

Keeping the Board in the Dark: CEO Compensation and Entrenchment*

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Abstract

The CEO's control over information in the boardroom limits the board's ability to monitor the CEO. We examine how the incentives of CEOs to hide negative information from the board depend on their compensation structure, and how the board can structure CEO compensation optimally to mitigate the problem. The optimal compensation package consists of options and severance pay. Option pay forces the CEO "to put his money where his mouth is" by making it as costly as possible for him to falsely assert that the firm's future prospects are good. This minimizes the amount of severance pay needed to compensate the CEO for being fired, thus minimizing his rents. The model suggests how deregulation and technological changes in the 1980s and 1990s may have contributed to the dramatic increase in both CEO pay and forced turnover over the same period.

[M]any CEOs still take the "mushroom" approach to their boards: Keep them in the dark and cover them with manure.

James E. Orlikoff

1 Introduction

The decision to replace the CEO is arguably one of the most important decisions made by the board of directors. Yet, to make this decision the board needs information—information that is often controlled by the very CEO it is supposed to discipline. The CEO’s control over information in the boardroom consequently puts a natural limit on the board’s ability to effectively monitor him: “[T]he CEO most always determines the agenda and the information given to the board. This limitation severely hinders the ability of even highly talented board members to contribute effectively to the monitoring of the CEO and the company’s strategy” (Jensen (1993)).¹

There are consequently two sides to the monitoring of the CEO. One relates to the board’s ability and incentives to acquire information about the CEO, while the other relates to the CEO’s willingness to provide the board with information. Indeed, Hermalin (2004) emphasizes that “this monitoring need not be particularly “active”; one could as easily interpret it as ... making an effort to seek from the *data made available to the board* information relevant for estimating the CEO’s ability” (italics added).

This paper examines the incentives of CEOs to hide negative information from the board to avoid being fired. Hiding information is a natural, perhaps the most natural, form of entrenchment. While we focus on information-based entrenchment, the CEO’s decision to hide information can be interpreted more broadly as any action that makes it more difficult or costly for the board to fire him. Of course, there is information that the CEO cannot hide, such as certain quantitative information and any sort of publicly accessible data. While this information also affects the board’s decision, it is not what we are interested in here.² What we are interested in is information that is controlled by the CEO. Information that is indicative, albeit in a noisy

¹Relatedly, Coffee (2003) argues that “one must look beyond the board, in particular to those who provide or control its informational inputs”.

²It is straightforward to extend our model to include a public signal about the CEO’s performance that everyone can observe. In this case, the CEO may be fired either on the basis of public or private information, like in Hermalin and Weisbach (1998). What is essential for our argument is that the CEO has an informational advantage vis-à-vis the board.

sense, of the firm’s future performance under his continuing leadership. If the CEO remains in power, all this information will eventually be reflected in the firm’s publicly observable profits and losses. But had the board known this information early enough, it might have been able to avoid losses by replacing the CEO.

In our model, the CEO privately observes the “state of nature”, which is a noisy signal of the firm’s future performance under his leadership. The notion that the CEO has private information is a metaphor for his control over information in the boardroom. If the CEO hides information, the board will not see it. And if the CEO manipulates information, the board will only see the manipulated information. The term “state of nature” is sufficiently general to admit different interpretations. Perhaps the most natural interpretation is that it constitutes a signal of the CEO’s ability to perform at this particular job at this particular firm, like in Hermalin and Weisbach (1998) and Hermalin (2004). Accordingly, the state of nature is a noisy measure of the quality of the match between the CEO and the firm.³ Another interpretation is that the CEO is hired to implement a particular strategy, and he observes an early signal indicating the likely success of this strategy. If the initial hiring of the CEO is tied to this particular strategy—e.g., the CEO was hired because of his reputation as a cost-cutter—he might want to hide information that the firm’s strategy is unsuccessful to avoid being replaced.⁴

Given that the CEO can entrench himself by influencing the board’s information, we ask how his compensation ought to be structured to minimize such entrenchment. In our model, the CEO is inherently biased towards staying in power, a bias that arises endogenously from our assumptions. Any optimal compensation package must consequently include some form of severance pay. Without it, the CEO would always want to remain in power. But severance pay is only one side of the coin. When considering whether or not to entrench himself, the CEO trades off the value of his severance package against the expected value of his on-the-job compensation that he receives when staying in power.

³In Hermalin and Weisbach (1998) and Hermalin (2004), the board can actively acquire this signal at a cost, while the CEO exerts no immediate control over the board’s information. In contrast, in our model the CEO actively influences the board’s information.

⁴The management literature provides ample evidence that fundamental strategy changes are often accomplished by hiring a new CEO (e.g., Hambrick, Geletkanycz, and Fredrickson (1993), Barker and Duhaime (1997), Gordon et al. (2000)). Conversely, Bertrand and Schoar (2003) provide evidence that CEOs are hired because of their specific managerial style. Relatedly, Rotemberg and Saloner (2000) argue that hiring a CEO with a particular vision and style is a signal to the firm’s employees that the firm will pursue a particular strategy.

This suggests that the optimal on-the-job compensation should force the CEO to “put his money where his mouth is”. If the CEO contends that the firm’s future under its current strategy and leadership looks good, then he should be rewarded generously if the firm’s future performance is good but punished harshly if it is bad. By this argument, it is intuitive that the CEO’s optimal on-the-job compensation package should consist of options. Options *minimize* the CEO’s expected on-the-job compensation if the firm performs poorly, thus minimizing his incentives to entrench himself after observing a low state of nature.

But if options minimize the CEO’s expected on-the-job compensation when poor performance is likely, less severance pay is needed to induce him not to become entrenched. In our model, severance pay is a measure of the CEO’s (informational) rents. Hence, options minimize the rents necessary to induce the CEO not to entrench himself. Note that everything in our model hinges on the right balance between options and severance pay. If the option grant is too large relative to his severance package, the CEO will always prefer to entrench himself. Conversely, if his severance package is too large relative to the option grant, the CEO will inefficiently focus on his exit options. While a combination of options and severance pay is the least-cost way of mitigating entrenchment, it is still costly. Because of these costs, it is not optimal to fully eliminate the CEO’s entrenchment, but only to mitigate it. In other words, the optimal compensation package in our model is second-, but not first-best efficient.

