager's compensation is determined by maximizing the board's objective function, taking into account the manager's optimal efforts given his compensation (incentive compatibility constraint IC_t^M), and ensuring that the contract can be enforced (individual rationality constraints IR^F and IR^M). The equilibrium of the full commitment game then consists of the board's contract offer that determines the optimal fixed and variable payments, $w^* = (f^*, v_1^*, v_2^*)$, such that the firm and the manager accept the contract and conjectured and equilibrium actions coincide. Formally, for a given level b of monitoring technology, the board faces the following optimization program:

$$\begin{aligned}
&\max_{f,v_1,v_2} \delta\, CE[U^M(b)] + (1-\delta)\, E[U^F(b)] \\
&\qquad = (1-\delta)\, E[x] + (2\,\delta - 1)\,\big(f + v_1\, E[y_1|b] + v_2\, E[y_2|b]\big) \\
&\qquad - \delta\,\Big(C(\boldsymbol{a}) + \frac{r}{2}\, Var(w|b)\Big) \qquad (11)
\end{aligned}$$

subject to

$$CE[U^M(b)] \geq 0, \tag{IR^M}$$

$$E[U^F(b)] \geq 0, \tag{IR^F}$$

$$\arg\max_{a_t'} CE[U^M(b)] = \gamma_t\, v_t, \qquad t = 1, 2. \tag{IC_t^M}$$

It follows from (11) that for $\delta > 1/2$, the board's objective function is strictly increasing in the fixed payment f, and weakly decreasing for $\delta \leq 1/2$. Therefore, if the board is constituted with a majority of insiders, $\delta > 1/2$, it will optimally set f as high as possible, taking into account the firm's zero-expected-profit condition, $E[U^{F*}] = 0$. In contrast, a majority-independent board, $\delta \leq 1/2$, will set f at its lowest possible level, provided that the manager's participation constraint is binding, $CE[U^{M*}] = 0$.[12] Hence, for any value of b, the firm's and the manager's payoff structures are governed by a majority-rule equilibrium in which the board will either maximize the manager's certainty equivalent income, $\max_{v_1,v_2} \delta\, CE[U^M(b)] = \delta\, E[Z(b)]$ for $\delta > 1/2$, or the firm's expected profit, $\max_{v_1,v_2}(1-\delta)E[U^F(b)] = (1-\delta)\, E[Z(b)]$ for $\delta \leq 1/2$.[13] Consequently, for given optimal effort $a_t^*(v_t)$ and optimal fixed payment f^*, this equilibrium is characterized by an incentive structure that is defined in a welfare-maximizing way. We obtain the following proposition.

Proposition 2 *The board's optimal bonus weights $v_1^*(b)$ and $v_2^*(b)$ always maximize the expected total surplus $E[Z(b)]$. Under full commitment, the manager is compensated according to*

$$v_t^*(b) = \frac{\gamma_t - r\,(1-b)\,\rho\, v_\tau^*(b)\,\sigma^2}{\gamma_t^2 + r\,(1-b)\,\sigma^2}, \qquad t, \tau = 1, 2 \text{ and } \tau \neq t. \tag{12}$$

It can be directly seen from (12) that $v_1^*(b) + v_2^*(b) \leq 1/\gamma_1 + 1/\gamma_2$. Since the manager's optimal effort linearly increases with $v_t^*(b)$, we can establish the form of the inefficiencies that emerge under this compensation scheme.

Corollary 1 *In the full commitment solution, the manager's aggregate efforts are always (weakly) smaller than the first best efforts.*

Even though an explicit solution for $v_t^*(b)$ can easily be obtained (see the Appendix), we use the formulation in (12) because it allows a more meaningful interpretation of

[12] For $\delta = 1/2$, the board is indifferent with respect to the level of f, so without loss of generality we assume that the board resolves this indifference in favor of the firm.

[13] The case of $\delta > 1/2$ applies particularly to unlisted and family-controlled companies, since NYSE (303A0.1) and NASDAQ (Rule 5605) both require listed companies to have a majority of independent directors on the board.

the results. Intuitively, if the board and the manager can commit not to renegotiate the initial contract, the board will use the ex ante available information to motivate the manager to work hard and thus, will optimally provide symmetric incentives for both periods. These incentives, and with it also the optimal contract, depend on the board's monitoring technology b, and on the resulting implications for compensation and risk taking. Specifically, the two bonus rates are substitutes if $\rho > 0$, and complements if $\rho < 0$. The main intuition is that with positively correlated noise, a higher v_t will increase the manger's marginal disutility from risk taking; and thus, it is optimal to decrease v_τ. With negative correlation, there is a diversification effect on the manager's wage risk, and v_t and v_τ are positively related. Thereby, note that the two bonus rates are independent of λ, which determines the effect of board monitoring on firm productivity. This is because λ has no impact on the performance measure y_t and thus, is not effective in creating incentives for the manager.

