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When Less is More: How Limits on Executive Pay can Result in Greater Managerial Effort and the Adoption of Better Strategies*

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Abstract

We derive conditions under which state-imposed limits on executive compensation can enhance efficiency and benefit shareholders (but not executives). Having their hands tied in the future allows a board of directors to credibly enter into relational contracts with executives that are more efficient than performance-based contracts. This in turn can have implications for firm strategy and the ideal composition of the board. The analysis also offers insights into the political economy of executive-compensation reform.

Keywords: Executive compensation, boards of directors, relational vs. performance-based contracting.

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1 Introduction

Executive compensation is a topic of seemingly endless concern. Resentment, rightly or wrongly, about the level and increase in that compensation has fueled political action, as witnessed, for instance, by the "say-on-pay" provisions of the Dodd-Frank law in the US or a recent Swiss referendum on executive pay.[1] Although some scholars have applauded restrictions on executive compensation (see, *e.g.,* Bebchuk, 2007, and Bebchuk and Fried, 2004, 2005), many have opposed them (see, *e.g.,* Bainbridge, 2011, Jensen and Murphy, 1990, Kaplan, 2007, and Larcker et al., 2012). Opposition—or at least suspicion—by economists is not surprising: most basic textbooks in economics caution against legally imposed restrictions on prices. Moreover, there is a significant economic literature that makes a strong case for freedom of contract (see Hermalin et al., 2007, especially Section 2.2, for a survey).

At the same time, the literature does recognize there are situations in which regulating private contracts can be welfare enhancing (see Hermalin et al., Section 2.3, for a survey). Among such situations are those in which the parties benefit by "lashing themselves to the mast": the parties can write better contracts today if their options tomorrow are limited. In this paper, we show that this logic could apply to executive compensation. To be sure, demonstrating, as we do, that circumstances exist in which restrictions on executive compensation can be welfare enhancing does not prove such restrictions are always beneficial; but it at least indicates that the issue is more complex and less straightforward than textbook-economic intuition might otherwise suggest.

The reason why restrictions could be beneficial is the following. Ideally, as in nearly every agency model,[2] the shareholders (or their representatives, the firm's directors) want to write contracts with the firm's executives that are contingent on the executives' actions, not the stochastic consequences of those actions. We assume, however, that there is an informational friction that prevents the parties from doing so: although the directors can observe the executives' actions,[3] that information cannot be verified and, thus, cannot serve directly as a contractual contingency in a formal contract.[4] On the other

[1]So-called say-on-pay provisions are requirements that executive compensation plans be voted upon by shareholders. The details of these laws, in particular the consequences if shareholders vote against compensation plans, vary across jurisdiction. In addition to the US and Switzerland, there are say-on-pay laws in Australia (Corporations Amendment Act 2011) and the UK (Companies Act 2006).

[2]That is, *e.g.,* as true of Grossman and Hart (1983), Holmstrom (1979), Sappington (1983), and Shavell (1979).

[3]We maintain that assumption for most of our analysis. Section 6 considers the case in which the board does not perfectly observe the executive's action.

[4]The literature distinguishes between observable information—that is, information known to the contracting parties—and verifiable information—that is, information that can be learned by a third party charged with adjudicating contractual disputes. If information is not verifiable—cannot be known by such a third party—then it cannot serve as a (formal) contractual contingency because there is no means of enforcing the contingency legally. See, *e.g.,* Hermalin et al. (2007, §4) for a survey of the literature on such "incomplete" contracts.

hand, because the board of directors plays repeatedly, it may be possible to overcome this contracting problem via reputation: the board promises to honor the terms of such an agreement and, even though not legally enforceable, that promise is credible because there is a net loss from reneging; a board that reneges today loses the ability to enter into similar agreements in the future—and thus the benefits accruing from doing so—because future executives will no longer see such agreements as credible. Agreements supported in this manner are known as reputational, relational, or informal contracts (see MacLeod, 2007, or Malcomson, 2013, for surveys of the relevant literature).

Just how costly it is to lose credibility—and hence how much the board is deterred from reneging—depends on how good the next-best alternative to such an informal contract is. Here, the next-best alternative is a series of future formal contracts in which the executives' compensation is positively tied to firm performance, a noisy signal of their actions. The more profitable those contracts are, the greater will be the board's temptation to renege on payments promised under a given relational contract. Indeed, if formal contracting is too good, it will prevent the board from utilizing a fully efficient or profit-maximizing relational contract: the temptation to renege will simply be too great and, anticipating that, the executives will not pursue the desired actions. In such a situation, state-imposed restrictions on the amount of contingent compensation in formal contracts can be beneficial:[5] by making formal contracting worse, the temptation to cheat on a relational contract is reduced, which permits the use of more optimal relational contracts.

It has long been recognized that relational contracts become more precarious as formal contracts become more attractive.[6] Of particular note is Baker et al. (1994), which, in many ways, is the work closest to ours. In that article, the authors assume the agent's action generates two signals, one observable, but not verifiable (what they call a subjective performance measure) and the other verifiable (what they call an objective performance measure). The subjective measure is also the agent's contribution to firm profit. The authors consider what happens as the objective measure becomes, on average, a better estimator of the subjective measure (their notion of formal contracting improving). They show that there is, essentially, a cutoff point, which, once achieved, renders relational contracting based on the subjective measure infeasible. Because, for high enough discount factors, the first-best outcome would otherwise be achieved under a relational contract, the principal is made worse off by improved formal contracting (*i.e.,* contracting on the objective measure): unless the objective measure is *perfectly* correlated with the subjective measure, having to rely only

[5]Some authors (*e.g.,* Bebchuk and Fried, 2004, Jensen and Murphy, 1990, or Roe, 1994) have suggested that moral or political pressure could serve—in addition or in lieu of legal restrictions—to limit executive compensation.

[6]Schmidt and Schnitzer (1995) show that, as the cost of writing formal contracts falls, the harder it will be sustain relational contracts. Other related work in this vein consider improvements in the legal system or other formal institutions: see, *e.g.,* Kranton (1996), Kranton and Swamy (1999), and McMillan and Woodruff (1999a,b).

on a formal contract means the first-best outcome is unattainable.

Although closer to us than other work in the literature, there are some key differences between our model and Baker et al.'s. First, the frictions that generate the agency problems differ: in particular, a major friction in our model stems from the agent's (executive's) limited liability—all payments to him must be non-negative—whereas in Baker et al. the friction is due to the agent's private information about a key parameter.[7] Second, we allow for the possibility that repetition not only supports a relational contract, but also permits an efficiency-wage effect under formal contracting: the board can induce greater effort from the executive than it could in a one-period model because it can threaten the executive with the loss of future rents. Third, we study the consequences of actually restricting the terms of the contract, not variations in the correlation between performance measures. Fourth, and in many ways most critical, a key finding of our analysis is that principal (board) and agent (executive) will tend to have opposing preferences concerning the use of relational versus formal contracts: as a rule, the principal prefers relational contracting and, therefore, favors caps on contingent compensation; while the agent prefers formal contracts, which allow him to earn a rent, and thus he is opposed to caps on contingent compensation. These opposing preferences are reflected in the actual public policy debate over restrictions on pay, with shareholder advocates on one side and executives on the other. In contrast, to the best of our knowledge, all the other work in this literature finds either that both sides of the contract are better off if relational contracting is sustainable or one side is better off and the other indifferent (as in Baker et al.).

We set forth our model in the next section. Among the model's assumptions, two warrant discussion upfront: we assume that the board of directors is a perfect agent for the shareholders and that the directors (hence, shareholders) possess all bargaining power *vis-à-vis* the executives. The first of these means we are not considering limits on executive compensation as a means of correcting the agency problem that exists between shareholders and their boards (a line of argument advanced by Bebchuk, 2007, among others). Although we briefly consider some issues complementary to that hypothesis in Section 5, we are basically agnostic as to the value of compensation limits as a means of addressing shareholder-board conflict. Instead, our focus is on demonstrating that such limits can be beneficial even in the absence of such conflict.

By assuming the directors (hence, shareholders) have all the bargaining power, we avoid another possible rationale for shareholders to seek limits on compensation: namely, a desire to achieve through legislation what they cannot achieve through direct bargaining. In other words, the benefits shareholders derive from limits on compensation in our model are not simply legislated redistribution: even when the shareholders/directors are free to choose the contract they wish, we show they could nevertheless benefit from limits for the lashing-

[7]Specifically, Baker et al. assume that the objective and subjective measures have correlation μ, which is a random variable that varies across periods. The agent learns each period's μ before choosing his action and his knowledge of μ is his private information.

themselves-to-the-mast reason given above.

That noted, we do briefly consider, in Section 5, the opposite scenario in which the executive holds all the bargaining power. In that scenario, imposing limits on compensation can reduce efficiency, but can nonetheless increase the well-being of shareholders. The reasoning, though, is subtle: in most models, restrictions on contracts harm the party with the bargaining power, but leave the other party unaffected because the other party remains held to its reservation payoff. Here, in contrast, restrictions can induce the executive (the party with the bargaining power) to move to a contract that generates some rents for the shareholders because doing so is necessary if he is to maximize his compensation given those restrictions (see Proposition 9 below).

In the second half of the next section (Section 2.2), we show that a board limited to offering formal contracts only will never achieve full efficiency (Proposition 1): a formal contract always entails leaving the executive with a rent, so the board faces a tradeoff between inducing greater effort and increasing the executive's rent. Consequently, the board's most-preferred formal contract is less than fully efficient. In contrast, as we show in that section and Section 3, the board can avoid paying the executive a rent under an informal (relational) contract. It follows that a sufficiently patient board can and will achieve full efficiency, with all surplus going to the shareholders.

The discussion so far might seem to suggest that the use of formal or informal contracts is an either-or proposition. That is not, in fact, what we consider: the board can offer a contract that is a "hybrid" of the two; that is, that possesses elements of both a purely formal and purely informal contract. Most of our analysis (principally in Section 4) concerns a board with the ability to offer hybrid contracts and sets forth conditions under which limits on contingent compensation enhance efficiency and firm profits (see, in particular, Propositions 3–6 and their corollaries). We underscore the nuanced nature of our results: although, in some circumstances, a prohibition on contingent compensation would be beneficial, in others, caps, but not outright bans, would be optimal. Furthermore, if the board is sufficiently patient, or the executive sufficiently impatient, or both, then limits on contingent compensation could simply be unnecessary: in those situations, formal contracting poses no "threat" to informal contracting.

In Section 6, we relax our assumption that the board is a perfect monitor. Instead, we assume boards vary in quality, which we model as the probability that a board learns the executive's action in any given period. When the board is an imperfect monitor, then it will wish to offer, *ceteris paribus*, a contract that contains a contingent-compensation provision. Nonetheless, for a range of parameter values, it can still benefit if a cap on contingent compensation is imposed. Because lower-quality boards will tend to offer more generous contingent compensation, all else equal, firms with lower-quality boards benefit less from the imposition of caps on contingent compensation than do higher-quality boards. We also show that the marginal value of improving board quality depends on whether contingent compensation is capped. If it is capped, then the marginal value of improving board quality is greater than if it is not. This particular relation between board quality and executive compensation is, we believe, novel and serves to complement other recent work that has also sought to examine the relation between the qualities of the board and executive pay (see, *e.g.,* Hermalin, 2005, and Kumar and Sivaramakrishnan, 2008; see, too, Adams et al., 2010, for a survey of some of the relevant literature). Among the implications of our analysis is that, if board quality is *endogenous*, we should expect to see greater board quality when contingent compensation is capped; or, somewhat conversely, we should expect to see a negative correlation between board quality and levels of contingent pay.

In Section 7, we consider the implications our model has for the firm's choice of strategy. We assume, there, that there are two possible strategies, one which yields verifiable metrics that can serve as contingencies for compensation under a formal contract and another for which such metrics are lacking. For the latter, essentially only informal contracting can be used to provide the executive incentives. Consequently, the board's ability to implement the latter strategy can depend on the former strategy's not being too good an alternative. A limit on contingent compensation shapes the attractiveness of the former as an alternative. On the whole, we imagine that short-term strategies, with relative quick resolutions, or strategies with clear metrics, such as acquisitions, are those for which formal contingent contracts are readily used, while long-term strategies, with delayed resolutions, or strategies with messier metrics, such as innovation, could be those for which the firm would need to rely on informal contracting (if sustainable). It follows that our model complements other models of firm or managerial myopia (*e.g.,* Bizjak et al., 1993, Bolton et al., 2006, or Stein, 1989). In particular, our model suggests that when or wherever there are limits on contingent compensation, there could be a greater tendency to pursue longer-run or less metric-rich strategies, *ceteris paribus*.