The argument that a combination of options and severance pay minimizes entrenchment is novel and, we believe, intuitive. It complements existing arguments for high-powered incentive pay based on moral hazard (Innes (1990)), risk-taking (Lambert (1986)), and the self-selection of high-ability CEOs (Lazear (1999)).⁵ There is also a growing literature on employee stock options arguing why individual employees should receive options even though, unlike the firm’s CEO, an individual employee has no significant impact on the firm’s output.⁶

We can alternatively interpret our model as being about a firm’s shutdown decision. Suppose

⁵These are arguments for incentive pay, not necessarily for options. See Jenter (2002) for a critical assessment of the argument that options are optimal incentive schemes to mitigate moral hazard, and Carpenter (2000) and Ross (2004) for critical assessments of the risk-taking argument. In Lazear’s model, compensation schemes are assumed to be of the form $w = a + bx$, which does not include options.

⁶See, e.g., Oyer (2004), Bergman and Jenter (2003), and Inderst and Mueller (2004). With few exceptions, these arguments do not easily apply to the firm’s CEO. In Inderst and Mueller, for example, employees who receive options have no private information or ability to affect the firm’s output in any significant way.

instead of deciding whether to fire the CEO, the board must decide whether to shut the firm down (in which case the CEO naturally loses his job). The CEO again observes the state of nature, which is now a signal of the firm's future profits if continued. For fear of losing his job, the CEO might propose to continue the firm even if shutting down is efficient. This is precisely what Jensen (1993) views as one of the main obstacles to what he refers to as “Modern Industrial Revolution”: Managers are reluctant to shut down their firms, thus impeding the efficient transfer of assets from old, declining industries into new, thriving industries.⁷

Viewed in this context, our model implies that options and severance pay are optimal instruments to induce managers to accept the shutdown of their firms. This is consistent with the findings by Mehran, Norgler, and Schwartz (1997) that CEO option grants have a positive effect on the likelihood of voluntary liquidation. It is also consistent with Dial and Murphy's (1995) clinical study of General Dynamic's partial liquidation, where generous stock option programs helped overcome managers' resistance to liquidate plants and sell off assets, even if this meant that they had to sacrifice their own jobs.

Our model has interesting comparative statics implications. For instance, when the ex-ante likelihood that a strategy change becomes optimal increases—like in the 1980s and 1990s when massive technological changes and deregulations fundamentally changed the industrial landscape in the U.S—our model implies that the *level* of CEO compensation (both in terms of the CEO's severance package and option grant) should increase as well. This is consistent with the widely documented rise in both the level of CEO compensation and the use of option grants during the 1980s and 1990s (Hall and Liebman (1998)).

Given the abundance of papers on boards and executive compensation, we cannot possibly do justice to all papers that are related to ours.⁸ Let us therefore only mention a few papers that we feel are closely related. Hermalin and Weisbach (1998) and, in particular, Hermalin (2004) consider settings that are similar to ours in many ways. Their focus is on the board's decision to acquire information about the CEO, however, and how this decision relates the board's

⁷ “Even when managers do acknowledge the requirement for exit, it is often difficult for them to accept and initiate the shutdown decision” (Jensen (1993)). Similarly, Holmström and Kaplan (2001) argue that to reallocate assets from declining into growing industries, it is often necessary to shut the old firm down: “A new firm, with a lack of commitments and old baggage, can offer a distinctive advantage in rapidly growing industries.”

⁸ See Hermalin and Weisbach (2003) for a survey of the literature on corporate boards, and Murphy (1999) for a review of the literature on executive compensation.

independence, while our focus is on the CEO's decision to provide the board with information.

Almazan and Suarez (2003) consider a model in which boards are either weak, in which case the CEO can veto his replacement, or strong, in which case he cannot. While it is commonly known whether or not replacing the CEO is efficient, the outcome depends on the bargaining between the CEO and the board. In our model, only the CEO knows whether replacing him is efficient. In Eisfeldt and Rampini (2004), the CEO is privately informed about the value of the assets under his control, which is related to our above discussion of the shutdown decision. While both papers highlight the importance of severance or bonus pay to induce managers to relinquish control, neither paper shares our focus regarding the optimal design of the CEO's on-the-job compensation in a general optimal contracting framework.

Finally, Dow and Raposo (2003) consider the link between CEO compensation and a firm's strategy choice, which is related to our above interpretation of our model where the CEO is replaced to make room for a fundamental strategy change. In their paper, the CEO has discretion over the firm's strategy choice, while different strategies involve different levels of CEO effort. In order to extract a higher surplus from shareholders, the CEO may choose an overtly ambitious strategy whose success depends largely on his own performance.

The rest of this paper is organized as follows. Section 2 presents the model. Section 3 shows how CEOs' incentives to become entrenched depend on their compensation, and how the board can structure CEO compensation optimally to mitigate entrenchment. Section 4 provides comparative statics analyses. It shows that CEO compensation should be larger in bigger firms, and it ties the recent surge in CEO compensation to technological innovations and industry deregulations in the 1980s and 1990s. Section 5 concludes. All proofs are in the Appendix.

2 The Model

The model has three dates: $t = 0, 1$, and 2 . At $t = 0$, the firm's board hires a CEO to run the firm and implement the firm's strategy. The choice of CEO is not random. The CEO is chosen because at the time he is believed to be the best candidate for the job. In $t = 1$, the board meets and decides whether or not to retain the CEO.

Prior to the board meeting, the CEO privately observes the state of nature θ . The state of nature is a noisy signal of the quality of the match between him and the firm. The board and the CEO initially have common expectations about this match quality, which are expressed by the

distribution function $F(\theta)$.⁹ All distribution functions in our model are atomless. The support of $F(\theta)$ is denoted by $\Theta := [\underline{\theta}, \bar{\theta}]$, while the density $f(\theta)$ is positive everywhere.

The quality of the match between the CEO and the firm affects the firm's value in $t = 2$. We denote this value by s . Precisely, we assume that s depends on θ via the conditional distribution function $G_\theta(s)$ with support $S := [\underline{s}, \bar{s}]$. The density function $g_\theta(s)$ is continuous in both θ and s . High states of nature are “good news” for the firm's future performance in the sense of the Monotone Likelihood Ratio Property (MLRP).¹⁰ That is, we assume that $g_{\theta'}(s)/g_\theta(s)$ is strictly increasing in s for all $\theta' > \theta$ in Θ .