If $\rho \geq 0$, then the manager's risk aversion always leads to a strict underinvestment in effort in both periods: with an extremely risk averse manager, $r \to \infty$ (and/or extremely large risk $\sigma \to \infty$), the equilibrium incentive weights tend to zero, $v_1^* = v_2^* \to 0$, and with it also the manager's optimal efforts, $e_1^* = e_2^* \to 0$. In contrast, if the manager's choice behavior tends to a risk neutral choice, $r \to 0$ (and/or $\sigma \to 0$), then the manager's optimal efforts converge to the socially optimal level, $v_t^* \to 1/\gamma_t$ for $t = 1, 2$, and hence, $e_1^* = e_2^* \to e^{FB}$. Intuitively, the same result arises in case the board provides perfect compensation insurance such that the variability in performance tends to zero, $b^* = b^H \to 1$ and thus $Var(w) \to 0$.

To hedge the wage risk efficiently, negative incentives may form part of an optimal compensation structure, $\exists! v_t^*(b) : v_t^*(b) < 0,\ t = 1, 2$. Implementing a negative bonus rate is optimal when the costs of exposing the manager to high performance risk outweigh the benefits of inducing value-increasing effort.[14] This requires performance measures to be positively correlated, $\rho > 0$, as only in this case a mixture of positive and negative incentive weights leads to a negative covariance error. A negative bonus weight v_t is therefore more likely to be imposed when the accounting measure y_t is relatively insensitive to effort a_t (small $\gamma_t/\gamma_\tau < 1$), and when the performance risk is large (large r, $\rho > 0$, σ, small b). Thus, as the board's action b can limit the manager's wage risk, it can make it worthwhile to induce positive effort by the manager in both periods.

If $\rho < 0$, then the optimal compensation may be increased to such a degree that the manager has incentives to overinvest in effort, $\exists! v_t^*(b) : v_t^*(b) \geq 1/\gamma_t$ for $t = 1, 2$. This overinvestment is more likely to occur when the performance measure y_t is relatively sensitive to effort (large $\gamma_t/\gamma_\tau > 1$), and when the diversification effect on the manager's wage risk is large (large r, σ, small b, $\rho < 0$). However, a large

[14] Negative effort can be used as a shorthand for any costly actions aimed at stealing or hiding efficiency (see Gibbons and Murphy (1992), Christensen, Feltham, and Şabac (2005)).

$\gamma_t/\gamma_\tau > 1$ implies that the optimal period-τ incentives will be low, $v^*_\tau(b) < 1/\gamma_\tau$. Hence, unless correlation is perfectly negative, $\rho = -1$, and sensitivities do not differ, $\gamma_t = \gamma_\tau$, the manager's aggregate efforts will be lower than the first best, $a^*_1(b) + a^*_2(b) < 2$. This implies that also for $\rho < 0$, the high monitoring technology $b = b^H$ is desirable, not only when the manager underinvests in effort in both periods, but also when both over- and underinvestment prevail.

Our results are as expected: In the first-best solution, the board's advisory role is unimportant since it determines the wealth dispersion between the firm and the manager. However, as monitoring decreases the manager's compensation risk, it contributes to increasing the expected aggregate welfare, $E[Z(b^H)] > E[Z(0)]$. If the board is fully independent, $\delta = 0$, then, ex post, it is not interested in adequately compensating the manager for his effort and it uses its monitoring technology too lightly. This implies that from an allocation efficiency perspective, having a sufficient number of insiders on the board is optimal, $\delta^{FB} \geq \hat{\hat{\delta}}$. However, for the firm it is not necessarily optimal to increase board independence, regardless of the magnitude of the positive effects on incentives and firm value. It is only advantageous if $\delta \leq 1/2$, as the firm then obtains the full benefits from the agency, $CE[U^{M^*}(b)] = 0$. Otherwise, if $\delta > 1/2$, the manager reaps all the benefits himself, and thus the firm cannot earn positive expected profit, $E[U^{F^*}(b)] = 0$.

3.3.2 Limited Commitment

When the commitment possibility is withdrawn, the board can propose to revise the manager's compensation w after the first period performance information becomes available. We consider a situation in which the board and the manager can commit to the employment relationship for two periods, but cannot commit not to renegotiate the initial contract at the interim stage.[15] The new contract, w^R, with the superscript R denoting renegotiation, can change the fixed payment f and the second period incentive rate v_2, provided that the firm and the manager agree to it. Intuitively, since the trade-off between providing incentives and imposing risk is different after the uncertainty with respect to y_1 has been resolved, the contractually specified outcome may turn out to be inefficient. Specifically, for any realization of y_1, the board will propose a new take-it-or-leave-it offer whenever it increases either the firm's expected utility ($\delta \leq 1/2$) or the manager's certainty equivalent income ($\delta > 1/2$), without reducing the other party's benefits. The new contract implicitly depends on y_1, because the first period performance conveys information about the second period output risk if performance measures are correlated.

[15] We abstract from short-term contracting since the lack of commitment to a long-term relationship would allow the manager to adopt a take-the-money-and-run-strategy, and thus would render multi-period employment impossible (Christensen, Feltham, and Şabac (2003)).