In Section 8, we discuss the various implications of the analysis for understanding general trends in governance and its implications for empirical research. Of particular note is our discussion of the model's implications for the political economy of restrictions on executive pay. In many economic models, if a reform would improve efficiency, it would be welcome, at least weakly, by all parties. A larger pie typically means more for everyone. Even if the gains flow to only one party, in many models the other party is no worse off. Here, though, as noted above, the effects are asymmetric: in most variants of our model, shareholders benefit from restrictions while executives lose. This, as noted, helps to explain the battle lines in the ongoing policy debates over executive compensation.[8] Section 8 also contains a brief conclusion.

Proofs that do not disrupt the flow of the argument are given in the main text. The remainder are presented in the appendix.

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[8]Consider, *e.g.,* the very different views of the Business Roundtable, an executives' organization, from those of shareholder advocates (Castellani, 2007, and Bebchuk, 2007, respectively).

2 Basic Model

2.1 Structure and Preferences

There are two parties: a board of directors and a chief executive officer (CEO). In what follows, we treat the board as if it were a single actor, which seeks to maximize the firm's profit (value); that is, the board is a perfect agent for the shareholders (we discuss this assumption further in Sections 5).

Our model supposes the infinite repetition of the following stage game. At the beginning of each period (stage), the board and CEO agree on the contract governing that period; next, the CEO takes an action, $p \in \mathcal{P}$; then the board obtains information about that action and, additionally, a verifiable outcome, success or failure, is realized.

Because, as we discuss below, the firm's payoff is a function of the verifiable outcome only, it is without loss of generality to let the CEO's action correspond to the probability of a successful outcome. That is, success is realized with probability p, failure with probability $1-p$, and $\mathcal{P} = [0,1]$.

The CEO's per-period utility is zero if he is not employed by the firm (this is his reservation utility) and it is $y - c(p)$ otherwise, where y is his compensation and $c : \mathcal{P} \to \mathbb{R}_+$ his disutility-of-action function. The firm's (board's) payoff is $g - y$ if success occurs and $-y$ otherwise (*i.e.,* g is the gain the firm derives from success relative to failure).[9] Note all actors are risk neutral.

Both CEO and board discount the future: let $\gamma \in [0,1)$ and $\delta \in (0,1)$ denote their respective discount factors. These discount factors reflect financial discounting, as well as any *exogenous* uncertainty about the game continuing to the next period. In particular, because the CEO likely has a higher exit rate than the firm,[10] it is reasonable to suppose $\gamma < \delta$. Indeed, a case of some interest is $\gamma = 0 < \delta$: the CEO is a short-run player (*i.e.,* the firm hires a succession of CEOs over time), but the board is a long-run player.[11] Although tractability dictates limiting attention to that case in Section 6, most of our analysis requires either no condition on γ versus δ or only that γ not exceed δ (*i.e.,* that the CEO not be more patient than the board).

To avoid corner solutions and multiple best responses for the CEO, we assume the following about the disutility-of-action function:[12]

- $c(0) = 0$;
- the CEO's *marginal* disutility of action is increasing—the function $c(\cdot)$ is strictly convex (*i.e.,* $c''(p) > 0$ for all $p \in [0,1]$); and

[9] Note nothing in the analysis precludes there being a component of profit that is independent of the activity modeled here: the amount g is the additional profit success brings, not necessarily the firm's total gross profit.

[10] By exit rate, we include incapacitation, retirement, and simply death.

[11] See Kreps (1990) for an analysis of how long-lived institutions can maintain long-term reputations even when composed of short-lived members (*e.g.,* individual directors).

[12] Throughout, we use a single prime to denote a first derivative (*e.g.,* $c'(p) = dc(p)/dp$) and a double prime to denote a second derivative (*e.g.,* $c''(p) = d^2c(p)/dp^2$).

- $0 \leq c'(0) < g < c'(1)$.

The last point implies that there is a positive action ($p > 0$) that is welfare superior to the null action ($p = 0$), but that guaranteed success ($p = 1$) is *not* welfare (surplus) maximizing. Given $c'(0) \geq 0$, integrating c'' establishes that the CEO's disutility of action increases with the probability of success: $c'(p) > 0$ for all $p \in (0, 1]$.

Lemma 1. *A unique surplus-maximizing action, $p^*(g)$, exists, $0 < p^*(g) < 1$.*[13]

2.2 Information and Contracts

Except in Section 5, we assume that the bargaining power resides with the board: each period, the board offers the CEO a contract on a take-it-or-leave-it basis. There are, however, limits on what the board can propose: consistent with reality, as well as limited-liability protections and other legal restrictions, we assume the CEO cannot be compelled to make payments to the firm.

Recall the outcome, success or failure, is verifiable. It can, thus, serve as a contractual contingency. Let $b \in \mathbb{R}_+$ denote the additional compensation (bonus) the CEO is contractually promised for achieving success.[14]

Payments are also verifiable. Hence, the board can promise a non-contingent level of compensation, $w \in \mathbb{R}_+$ (the base wage or salary).

We earlier assumed that the board also obtains other information about the CEO's action beyond whether the outcome is a success or not. In what follows, we assume that this other information is not verifiable: no third party, who might be called upon to adjudicate a contractual dispute between board and CEO, can learn it. Hence, direct enforcement of a promised payment that is contingent on this information is impossible. Enforcement must be indirect: a broken promise today can be punished in the future only.[15] Specifically, we assume grim-trigger strategies: if the firm (board) reneges on a promised payment to the CEO, neither that CEO nor any subsequently hired CEO will ever trust such a promise in the future.[16]

[13]The rationale for labeling the surplus-maximizing action $p^*(g)$ will become clear shortly.

[14]Although we refer to b as a bonus, it should be understood that this could represent stock-based compensation (*e.g.,* stock options). The critical feature is that it is compensation contractually linked to a verifiable measure of performance.

[15]In light of Hermalin and Katz (1991), one might wonder whether renegotiation would be another means for the parties to contract effectively on this other information, at least if there is time to renegotiate a contract between the realization of this information and the verifiable outcome. The answer is no and the reason is that, in Hermalin and Katz, the value of renegotiation is that it eliminates the insurance-incentive tradeoff that arises in agency models with risk-averse agents. Here the agent (the CEO) is risk neutral and the contractual friction is, instead, due to his limited liability; that is, the impossibility of making him pay the firm.

[16]There is a subtle issue of how a subsequently hired CEO would learn the board reneged given that information is assumed unverifiable. Some possibilities are that, once on the job, a new CEO would receive evidence that indicated his predecessor had been cheated (this is

We assume this other, unverifiable, information is perfect; that is, the board observes the CEO's action, p. Let $\tau : \mathcal{P} \to \mathbb{R}_+$ denote the transfer (payment) schedule that the board promises to follow. We refer to this as the *informal component* of compensation. Because payments themselves are verifiable, the board is contractually obligated to pay $\min_{p\in[0,1]} \tau(p)$; that is, the board has discretion only over the portion of $\tau(p)$ in excess of the minimum possible transfer. On the other hand, there is no loss of generality in folding $\min_{p\in[0,1]} \tau(p)$ into w, the base wage; that is, we can and will set $\min_{p\in[0,1]} \tau(p) = 0$.

To summarize, a contract, $\langle w, b, \tau(\cdot)\rangle$, is a triple containing a non-contingent payment, w; a bonus, b, paid if a successful outcome is realized; and an informal component, $\tau(\cdot)$, which is a function of the CEO's observable, but unverifiable, action, p. Call a contract of the form $\langle w, b, 0\rangle$ (*i.e.,* where $\tau(p) = 0$ for all p) a *formal contract*. When confusion is unlikely, we will sometimes omit the zero and write a formal contract as $\langle w, b\rangle$. Call a contract of the form $\langle w, 0, \tau(\cdot)\rangle$ (*i.e.,* with no bonus) an *informal contract*. Analogously, when confusion is unlikely, we will sometimes omit the zero and write an informal contract as $\langle w, \tau(\cdot)\rangle$. It is worth briefly analyzing these two contractual extremes before proceeding to a more complete analysis.

Formal Contracts. Suppose the board uses a formal contract only. Given the game's stationarity, it is without loss to assume that the same contract is offered in every period. We begin with a somewhat naïve analysis of such contracts—one that ignores the repeated-game aspect of the situation—then turn to a more sophisticated analysis.

Consider a wholly myopic CEO (*i.e.,* one whose $\gamma = 0$). Because only the current period matters to him, he responds to contract $\langle w, b\rangle$ by maximizing his current expected utility. His choice of action thus solves

$$\max_{p\in[0,1]} w + bp - c(p)\,. \tag{1}$$

Observe that w is irrelevant to the solution to that program. Given previously made assumptions, (1) has a unique solution, which we denote as $p^*(b)$.[17] It can be shown, via well-known comparative statics results (see Lemma A.1 in the Appendix), that $p^*(\cdot)$ is a nondecreasing function and it is strictly increasing when $p^*(b) \in (0, 1)$.

Because the CEO cannot be made to pay the firm, the firm cannot possibly profit from a contract in which $b > g$. Consequently, there is no loss in what follows to restricting $b \leq g$ and it should be understood, going forward, that $b \leq g$. Observe this entails $p^*(b) \leq p^*(g)$.

especially plausible if the new CEO comes from within the firm). Another is that industry insiders—such as a new CEO—would know, but such knowledge is so difficult and expensive to communicate to outsiders—such as judges—that it is infeasible to contract directly on it.

[17] In particular, it is straightforward to establish this by redoing the proof of Lemma 1 with b in place of g.

Lemma 2. *A myopic* CEO *earns a rent (expected utility in excess of his reservation utility) under a formal contract that induces an action greater than 0. In particular, if $p^*(b) > 0$, then $bp^*(b) - c\big(p^*(b)\big) > 0$.*

The CEO is not necessarily myopic; that is, we wish to allow for the possibility that $\gamma > 0$. This, in turn, gives the board an additional instrument in its contract design: it can threaten the CEO with the loss of future rents should he fail to take (or exceed) a target action $\widetilde{p}$.[18] Specifically, suppose the board offers the CEO the contract $\langle w, b\rangle$, but informs him it expects him to meet the target $\widetilde{p}$, $\widetilde{p} > p^*(b)$.[19] If he fails to meet the target, he will be dismissed. Given the stationarity of the game, if it is optimal for the board to offer that contract and set that target today, it will be optimal for it to do so in every period. Because $\widetilde{p} > p^*(b)$ and $bp - c(p)$ is strictly concave in p, the CEO will never wish to exceed the target. He will wish to meet the target if

$$\sum_{t=0}^{\infty} \gamma^t \big(w + b\widetilde{p} - c(\widetilde{p})\big) \geq w + bp^*(b) - c\big(p^*(b)\big)\,,$$

where the lefthand side is the present discounted value of the CEO's utility if he meets the target every period and the righthand side is the best he can do if he decides not to meet the target. This last expression can be rewritten as[20]

$$w + b\widetilde{p} - c(\widetilde{p}) \geq (1-\gamma)\Big(w + bp^*(b) - c\big(p^*(b)\big)\Big)\,. \tag{2}$$

Lemma 3. *Expression* (2) *holds as an equality in any equilibrium in which the firm offers a formal contract only.*

Intuitively, were (2) not binding, then the firm could profitably reduce the CEO's compensation without destroying his incentive to choose target action $\widetilde{p}$.

The next lemma considers whether the optimal formal contract consists of just a bonus, or a non-contingent wage, or some combination thereof.

Lemma 4. *Suppose there is no limit or cap on bonuses, then a firm limited to formal contracts only will offer a contract of the form $\langle 0, b\rangle$; that is, the non-contingent portion of compensation will be zero.*

Intuitively, consider a dollar reduction in the non-contingent portion of compensation, w, and a corresponding increase in the bonus rate of $1/\widetilde{p}$. This is income neutral (*i.e.,* the lefthand side of (2) is unchanged), but it *reduces* the CEO's rent by $1 - p^*(b)/\widetilde{p} > 0$ (*i.e.,* lowers the righthand side of (2)). By the logic of Lemma 3, this would benefit the firm: the optimal w for the unconstrained firm is, thus, zero.