Realistically, whether the firm's future performance will be good depends not only on the quality of the match between the firm and CEO, but also on whether the CEO is fully dedicated to implementing the firm's strategy. We assume that the above distributional assumptions hold only in the “good” case where the CEO is sufficiently dedicated to his job. This is costly, however. It implies that the CEO must forgo private benefits $B > 0$. If the CEO is not fully dedicated to implementing the firm's strategy, this results in a low state of nature in which shareholder value is higher under a different CEO.¹¹ Whether or not the CEO is sufficiently dedicated to implementing the firm's strategy is unobservable.

Let $E[s | \theta] := \int_S s g_\theta(s) ds$ denote the expected firm value under the CEO conditional on the state of nature, and let $V > 0$ denote the expected value to shareholders if the CEO is fired. Given that the current CEO will be replaced with a new CEO, V constitutes the expected firm value under the new CEO, which in turn depends on the expected match quality between the new CEO and the firm. There is no need to make distributional assumptions about V . This is because the quality of the match between the firm and the new CEO is not informative (in a statistical sense) about the match quality between the firm and its current CEO.

As we argued in the Introduction, our model admits alternative interpretations. If the hiring

⁹This setup is similar to Hermalin and Weisbach (1998) and Hermalin (2004). Our main point of departure is that we assume the CEO learns the match quality before anyone else.

¹⁰MLRP is satisfied by many standard probability distributions (see Milgrom (1981)).

¹¹For the moment we may assume that this results in $\theta = \underline{\theta}$. As we will see shortly, all we need is that it results in a sufficiently low state of nature $\theta < \theta^*$. While this incentive problem is admittedly simplistic, it is the most parsimonious way of creating a wedge between the CEO's severance pay and his on-the-job pay, which is why it is part of our model. Moreover, setting up the incentive problem this way ensures that it has no immediate implications for the optimal structure of the CEO's on-the-job pay (see Section 3.1, last paragraph).

of the CEO is closely tied to a particular strategy—so that a change in the firm’s strategy implies that the CEO will be replaced—then θ might be viewed as a signal of the likely success of the firm’s current strategy. In this case, s denotes the firm’s future value if it continues with its current strategy and CEO, while V denotes the expected firm value under a different strategy and CEO.¹² While there is little reason to believe that the current CEO has private information about the quality of the match between the firm and a different CEO, he might have private information about the firm’s future value under a different strategy. If this is true, it can be shown that his severance payment should be made contingent on the firm’s future value under the new strategy and CEO. Such payoff-contingent severance payments are, to the best of our knowledge, not observed in practice, however.

The board’s (first-best) optimal firing decision in case the state of nature was publicly observable is straightforward. It is first-best optimal to retain the CEO if $E[s \mid \theta] \geq V$ and to fire him if $E[s \mid \theta] < V$. Ruling out trivial cases where the CEO should be either fired or retained for all $\theta \in \Theta$, this implies there exists a unique interior cutoff state $\theta_{FB} \in (\underline{\theta}, \bar{\theta})$ such that the CEO should be retained if and only if $\theta \geq \theta_{FB}$.¹³

The crux with implementing this first-best outcome is that the board must rely on information that is controlled by the CEO. The CEO’s incentives to hide or manipulate information depend on his compensation scheme. If the CEO remains in power, his compensation in $t = 2$ is given by $w(s)$, which makes his on-the-job compensation a function of the realized firm value. On the other hand, if the CEO is fired he obtains a severance payment W .¹⁴ As we show in Section 3.3, restricting the CEO’s compensation package to $w(s)$ and W is without loss of generality. (In fact, it is strictly optimal.) That is, even though the CEO has private information in $t = 1$, it is not optimal to offer him a more complex menu in which either $w(s)$ or W depend nontrivially on θ . We further assume that it is optimal from the shareholders’ perspective to fire the CEO in some states but to retain him in others.¹⁵ Otherwise the board would have no

¹²An extreme form of a strategy change is the firm’s decision to shut down. In this case, V would be the firm’s liquidation value.

¹³As $G_\theta(s)$ satisfies MLRP, it also satisfies First-Order Stochastic Dominance (FOSD), which implies that $E[s \mid \theta]$ is strictly increasing in θ . In conjunction with continuity of $g_\theta(s)$, this implies the existence of a unique interior cutoff θ_{FB} given by $E[s \mid \theta_{FB}] = V$.

¹⁴In a detailed study, Schwab and Thomas (2004) find that the median contractually specified severance payment corresponds to two years’ salary, not including additional benefits such as augmented pensions.

¹⁵This is optimal, for instance, if i) $E[s \mid \theta]$ is sufficiently greater than V for high θ and sufficiently smaller than

interest in eliciting the CEO's private information.

We finally impose two constraints on the CEO's compensation scheme. The first is a minimum consumption constraint stating that the CEO's pay must equal or exceed some (small) minimum consumption level $C \geq 0$. While we believe that a minimum consumption constraint is realistic, none of our qualitative results hinge on this constraint, which is why we allow C to be zero. The second constraint is standard a monotonicity constraint requiring that both $w(s)$ and $s - w(s)$ must be nondecreasing.¹⁶

3 Analysis

3.1 The Board's Problem

Note that the board cannot pay the CEO a flat wage $w(s) = w$ for all $s \in S$. If it did, the CEO would either always (i.e., for all $\theta \in \Theta$) or never want to remain in power, depending on whether w is greater or smaller than W . Arguably, if $w = W$ the CEO is just indifferent. But if his compensation if he remains in power were exactly the same as his severance pay, the CEO would not work hard to implement the firm's strategy.

Consequently, the CEO's on-the-job compensation $w(s)$ must be strictly increasing in s for some $s \in S$ (on a set of positive measure). In conjunction with the fact that $G_\theta(s)$ satisfies MLRP and that $w(s)$ is everywhere nondecreasing, this implies that his expected on-the-job compensation $E[w(s) | \theta]$ must be strictly increasing in θ . We thus have that for *any* feasible compensation scheme the CEO's expected on-the-job compensation is larger in high states of nature where the match quality between him and the firm is good.

When deciding what information to give to the board, the CEO compares his expected on-the-job compensation $E[w(s) | \theta]$ with his severance pay W . This simple comparison, in conjunction with the fact that $E[w(s) | \theta]$ is increasing and continuous in θ , imposes a natural structure on the CEO's preferences. Precisely, there exists a unique interior cutoff state $\theta^* =$

V for low θ , and ii) $F(\theta)$ puts sufficient probability mass on both high and low θ .

¹⁶While the constraint that $w(s)$ is nondecreasing simplifies the analysis, it does not bind at the optimal solution. In contrast, the constraint that $s - w(s)$ is nondecreasing binds. The standard argument to motivate this constraint is that otherwise the firm's shareholders might have an incentive to artificially lower the share value (Innes (1990), DeMarzo and Duffie (1999)).