Within the context of the agency model presented here, where contracting is complete and no restrictions regarding renegotiation are imposed, there is no loss of generality to limit analysis to renegotiation-proof contracts (see Fudenberg and Tirole (1990)). Consequently, we can abstract from the renegotiation game at the end of the first period and focus on contracts that are initially robust against renegotiation. For the original contract to be renegotiation-proof, it must condition on the first period outcome and thus, must consider how a non-renegotiation-proof contract would be renegotiated. Let $w^R = (f^R, v_1^R, v_2^R)$ denote the optimal renegotiation-proof contract chosen at date 1. The equilibrium of the renegotiation game then consists of the board's contract proposal, w^R, that explicitly incorporates the future information on y_1 such that the firm and the manager accept the contract and there is no enforceable renegotiation offer that is strictly preferred by the board (renegotiation proofness constraint RP). As before, all equilibrium expectations are required to be accurate; that is, the board's and the manager's optimal actions are rationally anticipated.

The reasoning of Proposition 2 also holds under limited commitment: the optimal fixed payment f^R and with it also the division of the surplus are decided by a majority rule. They ensure that the the firm's expected utility and the manager's certainty equivalent are non-negative to obtain their participation (IR^F and IR^M). Hence, for a given level of monitoring technology b, the board maximizes the expected total surplus, $E[Z(b)]$, as before, but now considering not only IC_t^M but also RP. In a two-period equilibrium with linear contracts, Christensen, Feltham, and Şabac (2003) show that every initial contract is renegotiation-proof only if the second period incentive rate is chosen sequentially optimal. Let v_2^R be the sequentially optimal incentive rate. Then, the board's optimization program can be represented as

$$\max_{v_1, v_2} E[Z(b)] = E[x] - C(\boldsymbol{a}) + \frac{r}{2} Var(w|b) \tag{13}$$

subject to

$$\arg\max_{a_t'} CE[U^M(b)] = \gamma_t \, v_t, \qquad t = 1, 2, \tag*{(IC_t^M)}$$

$$\arg\max_{v_2'} E[Z(b|y_1)] = v_2^R. \tag*{(RP)}$$

The objective function corresponds to the full commitment case. Defining the optimum by backward induction implies that in period 2, the variance of the manager's wage conditions on y_1, and thus reduces to $Var(w|b, y_1) = (1-b)\,(1-\rho^2)\, v_2^2\, \sigma^2$. In period 1, the optimal incentive rate is chosen in consideration of the aggregate risk premium, and thus is based on the optimal second period bonus weight. This yields the following proposition.

Proposition 3 *Under limited commitment, the optimal renegotiation-proof bonus weights are given by*

$$v_1^R(b) = \frac{\gamma_1 - r\,(1-b)\,\rho\, v_2^R(b)\,\sigma^2}{\gamma_1^2 + r\,(1-b)\,\sigma^2}, \tag{14}$$

$$v_2^R(b) = \frac{\gamma_2}{\gamma_2^2 + r\,(1-b)\,(1-\rho^2)\,\sigma^2}. \tag{15}$$

Now, the manager's second period compensation is partly explained by the first period results. Recall that the board has to assess the implications from changes in the bonus rate v_t for incentives and risk-taking. While in $t = 1$, these implications involve the perspective of both periods, in $t = 2$, only the current effects are considered. If the manager underinvests in effort (see Corollary 1), the marginal effect from a higher v_t on incentives will be positive. However, the possibility of ex post renegotiation does not change the marginal benefits of increasing v_t, because the reported performance y_t relies on the manager's short-term effort only. But when y_1 is informative about future performance, i.e. $\rho \neq 0$, then a higher v_2 will be reflected in two different compensation risk effects: the first effect is positive and implies that the renegotiation possibility allows the manager to benefit from a lower wage risk in the second period. This is because, given the history y_1, the posterior variance $Var(w|b, y_1)$ of the manager's wage now decreases in the squared correlation ρ^2, which appears in the denominator of (15). The second effect arises from the incentive to alter v_2 to decrease the riskiness of the aggregate risk premium by reducing the covariance error of the two performance measures. Under limited commitment, the board is forced to play sequentially optimal; thus, it ignores the covariance risk between y_1 and y_2 in the second period. Therefore, this effect is only considered in the full commitment setting and is captured in the numerator of (12). The sign of this second risk effect is negative if the two bonus rates create substitute incentives, $\rho > 0$, and positive in case of complement incentives, $\rho < 0$. A comparison of the Propositions 2 and 3 reveals how these two risk effects contribute to changing the manager's optimal incentives when renegotiation is possible. We obtain the following two cases, each of which will be discussed below.

Corollary 2 *Relative to the full commitment case, the optimal renegotiation-proof incentive scheme exhibits the following properties:*
(i) For $\rho > 0$, incentives are higher in the second period and lower in first period.
(ii) For $\rho < 0$, incentives are either higher in the second period, increasing overinvestment in effort in the first period, or lower in both periods.

Ultimately, under limited commitment, changes in the optimal bonus rates depend on whether or not y_1 conveys information about y_2 and, if so, on the sign of the correlation ρ of the two performance measures: (i) if $\rho > 0$, then both risk effects result in lower marginal costs from v_2 compared to the full commitment case. In an optimal incentive mechanism, the manager should be given higher-powered incentives, $1/\gamma_2 \geq v_2^R(b) > v_2^*(b)$, such that $a^{FB} \geq a_2^R(b) > a_2^*(b)$. The implications on the optimal first period incentives are immediately clear: as performance measures are substitutes, a higher second period bonus rate will reduce the manager's variable compensation in the first period, $v_1^R(b) < v_1^*(b) < 1/\gamma_1$, and hence, $a_1^R(b) < a_1^*(b) < a^{FB}$.