The next lemma establishes a functional relation holds between the elements of a formal contract and the target action of the CEO:

[18] This logic is similar to that of efficiency wages (see, *e.g.,* Shapiro and Stiglitz, 1984).

[19] There is *no* possibility that $p^*(b) = 1$ because $b \leq g$.

[20] Recall the well-known fact that, for $\beta \in (0,1)$, $\sum_{t=k}^{\infty} \beta^t = \beta^k/(1-\beta)$.

Lemma 5. *Consider a firm limited to offering formal contracts only. For any* $\langle w, b\rangle$ *that could be offered in equilibrium, there is a unique* $\widetilde{p} > p^*(b)$ *that solves expression* (2) *as an equality. Let* $\widehat{p}(b, w)$ *denote that unique* $\widetilde{p}$. *The function* $\widehat{p}(\cdot,\cdot)$ *is increasing and differentiable in each argument.*

In light of Lemma 4, we will often be concerned with $\widehat{p}(b, 0)$, which, for convenience, we will write as $\widehat{p}(b)$.

There is a friction with formal contracting: the firm (board) cannot avoid paying the CEO a rent. This will lead to inefficiencies:

Proposition 1. *A firm limited to formal contracts will choose to implement an action strictly less than the surplus-maximizing action,* $p^*(g)$. *Such a firm's expected equilibrium profit increases with the* CEO*'s patience (i.e., increases with* γ*) except, possibly, if the expected profit is zero.*

The firm faces a tradeoff when increasing the bonus it offers: a higher bonus induces a higher probability of success (*i.e.,* greater $\widetilde{p}$), but also increases the CEO's rent. In the neighborhood of the optimal action, $p^*(g)$, an increase in $\widetilde{p}$ has second-order benefits, but first-order costs *vis-à-vis* the CEO's rent. Hence, $\widetilde{p} < p^*(g)$. From (2), it follows that the rent is diminishing in γ, which explains why the firm will seek a greater $\widetilde{p}$ the greater is γ.

Define π_{FC} to be the equilibrium per-period expected profit of a firm limited to using only formal contracts given whatever caps or limits on bonuses exist. Let π^*_{FC} be the equilibrium per-period expected profit when there are no caps or limits (or they do not bind). Note, in that case, $w = 0$ given Lemma 4. Finally, let π^0_{FC} be the equilibrium per-period expected profit when bonuses are completely forbidden (*i.e.,* when $b \equiv 0$). From Lemma 4, it follows that $\pi^*_{\text{FC}} \geq \pi_{\text{FC}} \geq \pi^0_{\text{FC}}$, with at least one inequality holding strictly.

Define

$$\pi^* \equiv p^*(g)g - c\big(p^*(g)\big)\,. \tag{3}$$

That amount is the maximum feasible expected per-period profit because the righthand side of expression (3) is the maximum expected surplus (see Lemma 1) and the CEO's reservation utility is zero.

A corollary to Proposition 1 is

Corollary 1. *A firm limited to using only formal contracts earns, in equilibrium, an expected per-period profit less than the maximum feasible expected per-period profit; that is,* $\pi_{\text{FC}} < \pi^*$.

Proof: From Lemma 1, $p^*(g)$ is the unique maximizer of surplus. From Proposition 1, the board implements an action less than $p^*(g)$; hence, surplus is not maximized. Because the firm's expected profit cannot exceed surplus, it follows that $\pi_{\text{FC}} < \pi^*$. ■

As a last result concerning formal contracts, observe that, if bonuses are forbidden, then Lemma 3 implies $\gamma w = c(\widetilde{p})$. Hence,

$$\pi^0_{\text{FC}} = \max_p pg - \frac{1}{\gamma}c(p)\,. \tag{4}$$

Observe, because the optimization program in (4) is equivalent to maximizing $p \times (\gamma g) - c(p)$, it follows from the usual comparative statics (*e.g.,* Lemma A.1) that the solution to (4) is less than $p^*(g)$ (this is a direct demonstration of the main claim of Proposition 1 for this case). On the other hand, because the program in (4) converges to the program for surplus maximization as $\gamma \to 1$ and given $\pi_{\text{FC}} \geq \pi^0_{\text{FC}}$, we have established:

Lemma 6. *A firm limited to formal contracts only can achieve expected per-period profits arbitrarily close to the maximum feasible per-period expected profit as the* CEO *becomes perfectly patient (i.e., as $\gamma \to 1$). In other words, $\pi_{\text{FC}} \to \pi^*$ as $\gamma \to 1$.*

Informal Contracts. Suppose the board wishes to use an informal contract only; that is, $\langle w, \tau(\cdot)\rangle$. As before, we start with a wholly myopic CEO. If he is confident that an informal contract will be honored, then, to maximize his utility, he will choose his action, p, to maximize $\tau(p) - c(p)$. Suppose the board offers $w = 0$ and

$$\tau(p) = \begin{cases} 0\,, & \text{if } p < \widetilde{p} \\ c(\widetilde{p})\,, & \text{if } p \geq \widetilde{p} \end{cases} . \tag{5}$$

If the CEO expects the board to honor the contract (*i.e.,* pay $c(\widetilde{p})$ if $p \geq \widetilde{p}$), then a best response is clearly for him to take action $\widetilde{p}$.

Because the board can never expect to pay less than $c(\widetilde{p})$ to induce a target action $\widetilde{p}$, it follows that the contract given by (5) is the cheapest way for the board to induce $\widetilde{p}$. Moreover, the CEO is earning no rent. Consequently, provided an informal contract is credible, the efficiency-wage-like issues that arose with formal contracts do not apply here. In other words, having begun the analysis by supposing a wholly myopic CEO was without loss.

Expected profit under the contract given by (5) is

$$\widetilde{p}g - c(\widetilde{p})\,.$$

As previously assumed, should the board renege on its promise to pay $\tau(p)$ when the CEO has taken action p, all future play will be governed by formal contracts only; that is, the firm's expected per-period profit will be π_{FC} going forward should it renege today. Given the stationarity of the game, if it makes sense for the board to offer contract (5) today, it makes sense for it to offer it in every period. Hence, the condition for the board not to renege is

$$\sum_{t=0}^{\infty} \delta^t \big(\widetilde{p}g - \tau(\widetilde{p})\big) \geq \widetilde{p}g + \sum_{t=1}^{\infty} \delta^t \pi_{\text{FC}}\,.$$

Or rewriting, using (5), provided that

$$\delta\big(\widetilde{p}g - c(\widetilde{p})\big) \geq (1-\delta)c(\widetilde{p}) + \delta\pi_{\text{FC}}\,. \tag{6}$$

If there exists a $\widetilde{p} > 0$ satisfying (6), then it follows the firm's expected per-period profit from using an informal contract only must exceed π_{FC}. This insight, previous analysis, and the fact that (6) can be rewritten as

$$\delta g\widetilde{p} - c(\widetilde{p}) \geq \delta\pi_{\text{FC}}$$

establish:

Lemma 7. *There exists an informal contract that is credible (i.e., that the* CEO *can trust will be honored) if and only if expression* (6) *holds for* $\widetilde{p} = p^*(\delta g)$*.*

A particularly important case of when an informal contract is credible is the following:

Proposition 2. *Consider a regime in which bonuses are prohibited. Suppose* $p^*(\delta g) > 0$*. Assume the board is at least as patient as the* CEO *(i.e.,* $\delta \geq \gamma$*). Then there is an informal contract that is credible and yields greater expected per-period profit than that achievable given the restrictions on formal contracting (i.e., yields expected per-period profit in excess of* π^0_{FC}*).*

Proof: The chain

$$\begin{aligned}\delta g p^*(\delta g) - c\big(p^*(\delta g)\big) &\geq \delta g p^*(\gamma g) - c\big(p^*(\gamma g)\big) \\ &\geq \delta g p^*(\gamma g) - \frac{\delta}{\gamma} c\big(p^*(\gamma g)\big) = \delta\pi^0_{\text{FC}} \qquad (7)\end{aligned}$$

is valid by the definition of an optimum (the first inequality) and because $\delta \geq \gamma$ (the second inequality).[21] Considering only the beginning and end of the chain, expression (7) can be rearranged to yield

$$\delta\Big(g p^*(\delta g) - c\big(p^*(\delta g)\big)\Big) \geq (1-\delta)c\big(p^*(\delta g)\big) + \delta\pi^0_{\text{FC}}\,. \qquad (8)$$

Expression (8) implies that the informal contract with $w = 0$ and informal component

$$\tau(p) = \begin{cases} c\big(p^*(\delta g)\big)\,, & \text{if } p \geq p^*(\delta g) \\ 0, & \text{otherwise} \end{cases}$$

is credible (*i.e.,* satisfies (6)). Moreover, because $c\big(p^*(\delta g)\big) > 0$, expression (8) implies $g p^*(\delta g) - c\big(p^*(\delta g)\big) > \pi^0_{\text{FC}}$: expected per-period profit is greater with the informal contract than the optimal formal contract. ■

[21] If $\gamma = 0$, then $\pi^0_{\text{FC}} = 0$ and it directly follows that $\delta g p^*(\delta g) - c\big(p^*(\delta g)\big) \geq \delta\pi^0_{\text{FC}}$ because, by the definition of an optimum,

$$\delta g p^*(\delta g) - c\big(p^*(\delta g)\big) \geq \delta g \times 0 - c(0) = 0\,.$$

3 Achieving the First Best with Informal Contracts

We begin by deriving conditions under which the board can achieve the maximum feasible expected per-period profit, π^*, defined earlier by expression (3).

The condition for the board to honor an informal contract is given by (6) above. Substituting $p^*(g)$ for $\widetilde{p}$, that expression becomes:

$$\delta\pi^* \geq (1-\delta)c\bigl(p^*(g)\bigr) + \delta\pi_{\text{FC}}\,.$$

Solving that expression for δ, there is an equilibrium in which the firm achieves maximum expected profit provided

$$\delta \geq \frac{c\bigl(p^*(g)\bigr)}{c\bigl(p^*(g)\bigr) + \pi^* - \pi_{\text{FC}}} = \frac{p^*(g)g - \pi^*}{p^*(g)g - \pi_{\text{FC}}}\,, \tag{9}$$

where the second equality derives from $c\bigl(p^*(g)\bigr) = p^*(g)g - \pi^*$. Because $\pi^* > \pi_{\text{FC}}$ (Corollary 1), it follows that the cutoff or minimum discount factor for sustaining the first best lies strictly between 0 and 1. Observe the ratios in expression (9) increase in π_{FC}. We have thus established:

Proposition 3. *Consider the minimum discount factor for the board such that the maximum expected profit is sustainable in equilibrium (i.e., the lower bound given in expression* (9) *above). The lower is the profit obtainable under formal contracting,* π_{FC}*, the lower is that minimum discount factor.*

Another way to state Proposition 3 is that the first-best outcome is more readily sustained (*i.e.,* for a larger set of discount factors) the lower is expected profit under formal contracting, *ceteris paribus*.

Recall that π_{FC} increases in γ (Proposition 1); hence, a corollary of Proposition 3 is:

Corollary 2. *The less patient is the* CEO *(i.e., the less is* γ*), the less patient the board needs to be to achieve maximum expected profit in equilibrium.*

Corollary 2 shows that whereas a more patient CEO is a plus for a firm limited to formal contracting, it could prove a negative for a firm seeking to rely on informal contracting. The intuition is that a more patient CEO makes formal contracting more effective because of the efficiency-wage effect, thereby making the board's commitment to an informal contract less credible *ceteris paribus*.

In light of Lemma 4, the profit obtainable under formal contracting, π_{FC}, is a non-decreasing function of the maximum bonus that can permissibly be paid. It is increasing in that cap when the cap binds; otherwise, it does not depend on the cap. Hence, lowering the cap can reduce the profit obtainable under formal contracting. This suggests the following: if the board's discount factor is too low to sustain the first best absent a cap (*i.e.,* the inequality in (9) is reversed), then a restriction on bonuses might permit the achievement of the first best.