$\theta^*(w, W) \in (\underline{\theta}, \bar{\theta})$ given by

$$E[w(s) | \theta^*] = W \tag{1}$$

such that the CEO prefers his on-the-job compensation if and only if $\theta \geq \theta^*$.¹⁷

Consequently, if $\theta \geq \theta^*$ the CEO provides the board with information that the state of nature is high, and the board (optimally) retains him. Below we show that at the optimal solution it holds that $\theta^* < \theta_{FB}$. Hence, there exists an interval $[\theta^*, \theta_{FB})$ where the CEO intentionally hides negative information to remain in power. That is, he will falsely assert that the state of nature is high, while the board—if it knew the true state of nature—would want to fire him. In this sense, the interval $[\theta^*, \theta_{FB})$ provides us with a measure of the severity of the CEO’s entrenchment problem. The lower is θ^* relative to θ_{FB} , the more likely is it (from an ex-ante perspective) that the CEO will hide or manipulate information that would lead to his dismissal. Finally, if $\theta < \theta^*$ the state of nature is so low that the CEO has no incentive to manipulate information, which implies he will be fired.¹⁸ Note that even though the CEO’s information (i.e., the state of nature) is a continuous variable, the information he gives to the board may be coarse. This is because from the board’s perspective all that matters is whether the CEO should be fired or retained. We will come back to this issue in Section 3.3 when we consider more general compensation schemes.

We can now set up the board’s program to choose the CEO’s optimal compensation package. The board chooses the CEO’s on-the-job compensation $w(s)$ and his severance pay W to maximize shareholders’ expected payoff

$$F(\theta^*)(V - W) + \int_{\theta^*}^{\bar{\theta}} E[s - w(s) | \theta] f(\theta) d\theta, \tag{2}$$

where θ^* depends on $w(s)$ and W as defined in (1). When choosing the CEO’s compensation package, the board must ensure that the CEO is sufficiently dedicated to implementing the

¹⁷The fact that $\theta^* > \underline{\theta}$ follows directly from our assumption that the board has an interest in eliciting the CEO’s private information (see p.10).

¹⁸Technical note: In the corresponding direct mechanism the CEO truthfully announces θ . What the above paragraph says is that for any feasible direct mechanism with compensation schemes $\{w(s), W\}$ it must hold that for all $\theta \geq \theta^*$ the CEO is retained and receives $w(s)$ while for all $\theta < \theta^*$ he is fired and receives W . This follows immediately from the truthtelling constraints in conjunction with the fact that $w(s) = w$ is not feasible.

firm's strategy. If the CEO works hard, his expected payoff equals

$$\int_{\theta^*}^{\bar{\theta}} E[w(s) | \theta] f(\theta) d\theta + F(\theta^*)W. \quad (3)$$

In contrast, if the CEO shirks his payoff is $B + W$: While he consumes private benefits of B , poor implementation of the firm's strategy results in a low state of nature in which he is fired. The CEO consequently only works hard if his expected payoff in (3) equals or exceeds $B + W$. Rearranging, we obtain

$$\int_{\theta^*}^{\bar{\theta}} E[w(s) - W | \theta] f(\theta) d\theta \geq B, \quad (4)$$

i.e., there must be a sufficiently large wedge between the CEO's expected on-the-job compensation and his severance pay. This wedge reflects the fact that the board cannot separately penalize the CEO for shirking. All it can do is fire him, for it does not know if the state of nature is low because the CEO has shirked or because the match quality is poor. Accordingly, the CEO obtains the same severance payment both if he shirks and if he is diligent but unlucky.

This wedge between the CEO's expected on-the-job compensation and his severance pay has one important implication: It endogenously biases the CEO to remain in power. On the other side, it has no immediate implications for the optimal design of the CEO's on-the-job compensation scheme $w(s)$. It merely requires that *on average* the CEO's expected on-the-job compensation be greater than his severance pay by a given amount, but it says nothing about how precisely $w(s)$ should vary with s . This is important, for it implies that our later results regarding the optimal design of $w(s)$ are solely driven by concerns of how to minimize the CEO's entrenchment, not by concerns of how to get him to work hard.¹⁹

3.2 The Optimal CEO Compensation Scheme

The following result follows from standard arguments.

Lemma 1. *The constraint (4) ensuring that the CEO is fully dedicated to implementing the firm's strategy must hold with equality.*

¹⁹Another way to see this is as follows. One can easily show that if the state of nature is contractible, there exists an infinite number of optimal mechanisms implementing the first best, including mechanisms where $w(s)$ takes the form of a flat wage. An example is where the CEO is retained if and only if $\theta \geq \theta_{FB}$, in which case he receives a fixed wage $w = B/[1 - F(\theta_{FB})]$. (The optimal severance payment in this case is zero.)

Inserting the binding constraint into (2), the board’s objective function becomes

$$\int_{\theta^*}^{\bar{\theta}} E[s | \theta] f(\theta) d\theta + F(\theta^*)V - B - W, \quad (5)$$

while it follows from (4) (with equality) that the CEO’s expected compensation net of his compensation for his forgone private benefits equals

$$\int_{\theta^*}^{\bar{\theta}} E[w(s) | \theta] f(\theta) d\theta + F(\theta^*)W - B = W.$$

Hence, the CEO extracts a *rent* equal to W on top of being compensated for his private benefits.

Proposition 1. *The CEO earns a rent equal to the size of his severance pay*

To see what causes the board to leave the CEO a rent, recall that there must be a positive wedge between the his expected on-the-job compensation and his severance pay. When offering the CEO severance pay, the board must consequently also increase his on-the-job compensation. Rearranging (4) yields

$$\int_{\theta^*}^{\bar{\theta}} E[w(s) | \theta] \frac{f(\theta)}{1 - F(\theta^*)} d\theta = W + \frac{B}{1 - F(\theta^*)}. \quad (6)$$

Hence, if the board wants to raise the CEO’s severance pay by \$1 million, it must also raise his expected on-the-job compensation by \$1 million.²⁰ Regardless of whether the CEO is fired or not, he is thus better off by \$1 million.²¹

The fact that severance pay constitutes a measure of the CEO’s rents strikes us as a realistic implication of our model. It derives from the fact that the board cannot disentangle the different causes of a low state of nature. The state of nature may be low because—despite the CEO’s honest efforts to implement the firm’s strategy—he is a poor match for the firm. Alternatively, the state of nature may be low because the CEO has shirked. In the first case, severance pay constitutes a reward for the CEO not to hide negative information. In the second case, severance pay constitutes a “reward” for the CEO’s shirking.