(ii) If $\rho < 0$, then the overall impact on the marginal costs from v_2 is ambiguous. This ambiguity arises from that fact that the two risk effects diverge in different directions. Specifically, the board relies on a lower posterior variance $Var(w|b, y_1)$, but disregards the (positive) risk insurance effect on the manager's wage. Both effects increase as the diversification effect on the manager's risk premium becomes larger (larger r, σ, smaller b, $\rho < 0$); hence, they cannot be disentangled. However, the second risk effect is likely to be small in period 2 if full commitment creates effort overinvestment in period 1 and thus, effort underinvestment in period 2 (large $\gamma_1/\gamma_2 > 1$). Here, the second risk effect will be overcompensated and hence, the optimal v_2 increases when commitment is limited. In contrast, when full commitment leads to effort overinvestment in period 2 (large $\gamma_2/\gamma_1 > 1$), or when underinvestment prevails in both periods, then the optimal v_2 will be lower under limited commitment. Thereby, as the two bonus weights are complements, they always move in the same direction. Hence, a higher v_2 leads to inefficiencies by increasing overinvestment in the first period, $1/\gamma_2 \geq v_2^R(b) > v_2^*(b)$ and $v_1^R(b) > v_1^*(b) > 1/\gamma_1$, and hence, $a^{FB} \geq a_2^R(b) > a_2^*(b)$ and $a_1^R(b) > a_1^*(b) > a^{FB}$. Otherwise, inefficiencies are created because underinvestment is exacerbated in the first period, $1/\gamma_2 \geq v_2^R(b) < v_2^*(b)$ and $v_1^R(b) < v_1^*(b) < 1/\gamma_1$, and thus, $a^{FB} \geq a_2^R(b) < a_2^*(b)$ and $a_1^R(b) < a_1^*(b) < a^{FB}$.

Note that in the limiting case in which y_1 perfectly reveals the future performance risk, $\rho \in \{-1, 1\}$, the contractually chosen second period bonus rate will be the optimal one, $v_2^R = 1/\gamma_2$, and thus, $a_2^R = a^{FB}$. Similar to the full commitment case, if $\rho = -1$ and $\gamma_1 = \gamma_2$, allowing for renegotiation results in an outcome that is jointly efficient, $v_t^R = 1/\gamma_t$ and $a_t^R = a^{FB}$ for $t = 1, 2$. If performance measures are uncorrelated, $\rho = 0$, the optimal contract will be the same as under full commitment, $v_t^R = v_t^*$, and hence, $a_t^R = a_t^*$ for $t = 1, 2$. Besides this very special cases, the possibility of renegotiation distorts the ex ante efficient trade-off between risk and incentives and creates a welfare loss from limited commitment, $E[Z^*(b)] \geq E[Z^R(b)]$. This distortion results from the fact that under risk aversion, the renegotiation-proofness requirement prevents the board from maximizing the expected aggregate surplus. Hence, the optimal contract differs from that under full commitment. Based on these suggestions, let us consider the role of board monitoring under the renegotiation-proof contract. Intuitively, if

$b^R = b^H$, risk-bearing will be reduced, and this will increase the manager's variable compensation in the second period, $v_2^R(b^H) \geq v_2^R(0)$. Therefore, if incentives are higher than under full commitment (see Corollary 2), the distortion in the optimal compensation may be reinforced. Consequently, having a non-working board, $b^R = b^L = 0$, may be desirable, even if the use of the efficient monitoring technology decreases compensation risk, and moreover, even if there are no additional cost of this use. This yields the following result.

Proposition 4 *With renegotiation-proof contracts, board monitoring may exacerbate the commitment problem with respect to the manager's compensation. As a result, expected aggregate surplus can be higher with a sufficiently large fraction of outside board members, $\delta^R < \hat{\delta}$.*

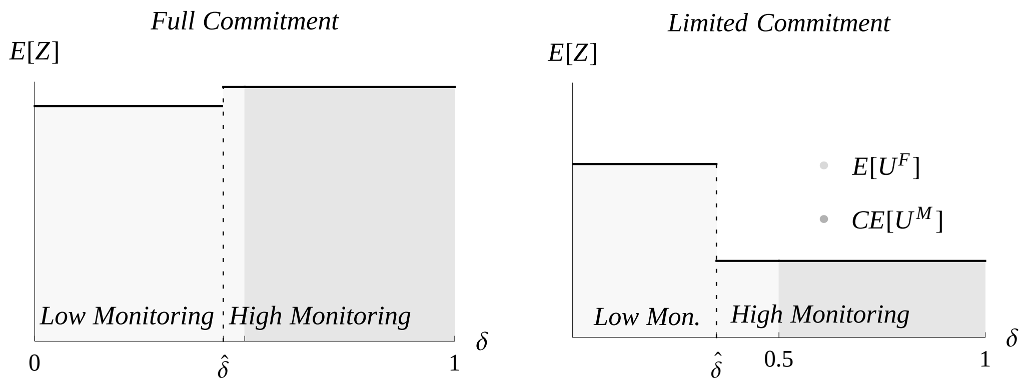

Figure 2: Expected Surplus $E[Z^*]$ ($E[Z^R]$) as a Function of Board Independence δ