That hypothesis is correct in the following sense: suppose that

$$\delta \geq \frac{c\bigl(p^*(g)\bigr)}{c\bigl(p^*(g)\bigr) + \pi^* - \pi^0_{\text{FC}}}\,; \tag{10}$$

that is, the board's discount factor is sufficiently great that the first best would obtain if bonuses were prohibited. Consequently, expression (10) implies condition (9) holds for some cap or limit on bonuses, $\bar{b}$. To summarize:

Corollary 3. *If the credibility condition* (9) *fails to hold, but condition* (10) *does, then there exists a cap on bonuses such that the first best is achievable in equilibrium under that cap, but not absent that cap.*

For example, if $c(p) = p^2/2$, $g = 1/2$, $\gamma = 16/25$, and $\delta = 4/5$, then $\pi^* = 10/80$, $c\big(p^*(g)\big) = 1/8$, and $\pi_{\text{FC}} = 9/80$ (absent a cap on bonuses). The first best is not achievable via informal contracting alone absent a cap:

$$\frac{1/8}{1/8 + 10/80 - 9/80} = \frac{10}{11} > \frac{4}{5}\,.$$

But it is achievable with a prohibition on bonuses ($\pi^0_{\text{FC}} = 2/25$):

$$\frac{1/8}{1/8 + 10/80 - 2/25} = \frac{25}{34} < \frac{4}{5}.$$

Indeed, if a cap of $\bar{b} \leq 1/12$ is imposed, then the first best is achievable because $b \leq 1/12$ implies $\pi_{\text{FC}} \leq 3/32$, which in turn implies

$$\frac{1/8}{1/8 + 10/80 - \pi_{\text{FC}}} \geq \frac{4}{5} = \delta\,.$$

What Corollary 3 does *not* show is that a cap on bonuses is *necessary* to achieve the first best. The reason is that if (9) fails to hold, then the board might choose to employ a contract with both a bonus and an informal component. If such a hybrid can achieve the first best and the board will choose to offer it, then there is no justification for limiting bonuses. Hence, we need to consider the use of hybrid contracts, the topic of the next section.

4 Analysis with Bonus and Informal Components

It is useful, for what follows, to define

$$u(b) = bp^*(b) - c\big(p^*(b)\big)\,.$$

Observe that the CEO can guarantee himself at least an expected utility of $u(b)$ if he has a contract that promises a bonus b in the event of success. Observe, too, that $u(b) \geq 0$ for all b. Via the envelope theorem, $u'(b) = p^*(b) \geq 0$. Define $\underline{b}$ as the greatest lower bound of the set $\big\{b \big| u(b) > 0\big\}$. Because $u(\cdot)$ is continuous, $u(\underline{b}) = 0$.

Lemma 8. *The greatest lower bound on bonuses that guarantee the* CEO *a positive expected utility,* $\underline{b}$*, equals* $c'(0)$.

If $\underline{b} > 0$, then utilizing a bonus in its contract could be a costless way for the board to overcome a credibility issue with informal contracts. In particular, if δ is such that

$$\frac{c\big(p^*(g)\big)}{c\big(p^*(g)\big) + \pi^* - \pi_{\text{FC}}} > \delta \geq \frac{c\big(p^*(g)\big) - \underline{b}p^*(g)}{c\big(p^*(g)\big) - \underline{b}p^*(g) + \pi^* - \pi_{\text{FC}}}\,, \tag{11}$$

then the first-best outcome (maximum firm profit) can be obtained in equilibrium via the addition of a bonus to an informal contract, even though an informal contract alone can't achieve the first best in equilibrium. To see this, suppose the board offers[22]

$$\langle 0, \underline{b}, \tau(p)\rangle\,,\ \text{where } \tau(p) = \begin{cases} c\big(p^*(g)\big) - \underline{b}p^*(g)\,,\ \text{if } p \geq p^*(g) \\ 0,\ \text{otherwise} \end{cases} \tag{12}$$

A best response for the CEO is $p = p^*(g)$ given that

$$\tau\big(p^*(g)\big) + \underline{b}p^*(g) - c\big(p^*(g)\big) = 0 \geq \tau(p) + \underline{b}p - c(p) \tag{13}$$

for all p.[23] By construction, expected per-period profit under the contract given in (12) is

$$p^*(g)(g - \underline{b}) - \tau\big(p^*(g)\big) = p^*(g)g - c\big(p^*(g)\big) = \pi^*$$

if the CEO plays $p^*(g)$. Finally, it will be credible that the board will honor the informal component of the contract in (12) if

$$\delta\pi^* \geq (1-\delta) \underbrace{\tau\big(p^*(g)\big)}_{c(p^*(g)) - \underline{b}p^*(g)} + \delta\pi_{\text{FC}}\,.$$

It is readily verified this last expression holds given (11). This analysis and the fact that $\pi_{\text{FC}} = \pi_{\text{FC}}^0$ if the cap on bonuses, $\bar{b}$, does not exceed $\underline{b}$ yield:

Proposition 4. *Suppose that the greatest lower bound on bonuses that guarantee the* CEO *positive expected utility, $\underline{b}$, is positive. Assume, too, that the board's discount factor, δ, satisfies*

$$\frac{c\big(p^*(g)\big)}{c\big(p^*(g)\big) + \pi^* - \pi_{\text{FC}}^0} > \delta \geq \frac{c\big(p^*(g)\big) - \underline{b}p^*(g)}{c\big(p^*(g)\big) - \underline{b}p^*(g) + \pi^* - \pi_{\text{FC}}^0}\,.$$

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[22] It is readily verified that $\tau(p) \geq 0$ (*i.e.,* the non-negativity constraint is met): a convex function lies above its first-order Taylor series approximation; hence, because $c(\cdot)$ is convex,

$$c\big(p^*(g)\big) \geq \underbrace{c(0)}_{=0} + \underbrace{c'(0)}_{=\underline{b}}\big(p^*(g) - 0\big)\,.$$

So $\tau(p) \geq 0$.

[23] To verify (13), observe that, for $p \neq p^*(g)$,

$$\frac{d}{dp}\Big(\tau(p) + \underline{b}p - c(p)\Big) = \underline{b} - c'(p) = c'(0) - c'(p) \leq 0\,.$$

So the CEO deems all $p \neq p^*(g)$ or 0 to be dominated. The rightmost expression in (13) is zero at $p = p^*(g)$ and $p = 0$.

Then going from a regime in which bonuses were not permitted (the cap, $\bar{b}$, was zero) to one in which it equaled $\underline{b}$, would, in equilibrium, increase both expected surplus and the firm's expected profit to the first-best levels.

Although Proposition 4 and the analysis preceding it demonstrate that conditions exist such that relaxing a cap on bonuses could be welfare improving and, indeed, facilitate the achievement of the first best, these conditions could be deemed special insofar as they rely on the CEO's marginal disutility of action being positive at the zero (null) action. Rather than having to contend with that case going forward, we now assume:

Assumption 1. *The* CEO*'s marginal disutility of action at the null action is zero; that is,* $c'(0) = 0$.

Suppose the CEO has accepted the contract $\langle w, b, \tau(\cdot)\rangle$ along with a target action, $\widetilde{p}$. Suppose the CEO expects the informal component to be honored and the same contract to be offered him if he remains employed. The CEO will, then, choose the target $\widetilde{p}$ provided

$$\frac{1}{1-\gamma}\big(w + \tau(\widetilde{p}) + b\widetilde{p} - c(\widetilde{p})\big) \geq w + \tau(p) + bp - c(p) \tag{14}$$

for all $p \neq \widetilde{p}$.

A useful lemma for what follows is

Lemma 9. *Suppose the board wishes to induce a target action $\widetilde{p}$. It is without loss of generality to limit the board to offering contracts that have an informal component of the form*

$$\tau(p) = \begin{cases} \widehat{\tau}\,, & \text{if } p = \widetilde{p} \\ 0\,, & \text{if } p \neq \widetilde{p} \end{cases}\,. \tag{15}$$

Intuitively, the board would like to the constraint (14) to be as relaxed as possible, which explains why it would set $\tau(p) = 0$ for $p \neq \widetilde{p}$. In light of Lemma 9, it follows that if the CEO were *not* to choose the target action, $\widetilde{p}$, he does best to choose the action that maximizes $bp - c(p)$; that is, $p^*(b)$. Consequently, (14) holds if

$$w + \tau(\widetilde{p}) + b\widetilde{p} - c(\widetilde{p}) \geq (1-\gamma)\big(u(b) + w\big)\,. \tag{16}$$

If the inequality in (16) were strict, then the board could, without violating (16), reduce the CEO's compensation and make the informal component more credible by lowering $\tau(\widetilde{p})$. It follows that, in equilibrium, (16) is an equality. Note that per-period expected CEO compensation is

$$w + \tau(\widetilde{p}) + b\widetilde{p} = c(\widetilde{p}) + (1-\gamma)\big(u(b) + w\big)\,. \tag{17}$$

From (17), a firm's per-period expected profit is

$$g\widetilde{p} - c(\widetilde{p}) - (1-\gamma)\big(u(b) + w\big)\,. \tag{18}$$

Because $u(0) = 0$ and Assumption 1 implies $u(b) > 0$ for $b > 0$, it follows, for any $\widetilde{p}$, that the board would ideally like to set $b = 0$ and $w = 0$. It further follows that if (9) holds, then the board will only offer an informal contract in equilibrium. If (9) holds for $\pi_{\text{FC}} = \pi^*_{\text{FC}}$, then the board is indifferent to constraints on bonuses—they are simply irrelevant.[24] If (9) fails for $\pi_{\text{FC}} = \pi^*_{\text{FC}}$, but (10) holds, then there is a restriction on the bonuses that would necessarily benefit the board. To summarize:

Proposition 5. *For any given action it wishes to induce, the board would prefer—if credible—to induce it via a contract with no bonus or base wage (i.e., one in which $b = w = 0$). If the credibility condition (9) holds for the first-best action regardless of the maximum expected profit possible under a formal contract, then the board is indifferent to restrictions on bonuses. If that is not true, but condition (10) holds, then there is a restriction on bonuses that would enhance efficiency and benefit the firm.*

What if the conditions of Proposition 5 are not met (*i.e.,* what if credibility conditions (9) and (10) both fail to hold)? Would the firm (board) still be better off with some restrictions on bonuses? We explore that question now. To that end, the condition for the board not to renege on the informal component is, from (17) and (18),

$$\underbrace{b\widetilde{p} - c(\widetilde{p}) - (1-\gamma)u(b) + \gamma w}_{-\tau(\widetilde{p})} + \sum_{t=1}^{\infty} \delta^t \Big(g\widetilde{p} - c(\widetilde{p}) - (1-\gamma)\big(u(b)+w\big) \Big) \geq \sum_{t=1}^{\infty} \delta^t \pi_{\text{FC}}\,;$$

or, rearranging,

$$g\widetilde{p} - \big(c(\widetilde{p}) + (1-\gamma)u(b)\big) \geq (\delta - \gamma)w + (1-\delta)(g-b)\widetilde{p} + \delta\pi_{\text{FC}}\,. \tag{19}$$

If $\delta \geq \gamma$, then the constraint (19) is more readily satisfied if $w = 0$. Because the firm's expected per-period profit is maximized if $w = 0$, it follows that the firm will set $w = 0$ if $\delta \geq \gamma$. To summarize, we've established:

Lemma 10. *If the board is at least as patient as the* CEO *(i.e., $\delta \geq \gamma$), then the base wage, w, in any contract offered in equilibrium will be zero.*

A consequence of Lemma 10 is that the lefthand side of (19) is expected per-period profit. For future reference, it is useful to define

$$U(b) = (1-\gamma)u(b)\,.$$

We can now establish the following.