Also plausible, we believe, is the implication that an increase in the CEO’s severance pay must be matched by a contemporaneous increase in his on-the-job compensation. If the CEO’s

²⁰The LHS in (6) depicts the CEO’s expected on-the-job compensation conditional on not being fired.

²¹Yermack (2004) finds that the size of the CEO’s severance pay is positively correlated with his on-the-job pay. Likewise, Lefanowicz, Robinson, and Smith (2000) find that managers whose contracts stipulate generous golden parachutes tend to be more highly compensated in their jobs.

on-the-job compensation does not increase along with his severance pay, the CEO will focus too much on his exit options, implying that he will not have sufficient incentives to forgo private benefits in the interest of the firm’s long-run performance.

Consequently, granting the CEO severance pay is costly as it leaves him rents. However, without severance pay the CEO would always want to remain in power because his expected on-the-job compensation is always strictly positive. The CEO’s expected on-the-job compensation is always positive—even if $W = 0$ —because he must be compensated for his private benefits.²² Without severance pay, we would therefore have that $\theta^* = \underline{\theta}$.

The board consequently faces a trade-off between reducing the CEO’s entrenchment—i.e., implementing a higher cutoff θ^* that is closer to the first-best cutoff θ_{FB} —and reducing the CEO’s severance pay and therefore his rents. The CEO’s optimal on-the-job compensation scheme reflects this tradeoff. We can state this in two equivalent ways. Holding the CEO’s severance pay W fixed, the optimal on-the-job compensation scheme must maximize θ^* , thus minimizing the CEO’s entrenchment. Conversely, holding θ^* fixed, the optimal on-the-job compensation scheme must minimize W , thus minimizing the CEO’s rents. We have the following result.

Proposition 2. *The CEO’s uniquely optimal compensation package consists of severance pay, options, and a base wage.*

Proof. See Appendix.

The reason for why the CEO must receive severance pay has already been explained. The role of the base wage is to satisfy the CEO’s binding minimum consumption requirement, which implies that the base wage will be set exactly equal to $C \geq 0$. Let us now explain why the CEO should receive options.

An option shifts as much as possible of the CEO’s on-the-job compensation into states where the firm’s value s is high while minimizing his on-the-job compensation in states where s is low. As low values of s are relatively more likely after low states of nature (due to our assumption that $G_\theta(s)$ satisfies MLRP), an option therefore minimizes the CEO’s expected on-the-job compensation $E[w(s) | \theta]$ in low states of nature. This makes it as unattractive as

²²This can be easily seen by setting $W = 0$ in (6).

possible for the CEO to stay on in these states, which in turn implies that less severance pay is needed to induce the CEO not to entrench himself.

The flip side is that—by shifting the bulk of the CEO’s on-the-job compensation into states where the firm’s value is high—an option provides the CEO with a relatively high expected compensation in high states of nature. This is inconsequential, however, as in high states of nature the firm’s value is maximized if the CEO stays on.

The only choice variable left at this point is the CEO’s severance pay. We argued above that if $W = 0$ the CEO would always want to remain in power. But this does not necessarily imply that raising W makes him less entrenched. Indeed, given that an increase in W must be matched by a contemporaneous increase in his expected on-the-job compensation, this is not obvious. It is, however, true under the *optimal* CEO on-the-job compensation scheme derived in Proposition 2. Intuitively, if the CEO receives options, the required increase in his on-the-job compensation to match an increase in W occurs primarily at high values of s , implying that the CEO’s expected on-the-job compensation $E[w(s) | \theta]$ increases primarily in high states of nature. Conversely, in low states of nature the CEO’s expected on-the-job compensation increases only little. Accordingly, while *on average* the CEO’s expected on-the-job compensation must increase one-for-one with his severance pay, it increases by more than W in high and by less than W in low states of nature. In low states of nature the difference $E[w(s) | \theta] - W$ consequently *decreases*, implying that an increase in W indeed pushes the cutoff θ^* upwards.

Proposition 3. *Under the optimal CEO compensation scheme in Proposition 2, the board can reduce the CEO’s entrenchment by increasing his severance pay. This is despite the fact that an increase in the CEO’s severance pay must be matched by a simultaneous increase in his expected on-the-job compensation.*

Proof. See Appendix.

The optimal value of W trades off the benefit of reducing entrenchment against the cost of leaving the CEO more rents. While the optimal value of W depends on the distributional assumptions, it can be shown that it is never optimal to leave the CEO so much rents as to fully eliminate his entrenchment. That is, it is never optimal to set $\theta^* = \theta_{FB}$. To see this, note by standard arguments that a marginal change in θ^* at $\theta^* = \theta_{FB}$ has a negligible effect on total payoffs. A marginal reduction in the CEO’s rents, however, constitutes a first-order cost savings

for shareholders.

Proposition 4. *Under the optimal CEO compensation scheme in Proposition 2 there is always some entrenchment, i.e., there are states of nature in which the CEO hides negative information to avoid being fired while firing him would be first-best efficient.*

Proof. See Appendix.

3.3 General Compensation Schemes

The optimal compensation package is structured so as to minimize the CEO’s incentives to hide negative information. Given that the CEO’s information is a continuous variable θ , one might wonder if the board can possibly do better by tying his compensation closer to the state of nature. We now show that this is not the case.

A more general mechanism would specify that the CEO—after observing the state of nature—can choose from a menu of compensation packages. The corresponding direct mechanism would specify for any (announced) state of nature $\theta \in \Theta$ i) the board’s action whether to fire or retain the CEO, and ii) either a severance payment $W(\theta)$ if the CEO is fired or some on-the-job compensation scheme $w(s, \theta)$ if he is retained. Unlike previously, both w and W may now depend nontrivially on the state of nature. Denote the set of states in which the CEO is fired by Θ_- and the set of states in which he is retained by $\Theta_+ = \Theta/\Theta_-$.

It is straightforward to see that it is not possible to implement different levels of severance pay for different states of nature $\theta \in \Theta_-$. This is because the CEO—conditional on announcing some state $\theta \in \Theta_-$ —would always announce the state that yields him the highest severance pay. That is, he would always announce $\theta \in \arg \max_{\theta' \in \Theta_-} W(\theta')$. The CEO’s severance pay must consequently be a constant $W(\theta) = W$.