	Full Commitment		***Limited Commitment***	
	Low Monitoring	*High Monitoring*	*Low Monitoring*	*High Monitoring*
v_1	0.066454	0.0664829	0.0655938	0.0659697
v_2	0.138803	1.76379	1	6.89655
a_1	0.99681	0.997244	0.983907	0.989545
a_2	0.00694017	0.0881893	0.05	0.344828
$E[Z]$	0.501875	0.542716	0.408324	0.180499
$\hat{\delta}$		0.448998		0.348592

Table 1: Numerical Example

Note: The parameters are $r = 1$, $b^H = 0.9$, $\rho = 0.9$, $\gamma_1 = 15$, $\gamma_2 = 0.05$, $\lambda = 0$, and $\sigma = 0.5$.

The intuition from Proposition 4 can be inferred from Figure 2, which draws upon the numerical example in Table 1. This example is given to illustrate the potential magnitude of the effects of board monitoring and renegotiation on the optimal variable compensation, v_1^* and v_2^* (v_1^R and v_2^R), the manager's equilibrium actions, a_1^* and a_2^* (a_1^R and a_2^R) and the corresponding expected surplus $E[Z^*]$ ($E[Z^R]$). Recall that the high monitoring technology lowers the manager's compensation variance and thus, mitigates the negative effect of managerial risk aversion on incentives. When considering the dynamic contracting problem under full commitment (see the left picture of Figure 2 and the columns 2 and 3 of Table 1), this results in higher incentives and less effort underinvestment relative to the efficient level and therefore, in a higher expected level of the aggregate surplus, $E[Z^*(b)] > E[Z^*(0)]$. Notably, this surplus can only be obtained if the fraction of inside board members is sufficiently large, $\delta \geq 0.449$. Nevertheless, the firm may be reluctant to increase the number of inside directors, knowing that the entire surplus will go to the manager if the outside directors fail to obtain a majority of the board's seats, $\delta > 1/2$.

These results can be compared to the limited commitment setting (see the right picture of Figure 2 and the columns 4 and 5 of Table 1). Here, the parties can renegotiate the resulting contract after some uncertainty between the two periods is resolved. Since $\rho = 0.9 > 0$, renegotiation-proofness leads the board to offer a higher variable compensation in the second period, $v_2^R > v_2^*$ and hence, $a_2^R > a_2^*$. In consideration of the manager's aggregate risk premium, this comes at the cost of lower first period incentives, $v_1^R < v_1^*$ and $a_1^R < a_1^*$. When board monitoring is implemented, aggregate welfare declines as, in these circumstances, monitoring will have a more pronounced effect on the period 2 incentive distortion, $v_2^R(b) > v_2^R(0)$. Therefore, having a sufficiently independent board, $\delta < 0.348$, will serve as a commitment device for less strong incentives in the second period. This is desirable even though the manager's total compensation risk is increased, $E[Z^R(b)] < E[Z^R(0)]$. In any case, since the renegotiation-proofness constraint prevents the board from maximizing the aggregate surplus, expected welfare is always higher under the full commitment contract, $E[Z^*] > E[Z^R]$.

4 Conclusion

This paper studies the role of board independence in determining the board's incentives and the board's influence on welfare. To show our results we use a two-period principal-agent framework, where the shareholder's role in incentivizing, monitoring and advising the agent is delegated to the board of directors. By exerting effort, both the manager and the board influence the firm's productivity and the manager's compensation.

When full commitment is feasible, then the optimal incentives, and consequently the optimal contract, can only be achieved if the board implements an efficient monitoring technology. Interestingly, for such an efficient monitoring technology to be implemented, a sufficiently dependent board is necessary. Although counter intuitive at first glance, this is a direct consequence of the advising effect on the performance measure. Since monitoring increases the performance measure and the manager's compensation, and consequently decreases the expected value to the shareholders, it is ex post too lightly implemented by the independent members of the board of directors. Hence, a sufficient number of insiders on the board is needed to enable efficient monitoring.

When full commitment is not feasible, then a sufficiently independent board can act as a commitment device to lower the second period incentives and to increase the joint surplus of the owners and managers. Less monitoring can now be beneficial in the renegotiation situation, since it increases the joint surplus. Nevertheless, it is only feasible with a sufficiently independent board that is ex post not interested in monitoring, due to the fact that monitoring increases the compensation of the manager and lowers the firm's profits. In our setting a sufficiently independent board, relaxes the renegotiation constraint and, therefore, could be beneficial even though the total compensation risk of the agency has increased and the expected output is reduced.

In our model we have considered the board of directors as a single entity that simultaneously performs the tasks of compensating, monitoring and advising the manager. It would be worthwhile to analyze whether different board committees would have an influence on the results. Moreover, we consider the boards tasks as complements and not substitutes, and therefore, it would be interesting to see whether the results might change when considering the board's time as limited. Additionally, it would also be interesting to see how the results would change if we were to regard the manager's tasks in two periods as investment into short-term and long-term projects. Finally, in our model we have assumed that the board structure is exogenously given. A natural model extension would be to observe the influence of the model results on the choice and appointment of directors on the board.