Proposition 6. *Assume the board is at least as patient as the* CEO *(i.e., $\delta \geq \gamma$). Assume, too, that bonuses are permitted. Let b_{FC} be the smallest bonus the board*

[24]Recall π^*_{FC} is maximum expected profit using a formal contract only (*i.e.,* assuming no restriction on bonuses).

would rationally offer were it limited to formal contracts only.[25] *Let* b^e *denote the bonus the board does offer in equilibrium (when able to use a hybrid contract). Assume credibility condition* (9) *does* not *hold. If* $b^e < b_{\text{FC}}$*, then there exists a cap on bonuses* $\bar{b}$*,* $\bar{b} \leq b^e$ *(and equal only if* $b^e = 0$*), such that imposing that cap would raise the firm's expected equilibrium profit; that is, the firm would benefit if bonuses were capped* below *their equilibrium level (assuming the equilibrium level is positive).*

Proof: Given Assumption 1 and the logic of Lemma 4, $b_{\text{FC}} > 0$. By hypothesis, it is true for all $b'' \leq b^e$ that

$$\widehat{\pi}(b'') \equiv \max_{\substack{b' \in [0,b''] \\ w \in [0,g]}} \widehat{p}(b', w)(g - b') - w < \pi_{\text{FC}} \,.$$

Let $\widetilde{p}$ be the action the board induces in equilibrium; hence, equilibrium per-period expected profit is given by the lefthand side of (19). Because condition (9) is not satisfied, expression (19) must bind in equilibrium. Consequently,

$$g\widetilde{p} - \big(c(\widetilde{p}) + U(b^e)\big) > (1 - \delta)(g - b^e)\widetilde{p} + \delta\widehat{\pi}(b^e) \,. \tag{20}$$

If $b^e = 0$, then it follows from (20) that a ban on bonuses (a cap of zero) would strictly benefit the firm (it could increase $\widetilde{p}$).

Suppose $b^e > 0$. By continuity, it follows from (20) that there exists a $\hat{b} \in [0, b^e)$ such that

$$g\widetilde{p} - \big(c(\widetilde{p}) + U(\hat{b})\big) \geq (1 - \delta)(g - \hat{b})\widetilde{p} + \delta\widehat{\pi}(b^e) \,.$$

Because $\widehat{\pi}(\hat{b}) \leq \widehat{\pi}(b^e)$, it follows that

$$g\widetilde{p} - \big(c(\widetilde{p}) + U(\hat{b})\big) \geq (1 - \delta)(g - \hat{b})\widetilde{p} + \delta\widehat{\pi}(\hat{b}) \,. \tag{21}$$

Expression (21) shows that if the cap on bonuses were $\hat{b}$, then a hybrid contract with bonus $\hat{b}$ could credibly achieve a per-period profit of

$$g\widetilde{p} - \big(c(\widetilde{p}) + U(\hat{b})\big) \,,$$

which exceeds the original equilibrium's expected per-period profit (the lefthand side of (20)) because $U(\cdot)$ is an increasing function. ■

As an example, suppose $c(p) = p^2/2$, $g = 3/4$, $\delta = 13/25$, $\gamma = 1/4$, and there is no cap on bonuses. It is readily shown that $b_{\text{FC}} = 3/8 = .375$, $\widehat{p}(b_{\text{FC}}) = 9/16 =$

[25] The board's optimization program when limited to formal contracts, expression (41) in the Appendix, is not necessarily concave in b and w; hence, it is conceivable that more than one expected-profit-maximizing contract exists. Even if the optimal contract is not unique, by appeal to the Maximum Theorem (see, *e.g.,* Sundaram, 1996, p. 235), it is readily seen that b_{FC} is well defined (*i.e.,* a minimum—as opposed to just an infimum—optimal bonus must exist).

.5625, $\pi_{\text{FC}} = 27/128 \approx .211$, and that expression (10) fails (*i.e.,* Proposition 5 is not applicable). Solving for the equilibrium, it can be shown that the board would induce $\widetilde{p} \approx .564$ using a hybrid contract with bonus $b \approx .346$, for an expected per-period profit of approximately .219.[26] If a cap on bonuses of $\bar{b} = 1/4$ were imposed, then it can be shown that the board would induce $\widetilde{p} \approx .609$ using a hybrid contract with a bonus $b \approx .214$ for an expected per-period profit of approximately .254.

Noting, for this example, that the bonus the board would wish to offer *after* the imposition of a cap is less than the cap, Proposition 6 implies that an even lower cap would raise expected firm profit even higher. One might be tempted to imagine that this iterative process would lead to an optimal cap of zero. That proves not to be true, however: calculations reveal that expected equilibrium profits are maximized if the cap (*i.e.,* $\bar{b}$) is approximately .1033.

5 The CEO has Bargaining Power

We have, to this point, assumed the board has all the bargaining power (*i.e.,* an ability to make the CEO a take-it-or-leave-it offer). In this section, we briefly consider the opposite: the CEO is the one to make take-it-or-leave-it offers.

The first result is that if there are no restrictions on bonuses, then full efficiency (*i.e.,* $p = p^*(g)$) is achieved.

Proposition 7. *Assume that the CEO possesses all the bargaining power and there is no limit or cap on bonuses. Then full efficiency will be achieved in equilibrium. The CEO, however, will capture all surplus.*

Proof: Suppose the CEO offers the formal contract $\langle 0, g\rangle$ (*i.e.,* a contract with the bonus set equal to the gain from success). If the board accepts, then the CEO will choose p to solve

$$\max_p gp - c(p)\,.$$

From Lemma 1, this program has a unique solution $p = p^*(g)$. Hence, surplus will be maximized. The board is just willing to accept the contract given the firm's expected payoff will be zero under it. Given that full efficiency is achieved and the CEO captures all surplus, he can do no better than to offer $\langle 0, g\rangle$. ■

In fact, if the CEO is sufficiently patient, then full efficiency attains even if bonuses are prohibited:

Proposition 8. *Assume that the CEO possesses all the bargaining power. Provided he is sufficiently patient—specifically, that* $\gamma \geq c\big(p^*(g)\big)/\big(gp^*(g)\big)$*—then full efficiency will be achieved in equilibrium even if there are restrictions on the use of bonuses. The CEO, however, will capture all surplus.*

Proof: If the result holds given a complete prohibition on bonuses, then it will hold given less stringent restrictions. Hence, for convenience, assume $\bar{b} = 0$.

[26] All calculations available from authors upon request.

Consider a formal contract $\langle gp^*(g), 0\rangle$ (*i.e.,* the wage is $gp^*(g)$). It is credible that the CEO will choose action $p^*(g)$ provided

$$\sum_{t=0}^{\infty} \gamma^t \Big(gp^*(g) - c\big(p^*(g)\big)\Big) = \frac{gp^*(g) - c\left(p^*(g)\right)}{1-\gamma} \geq gp^*(g)\,. \tag{22}$$

Algebra reveals that (22) holds provided

$$\gamma \geq \frac{c\big(p^*(g)\big)}{gp^*(g)}\,.$$

The board is just willing to accept the contract given the firm's expected payoff will be zero under it. Given that full efficiency is achieved and the CEO captures all surplus, he can do no better than to offer $\langle gp^*(g), 0\rangle$. ■

On the other hand, if the CEO is sufficiently impatient and there is a sufficiently tight restriction on bonuses, then full efficiency can be unachievable. Yet, in such circumstances, given the CEO has the bargaining power, a cap on bonuses could make the firm (the board) better off than it would be in the equilibria of Propositions 7 or 8. To demonstrate this, consider the limiting case of a wholly myopic CEO (equivalently, the case in which the CEO is a short-run player) and a complete prohibition on bonuses (*i.e.,* $\bar{b} = 0$).[27]

Proposition 9. *Assume that the CEO possesses all the bargaining power. Assume that $\gamma = 0$; that is, the CEO is either wholly myopic or a short-run player. Assume that bonuses are prohibited (i.e., $\bar{b} = 0$). Then full efficiency is not attained in equilibrium. However, the firm will earn positive expected profit.*

Proof: Given the proposition's assumptions, a formal contract cannot induce any action from the CEO other than $p = 0$. It follows that $\pi_{\text{FC}} = 0$. Using by now familiar reasoning, the board will honor the informal contract $\langle w, \tau(\cdot)\rangle$ with

$$\tau(p) = \begin{cases} \widehat{\tau}\,, & \text{if } p \geq \widetilde{p} \\ 0\,, & \text{if } p < \widetilde{p} \end{cases} \tag{23}$$

only if

$$-\widehat{\tau} + \frac{\delta}{1-\delta}(g\widetilde{p} - w - \widehat{\tau}) \geq \frac{\delta}{1-\delta}\pi_{\text{FC}} = 0\,;$$

that is, only if

$$\widehat{\tau} \leq \delta g\widetilde{p} - \delta w\,. \tag{24}$$

The CEO will choose $\widetilde{p}$ rather than action 0 if and only if

$$\widehat{\tau} - c(\widetilde{p}) \geq 0\,. \tag{25}$$

[27] The following proposition can be extended to allow for an impatient, but long-lived CEO; that is, $\gamma > 0$ but not too large. It can also be extended to permit a less severe cap on bonuses. Doing so would not change the basic insights of the proposition. So, for the sake of brevity, we restrict attention to this simplest case.

In equilibrium, the CEO chooses $\langle w, \tau(\cdot)\rangle$ and action $\widetilde{p}$ to maximize

$$w + \widehat{\tau} - c(\widetilde{p})$$

subject to (24) and (25). Because, holding w and $\widetilde{p}$ fixed, the objective function increases in $\widehat{\tau}$, it follows that (24) must bind. Substituting that constraint, the CEO's seeks to choose $\widehat{\tau}$ and $\widetilde{p}$ to maximize

$$g\widetilde{p} - \frac{1-\delta}{\delta}\widehat{\tau} - c(\widetilde{p})$$

subject to (25). Because this objective function is decreasing in $\widehat{\tau}$, it follows that (25) binds. Substituting that constraint yields the unconstrained program

$$\max_{\widetilde{p}} g\widetilde{p} - \frac{1}{\delta}c(\widetilde{p}) \tag{26}$$

Because the solution to (26) is unaffected if that expression is multiplied by δ, it immediately follows that the solution is $\widetilde{p} = p^*(\delta g)$. Substituting back into the binding constraints yields the contract:[28]

$$w = gp^*(\delta g) - \frac{1}{\delta}c\big(p^*(\delta g)\big) \text{ and } \tau(p) = \begin{cases} c\left(p^*(\delta g)\right), \text{ if } p \geq p^*(\delta g) \\ 0, \text{ if } p < p^*(\delta g) \end{cases} \tag{27}$$

Observe that, under the contract (27) and given $\widetilde{p} = p^*(\delta g)$, per-period profit is

$$gp^*(\delta g) - w - \widehat{\tau} = \frac{1-\delta}{\delta}c\big(p^*(\delta g)\big) > 0\,. \tag{28}$$

So the board will accept the CEO's offer; that is, it is an equilibrium for the CEO to offer contract (27), for the board to accept, and for the CEO to choose action $p^*(\delta g)$. Because $p^*(\delta g) < p^*(g)$, full efficiency is not achieved. Given (28), the firm earns a positive expected profit each period, as was to be shown. ■

We based our analysis of the previous sections on the assumption that the board is a perfect agent for shareholders. As discussed in the Introduction, the principal purpose of that assumption was to make it possible to see that shareholders could benefit from limitations on contingent compensation even if there were no agency problems between them and their boards. If there is an agency problem, then the analysis could be more similar to the analysis just considered—think of the board as "captured" by the CEO and the CEO,

[28]Because $p^*(\delta g)$ uniquely maximizes

$$gp - \frac{1}{\delta}c(p)\,,$$

it follows that

$$gp^*(\delta g) - \frac{1}{\delta}c\big(p^*(\delta g)\big) > g \times 0 - \frac{1}{\delta}c(0) = 0\,;$$

hence, the contract must satisfy the no-negative-payment constraint.

thus, having the bargaining power. Limitations on contingent compensation could, then, raise shareholder profits (compare Propositions 7 and 9); that is, as suggested by Bebchuk (2007) and others, restrictions on pay could help redress the shareholder-board agency problem.

6 Board Quality

We have so far assumed that the board is a perfect monitor. In this section, we consider a variation of that assumption. To keep the analysis tractable, we limit attention to a version of the model in which the CEO is a short-run player (wholly myopic): $\gamma = 0$. We also return to our original assumption that the board has all the bargaining power.