There is a similarly straightforward argument why introducing a menu of on-the-job compensation schemes $w(s, \theta)$ is not helpful. All the board needs to know for its decision is whether θ is an element of Θ_- or Θ_+ . Neither in the case where the CEO is fired nor in the case where he is retained does the board gain anything by having more detailed information. Hence, there is no obvious benefit from letting the CEO choose from a menu that reveals more about the underlying state of nature. In what follows, we prove an even stronger result that a richer menu of on-the-job compensation schemes $w(s, \theta)$ is *strictly suboptimal*. The uniquely optimal solu-

tion to the board’s problem is thus to give the CEO the uniquely optimal “single” on-the-job compensation scheme $w(s, \theta) = w(s)$ derived in Proposition 2.

The intuition is as follows. As the CEO’s optimal on-the-job compensation scheme is an option, it shifts more of his compensation into states where the firm’s value s is high—thus shifting more of his expected on-the-job compensation $E[w | \theta]$ into high states of nature—than any other feasible on-the-job pay compensation scheme. By construction, any richer menu of compensation schemes $w(\theta, s)$ —regardless of whether or not it includes the optimal “single” compensation scheme—will therefore shift some of the CEO’s expected compensation “back” into low states of nature. In short, a richer menu does not minimize $E[w | \theta]$ in low states of nature. But this property of minimizing the CEO’s expected on-the-job compensation in low states of nature is precisely what drives optimality in our model, since it allows to reduce his entrenchment at the lowest cost to shareholders. Under any richer menu $w(\theta, s)$ the board would thus either have to pay the CEO more rents to implement the same cutoff θ^* , or—if it wants to hold the CEO’s rents fixed—tolerate more entrenchment, i.e., tolerate a lower cutoff θ^* .

Proposition 5. *Even though the CEO has private information in $t = 1$, it is uniquely optimal for the board to offer him a simple compensation package consisting of a single on-the-job compensation scheme $w(s)$ and a fixed severance pay W .*

Proof. See Appendix.

4 Comparative Statics Analysis

4.1 CEO Pay and the Firm’s Business Environment

Our previous analysis shows that mitigating CEO entrenchment is costly. To induce the CEO to make room for value-increasing changes in the firm’s strategy and leadership, he must be granted rents—rents that are potentially very costly to shareholders. Given that reducing CEO entrenchment is costly, the question is how much entrenchment should the board optimally tolerate? This section shows that the answer depends on the firm’s business environment. In a stable business environment where it is unlikely that a “regime change”—i.e., a fundamental change in the firm’s strategy and leadership—becomes optimal anytime soon, the cost to shareholders of having an entrenched CEO is relatively small. Conversely, in an uncertain business environment

where it is quite likely that a regime change becomes optimal, the cost of having an entrenched CEO is potentially severe.

In our model, the likelihood that a regime change becomes optimal is $F(\theta_{FB})$. As θ_{FB} increases, the cost to shareholders of having an entrenched CEO thus increases. The board's optimal response is consequently to give the CEO stronger incentives not to become entrenched. That is, the optimal response to an increase in θ_{FB} is to also increase θ^* . As we know from our previous analysis, this implies that the board must increase both the CEO's severance pay and his on-the-job option grant. The following proposition summarizes this discussion.²³

Proposition 6. *As the firm's business environment becomes more uncertain—so that it becomes more likely that a change in the firm's strategy and leadership becomes optimal—the board must i) grant the CEO more severance pay and thus more rents, and ii) raise the CEO's on-the-job option grant, implying that iii) the likelihood that the CEO will be fired increases.*

Proof. See Appendix.

Proposition 6 ties together some recent trends and developments. Holmström and Kaplan (2001), like others (e.g., Jensen (1993)), have argued that since the late 1970s, the “pace of economic change has accelerated”. Between 1978 and 1996, some of the most important industries in the U.S., including airlines, broadcasting, entertainment, natural gas, trucking, banks and thrifts, utilities, and telecommunications, have experienced massive deregulations (Andrade, Mitchell, and Stafford (2001)). The 1980s and 1990s also witnessed fundamental technological innovations, notably in the computer and telecommunications industry, that have fundamentally altered the industrial landscape in the U.S. These developments—key forces behind what Jensen (1993) calls “Modern Industrial Revolution”—have put increasing pressure on U.S. firms to change their business strategies, industry focus, and often their leaderships. The takeover and merger waves of the 1980s and 1990s are frequently viewed in this context.

Proposition 6 argues that the ability to adapt to changes in the firm's business environment comes at a cost: CEO compensation, both in terms of severance pay and option grants, must increase. This is consistent with both the recent surge in severance pay (Walker (2005)) and the dramatic increase in CEO option grants. As Hall and Liebman (1998) document, the mean

²³We assume that the optimal choice of W is unique, implying that both $w(s)$ and θ^* are uniquely determined. If we relax this assumption, all our results hold qualitatively for the respective sets of optimal values.

value of CEO option grants has increased almost sevenfold between 1980 and 1994, from about \$155,000 to over \$1,210,000; a trend that continued throughout the second half of the 1990s. Proposition 6 also implies that along with this trend, the likelihood of CEOs being fired should increase. This is consistent Huson, Parrino, and Starks' (2001) finding that forced CEO turnover has increased considerably over the past decades.

The recent surge in CEO pay is the subject of several related studies. Like our paper, Dow and Raposo (2003) link the surge in CEO pay to an increasing need for firms to change, albeit their explanation is different from ours. Bebchuk and Fried (2004), on the other hand, argue that entrenched CEOs have become more effective at stealing from shareholders. While entrenchment is also at the heart of our story, our model argues that the increase in CEO pay may be optimal from shareholders' perspective. Murphy and Zábojník (2004) argue that the increase in CEO pay reflects a fundamental shift in the relative importance of general versus firm-specific human capital. Beneficiaries are especially CEOs with above-average general human capital, whose compensation is bid up by the market. Finally, Hermalin (2003) argues that the surge in CEO pay reflects greater board diligence in monitoring CEOs. To compensate CEOs for the greater likelihood of being fired, their pay must increase.

Institutional investors in many countries have recently turned against large CEO compensation packages, mainly in response to public pressure.²⁴ Policymakers have also rallied against generous CEO option grants. For example, Paul Volcker, currently chairman of the International Accounting Standards Committee and formerly chairman of the Board of the Federal Reserve System, advocates to discourage public companies from using options to compensate their executives (The Conference Board (2002)). Our model does not imply that CEO option grants are unequivocally desirable. For instance, if the option grant is too large relative to the CEO's severance pay it will only aggravate the entrenchment problem. Our model does, however, suggest that putting a lid on the size of CEO option grants or replacing options with less high-powered incentive schemes may easily backfire. The consequences may be more CEO entrenchment, less flexibility and organizational change, and lower shareholder value.