Even though this is a highly stylized and simple model it never the less shows that board monitoring and insiders on the board cannot strictly be considered as good or bad, as sometimes regarded in the literature. Having an independent board that implements an inefficient monitoring technology may be the optimal choice if the renegotiation option influences a misbalance and increases the second period incentives. Otherwise, the insiders on the board are beneficial and increase the joint surplus.

A Appendix

Proof of Proposition 1

Assuming w is the final contract, then the board only has an incentive to choose $b = b^H$, for $b^H > b^L = 0$ if

$$\delta CE[U^M(b^H)] + (1-\delta)E[U^F(b^H)] \quad \geq \quad \delta CE[U^M(0)] + (1-\delta)E[U^F(0)]$$
$$\Longleftrightarrow$$

$$\delta\left[E(w \mid b^H) - C(\mathbf{a}) - \frac{r}{2}Var(w \mid b^H)\right] + (1-\delta)\left[E(x \mid b^H) - E(w \mid b^H)\right] \geq$$
$$\delta\left[E(w \mid 0) - C(\mathbf{a}) - \frac{r}{2}Var(w \mid 0)\right] + (1-\delta)\left[E(x \mid 0) - E(w \mid 0)\right]$$
$$\Longleftrightarrow$$

$$E(x \mid b^H) - E(w \mid b^H) - E(x \mid 0) + E(w \mid 0) \geqslant$$
$$\delta\left[E(x \mid b^H) - 2E(w \mid b^H) - E(x \mid 0) + 2E(w \mid 0) + \frac{r}{2}(Var(w \mid b^H) - Var(w \mid 0))\right]$$

Since the following holds

$$\left[E(x \mid b^H) - E(w \mid b^H)\right] - \left[E(x \mid 0) - E(w \mid 0)\right] = \lambda b^H - b^H(v_1 + v_2)$$
$$Var(w \mid b^H) - Var(w \mid 0) = -\sigma^2 b^H(v_1^2 + v_2^2 + 2v_1v_2\rho).$$

With some algebraic manipulation we get the inequality

$$\lambda - (v_1 + v_2) \geqslant \delta(\lambda - 2(v_1 + v_2) - \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho)).$$

To find the cut-off value of $\delta \in [0,1]$ that distinguishes whether the board will implement high or low monitoring technology we consider two cases:

1. When $2(v_1 + v_2) - \lambda + \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho) > 0$

   then it follows that $\delta \geqslant \hat{\delta} = \dfrac{v_1 + v_2 - \lambda}{2(v_1 + v_2) - \lambda + \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho)}$.

   Since it always holds that $(v_1^2 + v_2^2 + 2v_1v_2\rho) > 0$ then:

   (a) $v_1 + v_2 - \lambda > 0 \Rightarrow \hat{\delta} \in (0,1) \Rightarrow E[U^B(b^H)] \geq E[U^B(0)]$ iff $\delta \geqslant \hat{\delta} \in (0,1)$.

(b) $v_1 + v_2 - \lambda < 0 \Rightarrow \hat{\delta} \in (-\infty, 0) \Rightarrow E[U^B(b^H)] \geq E[U^B(0)]$ always holds since $\delta \geqslant \hat{\delta} \in (-\infty, 0)$.

2. When $2(v_1 + v_2) - \lambda + \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho) < 0$

   then it follows that $\delta \leqslant \hat{\delta} = \dfrac{v_1 + v_2 - \lambda}{2(v_1 + v_2) - \lambda + \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho)}$.

   This means that $v_1 + v_2 - \lambda < 0$ in order for the whole expression in the denominator to be negative. Therefore it holds that $|v_1 + v_2 - \lambda| > |2(v_1 + v_2) - \lambda + \frac{r}{2}\sigma^2(v_1^2 + v_2^2 + 2v_1v_2\rho)|$, from which it follows that $\hat{\delta} > 1 \Rightarrow E[U^B(b^H)] \geq E[U^B(0)]$ always holds since $\delta \leqslant \hat{\delta} \in (1, \infty)$. ■

Proof of Proposition 2 First assume $\delta < 1/2$ (majority on the board are independent directors). Then the board's objective function is strictly decreasing in the fixed payment so f will be chosen as low as possible such that $CE[U^{M*}] = 0$ and, hence, $f = C(\boldsymbol{a}) - \frac{r}{2}Var(w|b) - v_1E[y_1|b] - v_2E[y_2|b]$, respectively.

Inserting f into $E[U^F(b)]$ leads to $E[U^F(b)] = E[x|b] - C(\boldsymbol{a}) - \frac{r}{2}Var(w|b)$. Thus the board maximizes $(1-\delta)E[Z(b)]$, which is maximized if $E[Z(b)]$ is maximized.

Second, assume $\delta > 1/2$ (majority on the board are insiders). Then the board's objective function is strictly increasing in the fixed payment so f will be chosen as high as possible such that $E[U^{F*}] = 0$ and hence, $f = E[x] - v_1E[y_1|b] - v_2E[y_2|b]$.

Inserting f into $CE[U^M(b)]$ leads to $CE[U^M(b)] = E[x|b] - C(\boldsymbol{a}) - \frac{r}{2}Var(w|b)$. Thus the board maximizes $\delta E[Z(b)]$, which is maximized if $E[Z(b)]$ is maximized.