Although there are many dimensions to board quality, here we view a higher-quality board as one that has a better understanding of what is happening in the firm. Specifically, let $\theta \in (0, 1]$ denote the board's quality, which we interpret as the probability that, in a given period, the board observes the CEO's action. With probability $1-\theta$, it fails to observe his action. Assume the board's success or failure in observing the CEO's action is a series of independent events period to period. The board knows whether it has or hasn't observed the CEO's action, but the CEO does not.[29]

Consider a contract with an informal component. If the CEO plays the board's desired action, $\widetilde{p}$, as a pure strategy in equilibrium, then the board, must, if it wishes to preserve its reputation, pay $\tau(\widetilde{p})$ when it fails to observe the CEO's action. Consequently, the CEO will play $\widetilde{p}$ if and only if

$$w + \tau(\widetilde{p}) + b\widetilde{p} - c(\widetilde{p}) \geq w + (1-\theta)\tau(\widetilde{p}) + \max_{p\in[0,1]} \Big\{\theta\tau(p) + bp - c(p)\Big\}\,, \quad (29)$$

where the righthand side of (29) is the CEO's maximum expected utility if he deviates from playing $\widetilde{p}$. The logic of Lemma 9 still applies, so $\tau(p) = 0$ for $p \neq \widetilde{p}$. Hence, (29) can be rewritten as

$$\tau(\widetilde{p}) + b\widetilde{p} - c(\widetilde{p}) \geq (1-\theta)\tau(\widetilde{p}) + u(b)\,.$$

Rearranging, this yields

$$\tau(\widetilde{p}) \geq \frac{1}{\theta}\Big(u(b) - \big(b\widetilde{p} - c(\widetilde{p})\big)\Big)\,. \quad (30)$$

If the inequality in (30) were strict, then the board could, without violating (30), reduce the CEO's compensation, thus increasing per-period profit and making the informal component more credible. It follows, therefore, that (30) must be an equality in equilibrium.

[29] The alternative assumption that the CEO knows what the board has observed slightly complicates the analysis because the informal component could, then, be conditioned on whether the board observed the CEO's acton; that is, under the alternative assumption, $\tau : [0,1] \cup \{\text{no observation}\} \to \mathbb{R}_+$. That noted, a similar analysis to that pursued here follows.

Expected per-period compensation is $w + \tau(\widetilde{p}) + b\widetilde{p}$. Consequently, utilizing (30), expected per-period profit is

$$g\widetilde{p} - b\widetilde{p} - w + \frac{1}{\theta}\Big(\big(b\widetilde{p} - c(\widetilde{p})\big) - u(b)\Big)\,. \tag{31}$$

Lemma 11. *The firm's expected per-period profit is maximized if the base wage, w, is zero. Unless the board has maximum quality (i.e., unless $\theta = 1$), maximizing expected per-period profit entails a bonus (i.e., $b > 0$). Unless board quality is zero, expected per-period profit is maximized by inducing an action greater than one that would be induced by the bonus alone (i.e., $\widetilde{p} > p^*(b)$ if $\theta > 0$).*

As an example, if $c(p) = p^2/2$, then it can be shown (see Lemma A.2 in the Appendix) that the optimal bonus is given by

$$b = g\frac{1-\theta}{2-\theta}\,.$$

Note that, as $\theta \to 0$, $b \to g/2$, which is the optimal bonus for this example were the firm limited to formal contracts.

The board will honor the informal component in equilibrium if

$$\underbrace{\frac{1}{\theta}\Big(\big(b\widetilde{p} - c(\widetilde{p})\big) - u(b)\Big)}_{-\tau(\widetilde{p})} + \sum_{t=1}^{\infty}\delta^t\left(g\widetilde{p} - b\widetilde{p} - w + \frac{1}{\theta}\Big(\big(b\widetilde{p} - c(\widetilde{p})\big) - u(b)\Big)\right) \geq \sum_{t=1}^{\infty}\delta^t\pi_{\text{FC}}\,;$$

or, rearranging,

$$g\widetilde{p} - b\widetilde{p} + \frac{1}{\theta}\Big(\big(b\widetilde{p} - c(\widetilde{p})\big) - u(b)\Big) \geq \delta w + (1-\delta)(g-b)\widetilde{p} + \delta\pi_{\text{FC}}\,. \tag{32}$$

The credibility condition, (32), is most readily met if $w = 0$; hence, given Lemma 11, we can conclude that $w = 0$ in equilibrium.

If (32) holds when evaluated at the values of $\widetilde{p}$ and b that maximize per-period profit (expression (31)) and for $\pi_{\text{FC}} = \pi^*_{\text{FC}}$, then restrictions on bonuses are irrelevant. Conversely, if (32) fails to hold given those values, then restrictions are relevant.

To analyze further the role of board quality, tractability dictates that we restrict attention to an easy-to-work-with disutility-of-action function. For the remainder of this section, we therefore assume $c(p) = p^2/2$. So that $p^*(g) < 1$, this means $g < 1$. Lemma A.2 in the Appendix summarizes some useful consequent results. For this version of the model, we can establish the following:

Proposition 10. *Suppose the* CEO *is a short-run player or, equivalently, wholly myopic (i.e., assume $\gamma = 0$). Assume the* CEO*'s disutility-of-action function, $c(p)$, equals $p^2/2$. Then the following are true:*

(i) *the minimum level of board patience, δ, necessary for the credibility constraint, expression* (32)*, to hold is less the lower is the board's quality;*

(ii) *the* CEO*'s bonus for success is greater the lower is the quality of the board;*

(iii) *the* CEO*'s expected utility is greater the lower is the quality of the board;*

(iv) *there exists a cap on bonuses that raises expected per-period firm profit if*

$$\frac{2}{4-\theta} > \delta \geq \frac{1}{2}\,; \tag{33}$$

and

(v) *the gain in expected per-period firm profit from imposing that cap is greater the higher is the board's quality.*

Proposition 10(i) might, at first, seem counter-intuitive, given that we would expect a lower-quality board to be worse in all dimensions. It is, however, precisely because a lower-quality board is a worse monitor that it is credible for a larger set of discount factors: its imperfect monitoring means it relies more on bonuses and less on the informal component. Consequently, the informal component is smaller, which lessens the board's temptation to cheat the CEO. Of course, the value of reputation is also less—expected per-period profit falls as board quality falls—but the reduced-temptation effect dominates.

As noted, a lower-quality board will use bonuses more, *ceteris paribus*. This does not, however, necessarily mean it will pay higher bonuses: the CEO's total compensation is also a function of the action the board seeks to induce from the CEO. A lower-quality board could—and, in fact does—induce a lower-cost action (lower $\widetilde{p}$) from the CEO. However, at least for the functional forms assumed, the effect of a greater reliance on bonuses dominates the effect of a lower-cost action: in equilibrium, lower-quality boards offer greater bonuses than do higher-quality boards. Given that the former are offering higher bonuses and expecting less effort, it is not surprising that the CEO's expected utility is greater if he works for a low-quality board than if he works for a high-quality board.

Because a board of less-than-perfect quality (*i.e.,* one for which $\theta < 1$) will always wish to use bonuses, a complete prohibition on bonuses would not maximize expected profits. Neither, however, would no limit on bonuses for the reasons discussed previously in connection with Propositions 3 and 5 and their corollaries. Finally, because a higher-quality board would like to utilize a greater informal component, induce a greater action, and pay a lower bonus relative to a lower-quality board, *ceteris paribus*, it is not surprising that it has more to gain from a cap on bonuses than does a lower-quality board.

Proposition 10(v) has a straightforward, but important corollary:

Corollary 4. *Under the conditions of Proposition 10 and given condition* (33)*, the marginal value of improving board quality is greater when a cap exists on bonuses than when one does not.*

Proof: Let Π^r denote expected per-period profit under policy regime r, $r \in \{\textsc{cap}, \textsc{nocap}\}$. Proposition 10(v) established that

$$\frac{\partial}{\partial\theta}\left(\Pi^{\text{CAP}} - \Pi^{\text{NOCAP}}\right) > 0\,;$$

hence,

$$\frac{\partial\Pi^{\text{CAP}}}{\partial\theta} > \frac{\partial\Pi^{\text{NOCAP}}}{\partial\theta}\,,$$

which establishes the result. ■

We have heretofore treated board quality as an exogenously determined attribute. But there are many reasons to view board attributes as endogenously determined (see, *e.g.,* Adams et al., 2010, for a relevant survey on the literature on board determination). When board attributes are chosen endogenously and a higher-quality board is more expensive to assemble or maintain, then Corollary 4 suggests, via usual comparative statics (see, *e.g.,* Lemma A.1), that, in a regime of capped or limited bonuses, we should expect to see higher-quality boards (boards better able to evaluate the CEO's actions) than when bonuses are unrestricted.

7 Choice of Strategy

We can extend our model to shed some light on the relation between feasible compensation schemes and the firm's choice of strategy. To that end, we return to the basic model of Section 2 and the assumptions given there. However, we now suppose that there are two strategies the firm could follow in a given period: ℓ or m. We will use s to denote an arbitrary element of $\{\ell, m\}$. Only one strategy can be pursued in a period. With respect to strategy m, everything is as before, except let g_m denote the gain if strategy m is successful. With respect to strategy ℓ, most things are as before, except we assume (i) the firm's gross payoff if the CEO chooses action p is pg_ℓ;[30] and (ii) there is *no* verifiable outcome. Change (ii) means that there is no scope for using a bonus to induce action from the CEO if strategy ℓ is adopted.[31] An interpretation is that strategy m is a more immediate (possibly myopic) strategy that yields a clear outcome, whereas strategy ℓ is a more long-run strategy, the outcome of which is harder to measure, at least in the near term.[32] As we will discuss below, strategy m might be a strategy of growth through mergers and acquisitions, while strategy ℓ might be a strategy of growth through innovation and market development.

[30] Note pg_ℓ could still be an expected value. We are simply allowing for the possibility that it is not (it is deterministic).

[31] Note this version our model has something of the flavor of Baker et al. (1994), where the agent (CEO) can decide into which activity his effort goes. A key difference is that, in their model, the agent chooses, whereas here we assume the principal (board) chooses.

[32] Given this interpretation, g_ℓ might best be thought of as the present value of some future return.

Because the firm would never have any reason to pursue strategy ℓ if $g_\ell \leq g_m$, we limit attention to the case $g_\ell > g_m$.

We maintain the assumption of grim-trigger strategies: regardless of strategy, if the board ever reneges on paying the informal component, then the board is forever after limited to formal contracts.

Let $\pi^*(s)$ denote the maximum feasible expected per-period profit under strategy s (*i.e.,* as given by expression (3) with $g = g_s$). Let $\pi^*_{\text{FC}}(s)$, $\pi_{\text{FC}}(s)$, and $\pi^0_{\text{FC}}(s)$ denote per-period profit under strategy s when the firm utilizes a formal contract and, respectively, faces no caps on bonuses, may face a cap, or is prohibited from using bonuses. Because bonuses cannot be utilized with strategy ℓ, only $\pi^0_{\text{FC}}(\ell)$ is relevant for that strategy. Recall that Lemma 4 implies $\pi^*_{\text{FC}}(m) \geq \pi_{\text{FC}}(m) \geq \pi^0_{\text{FC}}(m)$, with at least one inequality being strict. For the sake of brevity, we assume the following:

Assumption 2. *If the board is limited to formal contracts only and faces no cap or limit on bonuses, then the board prefers to implement strategy m rather than strategy ℓ (i.e., $\pi^*_{\text{FC}}(m) > \pi^0_{\text{FC}}(\ell)$).*

One might imagine that if the inequality in Assumption 2 were reversed, then strategy m would be wholly irrelevant. This is not true: it is conceivable that if the relevant credibility conditions are sufficiently difficult to satisfy, the board might elect to pursue strategy m under a *hybrid* contract rather than strategy ℓ under a formal contract. The benefit to Assumption 2 is it means we need only consider one off-the-equilibrium-path alternative should the board renege on paying an informal component.