²⁴In the UK, listing rules were amended in 2002 to require firms to publish their directors' remuneration reports, which must be approved by shareholders. While this approval is only advisory, the vote helped shareholder activists to gain publicity in their fight against "fat-cat pay", e.g., in the case of the advertising company WPP, the retailing chain Sainsbury's, and perhaps most prominently, in the rejection of a £20 million severance package for the head of GlaxoSmithKline, Britain's biggest drug manufacturer.

4.2 CEO Pay and Firm Size

The cost of having an entrenched CEO is naturally greater the more there is at stake. Accordingly, entrenchment is more costly in larger firms. In conjunction with our previous results, this implies that CEOs in larger firms should receive severance packages and option grants. The following proposition confirms this intuition.²⁵

Proposition 7. *CEOs of larger firms should receive larger severance packages and more valuable option grants.*

Proof. See Appendix.

To model changes in firm size, we have scaled up both V and s by a factor $\alpha > 0$. We have not scaled up the CEO's private benefits B . This is because it seems not obvious to us if CEOs of larger firms need to work more or less hard. If B increases along with the firm's size, this would only reinforce the statement in Proposition 7. Finally, it goes without saying that there are many alternative reasons for why CEOs of larger firms might be paid more, e.g., larger firms might need more talented, and thus more expensive, CEOs.

5 Conclusion

This paper offers a simple theory of how CEOs' incentives to hide information from the board might depend on their compensation structure, and how boards can mitigate the problem by structuring CEO compensation optimally. The optimal CEO compensation scheme is a combination of severance pay and options. Option pay forces the CEO to "put his money where his mouth is" by making it as costly as possible for him to falsely assert that the firm's future prospects are good.

While we show that generous option grants and severance packages may be warranted in some circumstances, our model does not give a carte blanche to high CEO compensation. Options are only effective if the board strikes the right balance between the CEO's option grant and his severance package. If the option grant is too large, the CEO will never want to give up power. Conversely, if the severance package is too large, the CEO will inefficiently focus on his exit options. Finally, given that CEOs must be offered potentially large severance packages

²⁵As in Proposition 6, we assume that the optimal choice of W is unique.

and option grants, it is not optimal to eliminate CEO entrenchment completely. That is, our solution is second-, but not first-best efficient.

While we believe the basic insight from our model is intuitive, it ought to be said that we consider a particular problem in isolation, which implies our results must be interpreted accordingly. For instance, while the CEO can influence the board’s decision to fire or retain him at the interim stage, he cannot manipulate the firm’s publicly observable long-run share value (“ s ” in our model). If he could (e.g., through accounting fraud), his incentives to manipulate might be weaker under a less high-powered compensation scheme.²⁶ The precise answer would depend on how one models the CEO’s manipulation technology and cost function.

Finally, to derive a closed-form solution for the CEO’s compensation scheme, we have assumed that the CEO is risk neutral. While this assumption is restrictive, it is frequently argued that it is less of a problem for CEOs, who are potentially less risk averse than ordinary employees due to their high wealth and the selection process they have gone through to become CEO.²⁷ Note, however, that our basic argument that shifting the CEO’s compensation into states where the firm value is high minimizes his entrenchment carries over to risk-averse CEOs. That is, as long as the CEO’s utility function is increasing in his final wealth. The flip side, of course, is that risk-averse CEOs will require a higher expected compensation that—under standard assumptions—will increase with the steepness of their compensation scheme.

6 Appendix

Proof of Proposition 2. The fact that $W > 0$ follows from the argument in the main text. It remains to prove that it is uniquely optimal to compensate the CEO with an option and a fixed pay just equal to C .

We argue to a contradiction. Suppose thus that the board wants to implement some θ^* with an on-the-job pay scheme $\tilde{w}(s)$ satisfying $\tilde{w}(s) \neq C + \max\{0, s - \hat{s}\}$. We denote the corresponding severance pay by \tilde{W} . We show that there exists some $w(s)$ such that (i) the constraint (4) remains binding and that (ii) θ^* is still implemented—though now with a lower

²⁶See Bergstresser and Philippon (2004) and Peng and Roell (2004) for empirical evidence that accounting fraud is more likely when executives have high-powered incentive schemes.

²⁷Related models by Hermalin and Weisbach (1998), Hermalin (2004), Dow and Raposo (2003), Eisfeldt and Rampini (2004), and Almazan and Suarez (2003) all have risk-neutral CEOs.

severance pay W . That is, with a slight abuse of notation the new compensation scheme satisfies $\theta^*(w, W) = \theta^*(\tilde{w}, \tilde{W}) = \theta^*$ and $W < \tilde{W}$, which by inspection of (2) contradicts optimality of the original contract $\tilde{w}(s)$.

We proceed in two steps. We first choose $\overline{W} = \tilde{W}$ and $\overline{w}(s) = C + \max\{0, s - \hat{s}'\}$ such that $\theta^*(\overline{w}, \overline{W}) = \theta^*$, i.e., with $d(s) := \tilde{w}(s) - \overline{w}(s)$ we have that

$$\int_S d(s)g_{\theta^*}(s)ds = 0. \quad (7)$$

As $\tilde{w}(s)$ and $s - \tilde{w}(s)$ are both nondecreasing, there exists a value $\tilde{s} \in (\underline{s}, \overline{s})$ such that $d(s) \geq 0$ for all $s < \tilde{s}$ and $d(s) \leq 0$ for all $s > \tilde{s}$, where both inequalities are strict over sets of positive measure. Take now any $\hat{\theta} > \theta^*$. By MLRP of $G_{\theta}(s)$ and (7), it then holds that

$$\begin{aligned} \int_S d(s)g_{\hat{\theta}}(s)ds &= \int_{\underline{s}}^{\tilde{s}} d(s)g_{\theta^*}(s)\frac{g_{\hat{\theta}}(s)}{g_{\theta^*}(s)}ds + \int_{\tilde{s}}^{\overline{s}} d(s)g_{\theta^*}(s)\frac{g_{\hat{\theta}}(s)}{g_{\theta^*}(s)}ds \\ &< \frac{g_{\hat{\theta}}(\tilde{s})}{g_{\theta^*}(\tilde{s})} \int_S d(s)g_{\theta^*}(s)ds = 0, \end{aligned} \quad (8)$$