Now the board's optimization problem can be written as:

$$\begin{aligned} &\max_{v_1,v_2}(1-\delta)E[U^F(b)] = (1-\delta)\,E[Z(b)] && \text{for} \quad \delta \leq 1/2 \\ &\max_{v_1,v_2}\delta\, CE[U^M(b)] = \delta\, E[Z(b)] && \text{for} \quad \delta > 1/2 \\ &\text{subject to} \quad a_1 = v_1\gamma_1 \quad \text{and} \quad a_2 = v_2\gamma_2. \end{aligned}$$

Inserting the incentive constraints into $E[Z(b)]$ leads to the following unconstrained optimization problem

$$\max_{v_1,v_2} E[Z(v_1, v_2)] = \gamma_1 v_1 + \gamma_2 v_2 - \frac{1}{2}(v_1^2\gamma_1^2 + v_2^2\gamma_2^2) - \frac{r}{2}\sigma^2(1-b)(v_1^2 + v_2^2 + 2v_1v_2\rho).$$

Solving the two first-order conditions for (v_1, v_2)

$$\frac{\partial Z(\cdot)}{\partial v_1} = \frac{\gamma_1 - r(1-b)\rho v_2^*(b)\sigma^2}{\gamma_1^2 + r(1-b)\sigma^2} = 0$$
$$\frac{\partial Z(\cdot)}{\partial v_2} = \frac{\gamma_2 - r(1-b)\rho v_1^*(b)\sigma^2}{\gamma_2^2 + r(1-b)\sigma^2} = 0$$

leads to $v_1^*(b)$ and $v_2^*(b)$

$$v_1^*(b) = \frac{r(1-b)\sigma^2(\gamma_1 - \gamma_2\rho) + \gamma_1\gamma_2^2}{r^2(1-b)^2\sigma^4(1-\rho^2) + r(1-b)\sigma^2(\gamma_1^2+\gamma_2^2) + \gamma_1^2\gamma_2^2}$$
$$v_2^*(b) = \frac{r(1-b)\sigma^2(\gamma_2 - \gamma_1\rho) + \gamma_2\gamma_1^2}{r^2(1-b)^2\sigma^4(1-\rho^2) + r(1-b)\sigma^2(\gamma_1^2+\gamma_2^2) + \gamma_1^2\gamma_2^2}.$$

Substituting $v_1^*(b)$ and $v_2^*(b)$ for v_1 and v_2 into $E[Z(v_1, v_2, b)]$ leads to

$$E[Z^*(b)] = \frac{r(1-b)\sigma^2(\gamma_1^2+\gamma_2^2-2\gamma_1\gamma_2\rho) + 2\gamma_1^2\gamma_2^2}{2r(1-b)\sigma^2(\gamma_1^2+\gamma_2^2+r(1-b)\sigma^2(1-\rho^2)) + 2\gamma_1^2\gamma_2^2}.$$

■

Proof of Proposition 3

First we solve for the second period incentives by maximizing the second period surplus

$$\max_{v_2} a_2 - \frac{a_2^2}{2} - \frac{r}{2}Var(w|y_1)$$
$$\text{subject to} \quad a_2 = v_2\gamma_2$$
$$v_2 = v_2^R.$$

Knowing that $\frac{r}{2}Var(w|y_1) = \frac{r}{2}(v_2)^2\sigma^2(1-b)(1-\rho^2)$, and inserting the incentive constraint into the objective function leads to the following maximization problem

$$\max_{v_2} v_2\gamma_2 - \frac{v_2^2\gamma_2^2}{2} - \frac{r}{2}v_2^2\sigma^2(1-b)(1-\rho^2)$$

The first order condition of the maximization problem equals zero at the optimum and therefore the optimal solution for the second period incentive is

$$v_2^R(b) = \frac{\gamma_2}{\gamma_2^2 + r(1-b)(1-\rho^2)\sigma^2}$$

Substituting the incentive constraints and the renegotiation-proofness constraint for a_1^*, a_2^*, and v_2^R into the objective function of (13) leads to the unconstrained problem

$$\max_{v_1} E[Z(b, v_1, v_2^R)] =$$
$$v_1\gamma_1 + v_2^R\gamma_2 - \frac{(v_1\gamma_1)^2}{2} - \frac{(v_2^R\gamma_2)^2}{2} - \frac{r}{2}\sigma^2(1-b)(v_1^2 + (v_2^R)^2 + 2v_1v_2^R\rho)$$