Because $g_\ell > g_m$, it follows that $\pi^0_{\text{FC}}(\ell) \geq \pi^0_{\text{FC}}(m)$, with equality holding only if the CEO is wholly myopic or a short-run player ($\gamma = 0$). Continuity of $\pi_{\text{FC}}(m)$ with respect to a cap on bonuses (see Lemma 5) then establishes:

Lemma 12. *There exists a cap on bonuses such that implementing strategy ℓ with the profit-maximizing formal contract yields the same expected per-period profit as implementing strategy m with the restricted profit-maximizing contract (i.e., there exists a cap such that $\pi^0_{\text{FC}}(\ell) = \pi_{\text{FC}}(m)$).*

A consequence of Lemma 12 is the following:

Proposition 11. *Assume the board is at least as patient as the CEO (i.e., $\delta \geq \gamma$). Then there is a cap or limit on bonuses sufficient to induce the board to pursue strategy ℓ in equilibrium.*

Proof: Follows immediately from Assumption 1 and Proposition 2. ■

Proposition 11 establishes that the board's choice of strategy could depend on limits on bonuses. It does not, however, establish that the choice *will* depend on such limits nor that such limits are desirable. As part of exploring those issues, it is readily shown that Lemma 10 still holds. In the context of strategy ℓ, this means that if the contract the board chooses has an informal component, the base wage in that contract will be zero; that is, the contract will be $\langle 0, 0, \tau(\cdot)\rangle$ with

$$\tau(p) = \begin{cases} c(\widetilde{p})\,, \text{ if } p = \widetilde{p} \\ 0\,, \text{ if } p \neq \widetilde{p} \end{cases}\,,$$

where $\widetilde{p}$ is the target action. Employing by now familiar logic (see, in particular, the derivation of expression (6)), the board can implement $\widetilde{p}$ under such a contract for strategy ℓ if and only if

$$\delta g_\ell \widetilde{p} - c(\widetilde{p}) \geq \delta \max\left\{\pi^0_{\text{FC}}(\ell), \pi_{\text{FC}}(m)\right\}. \tag{34}$$

The same logic that led to Lemma 7 therefore yields

Lemma 13. *Assume no cap or limit on bonuses. In equilibrium, the board will implement strategy m if*

$$\delta g_\ell p^*(\delta g_\ell) - c\big(p^*(\delta g_\ell)\big) < \delta \pi^*_{\text{FC}}(m)\,. \tag{35}$$

Proof: Given (35), no informal contract is credible given strategy ℓ; hence, if the board pursues strategy ℓ, then it must do so under a formal contract. Per-period profit would thus be $\pi^0_{\text{FC}}(\ell)$. This is less than $\pi^*_{\text{FC}}(m)$ by Assumption 2. Finally $\pi^*_{\text{FC}}(m) \leq \pi^e(m)$, where $\pi^e(m)$ is expected per-period profit in an equilibrium in which the board implements strategy m (using perhaps a hybrid contract). ■

Given that $\pi^*(\ell) > \pi^*(m) \geq \pi^e(m)$, it follows that if there were a restriction on bonuses that permitted the board to induce $p^*(g_\ell)$ under strategy ℓ, then this would be ideal. In light of Lemma 12 and employing the reasoning behind credibility condition (10), we obtain

Lemma 14. *If $\pi_{\text{FC}}(m) \leq \pi^0_{\text{FC}}(\ell)$, then the first-best outcome is attainable if*

$$\delta g_\ell p^*(g_\ell) - c\big(p^*(g_\ell)\big) \geq \delta \pi^0_{\text{FC}}(\ell)\,. \tag{36}$$

Given that $\pi^*_{\text{FC}}(m) > \pi^0_{\text{FC}}(\ell)$ and

$$\delta g_\ell p^*(\delta g_\ell) - c\big(p^*(\delta g_\ell)\big) > \delta g_\ell p^*(g_\ell) - c\big(p^*(g_\ell)\big)\,,$$

there is nothing necessarily contradictory about (35) and (36) holding simultaneously. In other words, it is possible that restrictions on bonuses would lead the board to switch from strategy m to strategy ℓ and permit it to achieve the first best. For example, suppose that $c(p) = p^2/2$, which implies $p^*(\zeta) = \zeta$, $\pi^*_{\text{FC}}(s) = g_s^2(1+\sqrt{\gamma})/4$, and $\pi^0_{\text{FC}}(s) = g_s^2\gamma/2$. Assume further that $\gamma = 9/16$, $\delta = 3/4$, $g_\ell = 90/100$, and $g_m = 85/100$. Expressions (35) and (36) are, respectively,

$$\frac{729}{3200} < \frac{6069}{25,600} \text{ and } \frac{81}{400} > \frac{2187}{12,800}\,.$$

To summarize:

Proposition 12. *There exist conditions such that, absent a cap or limit on bonuses, the board will pursue the inferior strategy, m, in equilibrium, but such that, under suitable restrictions on bonuses, the board will pursue the superior strategy, ℓ, and achieve the first best in equilibrium.*

It is plausible that longer-term strategies, because of delays in when returns are realized, pose problems for contingent compensation (*e.g.,* the use of bonuses). Direct monitoring of the CEO may be essential and rewarding him appropriately could require the use of an informal component to compensation. Consequently, if a shorter-term strategy, for which contingent compensation works better, is sufficiently attractive, the board's commitment to honor the informal component when seeking to implement the longer-term strategy could prove incredible. It follows, then, that Proposition 12 and the analysis leading up to it could offer an explanation for myopic firm behavior that complements other explanations (*e.g.,* Stein, 1989, Bizjak et al., 1993, and Bolton et al., 2006).[33]

An example of such a difference in strategies could be between "organic" and "inorganic" growth strategies. The latter, which is growth through acquisition and merger, presumably has clear metrics and, thus, lends itself to contingent compensation. The former, which is growth through innovation and market development, likely has less obvious metrics, at least in the short term. It seems plausible that a good board could assess the CEO's actions as he pursues either strategy. In short, an organic growth strategy corresponds to strategy ℓ above, while an inorganic strategy corresponds to strategy m.

An upshot of this analysis is that as limits—legal, moral, or political—on contingent compensation become relaxed, firm myopia problems could get worse; there could be a greater tendency to inorganic over organic growth; or other related changes to firms' strategies could arise.

Causality, we note, could run the other way: expression (34) is harder to satisfy if g_m increases or g_ℓ decreases. Hence, if the relative returns to more readily measured activities improve or the relative returns to harder to measure activities decline, then there could be a switch from the ℓ to m strategy, which would result in a jump in contingent compensation.

Finally, we note that this analysis could shed light on why new, entrepreneur-run firms often seem more innovative than established firms. As his own boss, the entrepreneur's interests tend to be aligned with his firm's and he will, thus, pursue an ℓ-type strategy even in settings in which a separation of ownership and control would make it difficult to induce an employee-CEO to do so. In other words, established firms may find it difficult to be innovative because of

[33]Stein (1989) is a career-concerns (signal-jamming) model of managerial myopia. Bizjak et al. (1993) is a model of asymmetric information in which, because the firm is obliged, for exogenous reasons, to use some form of stock-based compensation, the CEO has an incentive to manipulate short-term returns. Bolton et al. (2006) considers how existing shareholders could optimally give the CEO incentives to emphasize short-term stock performance, at the expense of long-run fundamental value, given their option to sell the stock later to potentially overoptimistic investors.

the incredibility of providing their executives proper incentives to pursue such strategies.

8 Discussion and Conclusions

Our main finding is that circumstances exist such that a company achieves higher profit if there is an externally imposed cap on contingent CEO pay than if there is not. The basic driver of our model is the limited liability the CEO enjoys: because he cannot be made to pay the company in the event of poor outcomes (performance), an incentive (formal) contract based on outcomes necessarily entails his capturing a rent (in expectation), which lessens the efficiency and profitability of such contracting. Moreover, the ability to write formal contracts in the future can undermine the writing of more efficient informal contracts today. If performance (outcome)-based payments are capped, however, formal contracts become an even worse substitute for informal contracts, so the board is less tempted to renege on an informal contract, which facilitates the use of such contracts. Consequently, conditions exist such that limits or caps on performance-based payments increase surplus and company profits (see, in particular, Corollary 3 and Propositions 5 & 6).

This finding is not universal: the benefits of capping performance pay depend on a number of factors, as set forth in Propositions 4–8. In particular if the board is insufficiently patient (δ very low) or the CEO is extremely patient (γ very high), then caps offer no benefit because formal contracting is superior to any informal contract that is credible. Moreover, if surplus maximization is the sole criterion of interest, then caps are without benefit when the CEO possesses the bargaining power. It is also important to recognize that the relevant policy prescription could be *limits*, not bans, on performance-based compensation (see, *e.g.,* the example following Proposition 6, as well as Lemma 11).

As discussed in Section 6, the benefits of restricting performance-based pay also rely on the ability of the board to assess what is going on in the firm. The more able (higher quality) the board is, the more valuable is a cap on bonuses. The argument also runs in the other direction: the marginal value of improving board quality is greater when a cap is in place (Corollary 4).

Capping CEO performance pay can also induce a firm to change from a strategy built on readily measured transactions (*e.g.,* inorganic growth) to a strategy built on long-term innovation and market development (*e.g.,* organic growth)—see Propositions 11 and 12. Using the same logic, we could similarly predict a change in strategy from modular "plug-and-play" technologies (Baldwin and Clark, 2000) to integrated systems technologies.

The importance of the three attributes—patience, board quality, and strategy—highlight the first major implication of our argument, namely that the indirect effects of formally seeking to align the incentives of principals and agents may well be profoundly more important than the direct effects. Consider each attribute in turn. In recent decades, commentators have expressed concerns about both rapid increases in CEO compensation, especially in the US (see, *e.g.,* Bebchuk and Fried, 2003, 2004, 2005),[34] and increasing short-termism by institutional investors (see, *e.g.,* Bushee, 2001). Our analysis suggests that these two trends could well be linked: to the extent the short-termism and lack of engagement correspond to a lower discount factor (smaller δ), it could be harder to sustain informal contracts, and executive compensation will increase due to a greater reliance on formal contracts. Conversely, if social and political pressures (as suggested by Jensen and Murphy, 1990) previously acted as a break on executive compensation, then the erosion of such pressures could enhance the potential for formal contracting at the expense of informal contracting, thereby reducing the returns to investor patience and engagement.

Turning to board quality, there could be many reasons to welcome greater board independence.[35] However, independent directors—those having no prior or current commercial relationship with the firm—are likely less familiar with subtleties of the firm's business, and so could be less expert in understanding the CEO's actions. Consequently, even absent the issue of compensation restrictions, trends in board composition could be related to trends in executive compensation (consider Proposition 10(ii) and (iii)). Thus, it is possible that earlier governance reforms by legislatures and exchanges aimed at increasing board independence could have been a factor in the rise in executive pay.[36]

Third, an increased emphasis on measurable CEO performance may be associated with changes in both the mix of firms in the economy (more companies built on transactions, fewer built around long-term innovation and market development); the strategies of those companies (more inorganic growth, less organic growth); and the way organic growth strategies are constructed (more emphasis on modular technologies, less emphasis on systems technologies). Each of these is worthy of further policy consideration in its own right.

These attributes, as well as related variables such as CEO pay (see, *e.g.,* Hall and Liebman, 1998, on trends), director independence (Borokhovich et al., 1996, and Huson et al., 2001), investor short-termism (Bushee, 2001), and a transfor-

[34]Hall and Liebman (1998) document the rapid increase of the 1990s. Kaplan (2012) suggests that this increase in executive pay—at least relative to other high-income groups—"leveled off" after the 1990s. We do not wish to enter into that debate *per se*: but Kaplan's data do indicate that top executives continue to be compensated at real levels well above their long-run average. A recent *New York Times* article, "That Unstoppable Climb in C.E.O. Pay" by Gretchen Morgenson (page 1 of the Business Section, June 29, 2013) suggests that CEO compensation could again be on the rise.

[35]For data on trends concerning the shift to more independent boards see Borokhovich et al. (1996) and Huson et al. (2001) for data on US firms. For similar evidence concerning the UK, see Dahya and McConnell (2007).