which implies that the constraint (4) is slack if we choose $\overline{w}(x)$ and \overline{W} . In a second step, we can now construct the asserted compensation scheme with $w(s) = C + \max\{0, s - \hat{s}\}$ and $W < \overline{W} = \tilde{W}$. For this we (continually) increase \hat{s}' in $\overline{w}(s) = C + \max\{0, s - \hat{s}'\}$ and decrease \overline{W} , while still satisfying $\theta^*(\overline{w}, \overline{W}) = \theta^*$, until (4) becomes again binding. That this is possible follows as, while we keep $E[\overline{w}(s) | \theta^*] = \overline{W}$ satisfied, the difference $E[\overline{w}(s) | \theta] - \overline{W}$ continuously decreases for all $\theta > \theta^*$. To see this, note that after partial integration we have $dE[\overline{w}(s) | \theta]/d\hat{s}' = -[1 - G_{\theta}(\hat{s}')]$, which by FOSD of $G_{\theta}(s)$ (implied by MLRP) is strictly decreasing in θ . This completes the proof of Proposition 2. **Q.E.D.**

Proof of Proposition 3. We know from Proposition 2 that in order to implement a given θ^* it is uniquely optimal to do so with $w(s) = C + \max\{0, s - \hat{s}\}$. Substituting $w(s)$ and using partial integration, (1) transforms to

$$C + (\overline{s} - \hat{s}) - \int_{\hat{s}}^{\overline{s}} G_{\theta^*}(s)ds = W \quad (9)$$

and (6) transforms to

$$\int_{\theta^*}^{\overline{\theta}} \left[C + (\overline{s} - \hat{s}) - \int_{\hat{s}}^{\overline{s}} G_{\theta}(s)ds - W \right] f(\theta)d\theta = B. \quad (10)$$

From (9) and (10) we then have by total differentiation (and the assumed differentiability of $G_\theta(s)$) that

$$\frac{d\theta^*}{dW} = \frac{\int_{\theta^*}^{\bar{\theta}} [G_\theta(\hat{s}) - G_{\theta^*}(\hat{s})] f(\theta) d\theta}{\left[\int_{\theta^*}^{\bar{\theta}} [1 - G_\theta(\hat{s})] f(\theta) d\theta \right] \left[\int_{\hat{s}}^{\bar{s}} \frac{G_\theta(s)}{d\theta} \Big|_{\theta=\theta^*} ds \right]} > 0, \quad (11)$$

where we used that $G_\theta(s)$ satisfies FOSD (implied by MLRP). That is, in order to implement a higher θ^* it is necessary to increase W . By (9) this also requires to increase the value of the on-the-job pay by decreasing \hat{s} . **Q.E.D.**

Proof of Proposition 4. From (2) and using that $E[w(s) | \theta^*] = W$, the first-order condition w.r.t. W equals

$$E[s | \theta^*] - V = \frac{-F(\theta^*)}{f(\theta^*)(d\theta^*/dW)}, \quad (12)$$

where we can substitute $d\theta^*/dW$ from (11). As $d\theta^*/dW > 0$, we have at an interior solution that $E[s | \theta^*] - V < 0$ and thus that $\theta^* < \theta_{FB}$. **Q.E.D.**

Proof of Proposition 5. We can again restrict consideration to on-the-job pay schemes $w(s, \theta)$ that are strictly increasing at some s . Given that all $w(s, \theta)$ are thus strictly increasing somewhere and that $G_\theta(s)$ satisfies MLRP, the truthtelling constraint implies again that $\Theta_- = [\underline{\theta}, \theta^*]$ and $\Theta_+ = [\theta^*, \bar{\theta}]$ with $E[w(s, \theta^*) | \theta^*] = W$. The following auxiliary result follows now immediately from the proof of Proposition 2.

Claim 1. *Take two different feasible pay schemes $\tilde{w}(s)$ and $\hat{w}(s) = C + \max\{0, s - \hat{s}\}$. Then if $E[\hat{w}(s) | \theta'] \geq E[\tilde{w}(s) | \theta']$ holds for some $\theta' < \bar{\theta}$, it holds strictly for all $\theta > \theta'$.*

To complete the proof, we distinguish between two cases. If $w(s, \theta^*) = C + \max\{0, s - \hat{s}\}$, Claim 1 and truthtelling imply that $w(s, \theta) = C + \max\{0, s - \hat{s}\}$ holds for all θ , i.e., the menu is degenerate. Suppose next that $w(s, \theta^*) \neq C + \max\{0, s - \hat{s}\}$. As in the proof of Proposition 2, we can then construct a single offer $\hat{w}(s) = C + \max\{0, s - \hat{s}\}$ that leads to the same decision rule θ^* and relaxes the constraint (4). This follows as for all $\theta > \theta^*$ we have that $E[\hat{w}(s) | \theta] > E[w(s, \theta) | \theta]$, which in turn follows immediately from Claim 1 and the truthtelling requirement for the original menu. As in Proposition 2, we can then adjust the new (single) on-the-job pay scheme $\hat{w}(s)$ so as to implement θ^* with a lower severance pay. **Q.E.D.**

Proof of Proposition 6. We show that the optimal choice of W is strictly increasing in B , which by (11) implies that the corresponding optimal choice of θ^* is also strictly increasing. Implicit differentiation of the first-order condition for W in (12) gives

$$\frac{dW}{dB} = -\frac{f(\theta^*)(d\theta^*/dW)}{SOC} > 0,$$

where $SOC < 0$ represents the second-order condition, which must be satisfied at an interior optimum. **Q.E.D.**

Proof of Proposition 7. We show that the optimal choice of W is strictly increasing in α , which by (11) implies that the corresponding optimal choice of θ^* is also strictly increasing. Note first that the first-order condition (12) now transforms to

$$\alpha [E[s | \theta^*] - V] = \frac{-F(\theta^*)}{f(\theta^*)(d\theta^*/dW)}, \quad (13)$$

where we can again substitute $d\theta^*/dW$ from (11). Implicit differentiation of (13) gives

$$\frac{dW}{d\alpha} = \frac{E[s | \theta^*] - V}{SOC} > 0,$$

where we used from Proposition 4 that $\theta^* < \theta_{FB}$ at the optimum and that the second-order condition at the optimum requires $SOC < 0$. **Q.E.D.**

7 References

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