From the first-order condition $dZ/dv_1 = \gamma_1 - v_1^R\gamma_1^2 - \frac{r}{2}\sigma^2(1-b)(2v_1^R + 2v_2^R\rho) = 0$ it follows that

$$v_1^R(b) = \frac{\gamma_1 - r(1-b)\rho v_2^R(b)\sigma^2}{\gamma_1^2 + (1-b)r\sigma^2}$$

or

$$v_1^R(b) = \frac{r\sigma^2(1-b)\cdot(\gamma_1(1-\rho^2) - \gamma_2\rho) + \gamma_1\gamma_2^2}{(\gamma_1^2 + r\sigma^2(1-b))(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)}$$

with the corresponding maximum objective function value $E[Z^R(b)] = E[Z(b, v_1^R, v_2^R)]$, where

$$E[Z^R(b)] = \frac{\gamma_1^2\big((1-b)\gamma_2^2(3-4\rho^2)r\sigma^2 + (1-b)^2(1-\rho^2)^2r^2\sigma^4 + 2\gamma_2^4\big)}{2(\gamma_1^2 + r\sigma^2(1-b))\cdot(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)^2}$$
$$+ \frac{r\sigma^2(1-b)\gamma_2\big((1-b)(1-\rho^2)r\sigma^2 + \gamma_2^2\big)\big(\gamma_2 - 2\gamma_1\rho\big)}{2(\gamma_1^2 + r\sigma^2(1-b))\cdot(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)^2}$$

■

Proof of Corollary 2 Comparing the optimal incentive weights under full commitment (from Proposition 2) and limited commitment (from Proposition 3), v_t^* and v_t^R for $t = 1, 2$, respectively, the following can be shown.

I. Difference between v_1^* and v_t^R equals:

$$v_1^*(b) - v_1^R(b) = \frac{(1-b)^2\gamma_1\rho^2r^2}{(\gamma_1^2 + r\sigma^2(1-b))(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)}$$
$$\cdot \frac{(1-b)(1-\rho^2)r\sigma^2 + \gamma_1\gamma_2\rho + \gamma_2^2}{\gamma_1^2(r\sigma^2(1-b) + \gamma_2^2) + r\sigma^2(1-b)(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)}$$

The first term is always positive, as well as, the denominator of the second term since $\gamma_1 \in (0, \infty)$, $\gamma_2 \in (0, \infty)$, $b \in [0, 1]$ and $\rho \in [-1, 1]$. The numerator of the second term can take on positive or negative values, depending on the correlation, ρ. Therefore the following is true:

1. For positive correlation the numerator is always positive, therefore
   for $\rho \in (0,1] \Rightarrow v_1^* > v_1^R$.

2. For negative correlation the difference also depends on the incentive weights γ. The following holds:
   for $(\gamma_1/\gamma_2) \in (0,1)$ and $\rho \in [-1,0) \Rightarrow v_1^* > v_1^R$,
   for $(\gamma_1/\gamma_2) \in [1,\infty)$ and $\rho \in (\rho',0) \Rightarrow v_1^* > v_1^R$,
   for $(\gamma_1/\gamma_2) \in [1,\infty)$ and $\rho \in [-1,\rho') \Rightarrow v_1^* < v_1^R$,
   where $\rho' = \frac{\gamma_1\gamma_2}{2(1-b)r\sigma^2} - \frac{1}{2}\sqrt{4 + \frac{\gamma_2^2(\gamma_1^2+4r\sigma^2(1-b))}{r^2\sigma^4(1-b)^2}}$.

II. Difference between v_2^* and v_2^R equals:

$$v_2^*(b) - v_2^R(b) = \frac{-\rho(r\sigma^2(1-b)(1-\rho^2) + \gamma_1\gamma_2\rho + \gamma_2^2)}{(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)} \cdot \frac{r\sigma^2(1-b)\gamma_1}{\gamma_1^2(r\sigma^2(1-b) + \gamma_2^2) + r\sigma^2(1-b)(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)}$$

The second term is always positive, as well as, the denominator of the first term since $\gamma_1 \in (0,\infty)$, $\gamma_2 \in (0,\infty)$, $b \in [0,1]$ and $\rho \in [-1,1]$. The numerator of the first term can take on positive or negative values, depending on the correlation, ρ. Therefore the following is true:

1. For positive correlation the numerator is always negative, therefore
   for $\rho \in (0,1] \Rightarrow v_2^* < v_2^R$.

2. For negative correlation the difference also depends on the incentive weights γ. The following holds:
   for $(\gamma_1/\gamma_2) \in (0,1)$ and $\rho \in [-1,0) \Rightarrow v_2^* > v_2^R$,
   for $(\gamma_1/\gamma_2) \in [1,\infty)$ and $\rho \in (\rho',0) \Rightarrow v_2^* > v_2^R$,
   for $(\gamma_1/\gamma_2) \in [1,\infty)$ and $\rho \in [-1,\rho') \Rightarrow v_2^* < v_2^R$. ■

Proof of Proposition 4 Comparing the optimal welfare under full commitment (from Proposition 2) and under limited commitment (from Proposition 3), $E[Z^*(b)]$ and $E[Z^R(b)]$, the following can be shown.

$$E[Z^*(b)] - E[Z^R(b)] = \frac{(1-b)^2\gamma_1^2\rho^2r^2\sigma^4}{2(r\sigma^2(1-b) + \gamma_1^2)(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)^2} \cdot \frac{(r\sigma^2(1-b)(1-\rho^2) + \gamma_1\gamma_2\rho + \gamma_2^2)^2}{\gamma_1^2(r\sigma^2(1-b) + \gamma_2^2) + r\sigma^2(1-b)(r\sigma^2(1-b)(1-\rho^2) + \gamma_2^2)}$$

The difference is always positive meaning that $E[Z^*(b)] > E[Z^R(b)]$. ■

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