[36]Hermalin (2005) discusses some of these reforms (see also Adams et al., 2010). Hermalin offers a complementary model for why increased board independence could have contributed to the rise in executive compensation: because independent boards are more likely to dismiss their CEOs, they expose their CEOs to greater risk, for which the CEOs will require compensation (see Hermalin for details). Another complementary model is Kumar and Sivaramakrishnan (2008): a less-independent board, knowing it will not be as strong a negotiator against the CEO when setting his compensation, has a greater incentive than does a more-independent board to learn payoff-relevant information prior to those negotiations. The reason is that such information helps to offset its weaker bargaining position.

mation of the economy to emphasize networked organizational forms (Davis, 2009), modular technologies (Baldwin and Clark, 2000), and transaction-based strategies (Davis again) have all changed profoundly in recent decades. To understand how these trends may be related, it is useful to invoke the idea of an "institutional logic": different equilibria arise depending on the cluster of beliefs, capabilities, contracts, and technology that shape the expectations and behaviors of actors within an organization.[37] A shift in the norms, laws, and other factors governing how CEOs are compensated could potentially be a transformative driver of the entire logic of an industry, moving all the relevant behaviors to new equilibria; in particular, they could end up influencing changes in innovation and corporate strategy, board quality, and investor engagement. These, in turn, could alter the relative attractiveness of different industries to investors (*e.g.,* industries with readily assessed performance—"m-type strategies"—might become relative more attractive than those with harder-to-assess performance—"ℓ-type strategies") or investors' time horizons (*e.g.,* the attractiveness of long-term investing could fall *vis-à-vis* short-term trading). These, in turn, could feed back and drive an emphasis on performance-based CEO compensation.

A second major implication of the analysis, as noted in the Introduction, is it offers insights into the politics behind public policy on executive pay. Shareholders (boards), because of the benefit they derive from being "lashed to the mast," can desire legislation or regulation that restricts executive compensation. Executives, in contrast, will tend to realize generate greater utility from formal contracts (*i.e.,* with bonuses) than under purely informal contracts. Hence, executives don't want to see boards lashed to the mast. The political battle lines with regard to executive compensation, such as "say on pay," have indeed had that flavor. For example, major business groups campaigned hard against the Swiss "say-on-pay" referendum of 2013.[38] Similarly, in the US, CEOs tended to oppose the say-on-pay provisions of the Dodd-Frank bill.[39] As remarked on earlier, such explicit conflict is a somewhat unique feature of our analysis: in previous work, if one side wishes to see informal contracting facilitated, the other side either also wants that or is, at worst, indifferent to such facilitation.

Many of the arguments in this article are amenable to empirical testing. A viable empirical strategy would compare organizations across regulatory environments and look for differences in our four principal variables: CEO compensation, patience, board quality, and strategy. For example, a study could compare firms in a given economy along the dimensions of compensation models, styles of corporate governance (especially levels of trust between directors and execu-

[37]This relates to ideas in Milgrom and Roberts (1990) and Aoki (2010). The term "institutional logic" itself is drawn from sociology, where it carries similar connotations (see, *e.g.,* Thornton et al., 2012).

[38]See, *e.g.,* "Minders Kampf" by Peter Teuwsen, originally published in *Die Zeit*, January 24, 2013. Retrieved from *Zeit Online* May 28, 2013.

[39]See, *e.g.,* "CEOs Openly Oppose Push for Say-on-pay by Shareholders" by Del Jones, originally published in *USA Today*, July 17, 2009. Retrieved from *USA Today* website on May 28, 2013.

tives indicating the use of informal contracts), rates and modes of innovation, corporate strategy, and so forth. A notable confound in such a study might be corporate size: in particular, larger corporations could have more divisions or otherwise be more complex, which means directors are likely to have less understanding of the business, reinforcing the arguments we have made.

Alternatively, researchers might compare companies across industries, depending on whether the core technology favors organic (*e.g.,* manufacturing) or inorganic (*e.g.,* commodities trading) strategies.

Comparisons across countries provide a third option. We might expect to see differentials in the speed or extent of adoption of "good" corporate governance practices such as pay-for-performance and independent directors. Such differentials could result from different regulatory requirements by governments and exchanges, as well as different tax treatment of different forms of compensation. With respect to the last point, we note that a high marginal tax rate could serve to make formal contracts (high levels of contingent pay) less effective, thus helping to facilitate the use of informal contracting.

A fourth possibility is to examine the transformation of a given economy over time. This is alluded to in our discussion of institutional logics above. Davis (2009) has argued that, in recent years, the US economy has been transformed from one managed by industrialists to one controlled by the financial markets. In his review of that book, Fligstein (2010) points out that Davis fails to elucidate the mechanism of that transformation. This article lays out one possible mechanism, and it could be tested by examining the way the various variables change through time.

A further empirical strategy would be to look for performance differentials when companies adopt corporate governance systems that are poorly matched to their core technology.[40] For instance, if companies that, by necessity, pursue long-term strategies (*e.g.,* mining or manufacturing firms) make extensive use of formal contracts, we would expect to see worse relative performance *vis-à-vis* companies in the same industry that rely on informal contracts.

Beyond testing the model presented here, this research suggests the need for applied research examining the implications of the model. We have suggested that a move to a greater reliance on performance-based compensation (formal contracts) may have undermined corporate performance and that investor patience, board quality, and corporate strategy may have been implicated in the move. Is this true, and if so, to what extent? What has driven the relevant changes in these factors? Noting that our analysis shows only that circumstances *can* exist in which restrictions on executive pay are desirable; how, as a matter of policy, do we determine whether those circumstances hold? And, if they do hold, how do we determine what appropriate limits might be?

In this article, we have argued that, contrary to conventional wisdom, allowing firms complete freedom to set performance-based compensation for their

[40] Although why companies would adopt such governance systems is unclear: a prevalent argument within economics is that firms adopt the optimal governance system given their circumstances (see, *e.g.,* Hermalin, 2013).

executives with the aim of aligning executives and shareholders' interests can be counter-productive. Rather, firm profitability may be increased by externally imposed caps on executive performance pay. Such a cap can make it feasible for a board of directors to utilize informal contracts that directly reward executive effort. It is also possible that such caps would drive an increase in corporate time horizons, improved board quality, and profitable changes in corporate strategy.

Appendix A: Proofs and Additional Material

Some of the analysis in this paper relies on the following well-known revealed-preference result, which is worth stating once, at a general level. Note our use of subscripts to denote partial derivatives.

Lemma A.1. *Let $f(\cdot,\cdot):\mathbb{R}^2\to\mathbb{R}$ be continuously differentiable in each argument function. Let $\hat{x}$ maximize $f(x,z)$ and let $\hat{x}'$ maximize $f(x,z')$, where $z>z'$. Suppose that $f_{12}(\cdot,\cdot)$ exists. Assume that cross-partial derivative has a constant sign (not zero) on $[\hat{x}'\wedge\hat{x},\hat{x}'\vee\hat{x}]\times[z',z]$.[41] Then $\hat{x}\geq\hat{x}'$ if $f_{12}(\cdot,\cdot)>0$ and $\hat{x}\leq\hat{x}'$ if $f_{12}(\cdot,\cdot)<0$. The inequalities are strict if either $\hat{x}$ or $\hat{x}'$ (or both) are interior maxima.*

Proof: By the definition of an optimum (revealed preference):

$$f(\hat{x},z)\geq f(\hat{x}',z)\text{ and }f(\hat{x}',z')\geq f(\hat{x},z')\,. \tag{37}$$

Expression (37) implies, via the fundamental theorem of calculus, that

$$\begin{aligned}0&\leq\big(f(\hat{x},z)-f(\hat{x}',z)\big)-\big(f(\hat{x},z')-f(\hat{x}',z')\big)\\&=\int_{\hat{x}'}^{\hat{x}}\big(f_1(x,z)-f_1(x,z')\big)dx=\int_{\hat{x}'}^{\hat{x}}\left(\int_{z'}^{z}f_{12}(x,y)dy\right)dx\,.\end{aligned}$$

Consider the last term: given that $z>z'$, the inner integral is positive if $f_{12}(\cdot,\cdot)>0$ and negative if $f_{12}(\cdot,\cdot)<0$. The direction of integration in the outer integral must be weakly left to right (*i.e.*, $\hat{x}'\leq\hat{x}$) if the inner integral is positive and weakly right to left (*i.e.*, $\hat{x}'\geq\hat{x}$) if the inner integral is negative. This establishes the first part of the lemma.

To establish the second part, because $f(\cdot,y)$ is differentiable for all y, if $\tilde{x}$ is an interior maximum, then it must satisfy the first-order condition

$$0=f_1(\tilde{x},y)\,.$$

Because $f_1(\hat{x},\cdot)$ is strictly monotone, $f_1(\hat{x},z)\neq f_1(\hat{x},z')$, $z\neq z'$. Hence, $\hat{x}$ does not satisfy the necessary first-order condition to maximize $f(\cdot,z')$. Therefore, $\hat{x}'\neq\hat{x}$; that is, the inequalities are strict. ■

[41] The operator $\wedge$ (the *meet*) denotes the pairwise minimum and the operator $\vee$ (the *join*) denotes the pairwise maximum.

Proof of Lemma 1: Surplus is $pg - c(p)$, a continuous function of p. By a well-known theorem of Weierstrass's (see, *e.g.,* Sundaram, 1996, p. 90), a $p \in [0,1]$ that maximizes that function must then exist. Because $pg - c(p)$ is strictly concave in p, the maximizer of $pg - c(p)$ is unique. That $0 < p^*(g) < 1$ was shown in the discussion preceding the lemma. ■

Proof of Lemma 2: If $p^*(b) > 0$, then it is the unique solution to the first-order condition, $b - c'(p) = 0$;[42] hence,

$$b = c'\big(p^*(b)\big) \tag{38}$$

if $p^*(b) > 0$. Because $c(\cdot)$ is strictly convex and a convex function lies above any first-order Taylor series approximation of it, we have

$$c\big(p^*(b)\big) - c'\big(p^*(b)\big)p^*(b) < c(0) = 0\,.$$

Multiplying that last expression by -1 and using (38) yields

$$bp^*(b) - c\big(p^*(b)\big) > 0\,. \tag{39}$$

Because $w \geq 0$ by assumption (the CEO can never be made to pay the firm), expression (39) entails the CEO must earn a rent. ■

Proof of Lemma 3: The firm cannot lose money in equilibrium, because it could always deviate to $\langle 0, 0\rangle$. If it offers that "contract," then (2) is trivially an equality.

Suppose that $\widetilde{p} = 0$. Hence, $p^*(b) = 0$ and, to avoid losing money, $w = 0$. It follows that (2) holds as an equality.

Suppose, henceforth, that $\widetilde{p} > 0$. Suppose that $w > 0$. Then if (2) were a strict inequality, the firm could profitably lower w by some small amount while maintaining the target $\widetilde{p}$; hence, there cannot be an equilibrium in which $w > 0$ and (2) holds as a strict inequality. Suppose $w = 0$. Because $\widetilde{p} > 0$, $c(\widetilde{p}) > 0$ and, thus, $b > 0$ if (2) is to hold (by Lemma 2 the righthand side of (2) is non-negative). But if (2) were a strict inequality, the firm could profitably lower b by some small amount while maintaining the target $\widetilde{p}$; hence, there cannot be an equilibrium in which $w = 0$ and (2) holds as a strict inequality. ■

Proof of Lemma 4: If $\widetilde{p} = 0$, then the firm must set $w = 0$ to avoid a loss. Assume, therefore, that $\widetilde{p} > 0$. Suppose, counter to the lemma's claim, that the firm offers $\langle w_0, b_0\rangle$ in equilibrium, $w_0 > 0$. By Lemma 3, expression (2) holds as an equality. Define

$$y_0 = w_0 + b_0\widetilde{p} \text{ and } \omega(b) = y_0 - b\widetilde{p}\,;$$

that is, y_0 is the CEO's expected compensation—and, thus, the firm's cost—under $\langle w_0, b_0\rangle$ and all contracts $\langle \omega(b), b\rangle$ have expected cost y_0. Consider the

[42] Because $b \leq g$ and $p^*(g) < 1$, there is no need to consider a corner solution of $p^*(b) = 1$. In what follows, we will not repeat this point.

following deviation from $\langle \omega(b_0), b_0 \rangle$: raise b slightly while setting $w = \omega(b)$. The lefthand side of (2) remains unchanged, while the righthand side *decreases*.[43] By continuity, there must exist a $b_1 > b_0$ such that $\omega(b_1) > 0$ and

$$\omega(b_1) + b_1\widetilde{p} - c(\widetilde{p}) > (1-\gamma)\Big(\omega(b_1) + b_1 p^*(b_1) - c\big(p^*(b_1)\big)\Big)\,.$$

But then there exists an $\varepsilon \in \big(0, \omega(b_1)\big)$ such that

$$\omega(b_1) - \varepsilon + b_1\widetilde{p} - c(\widetilde{p}) \geq (1-\gamma)\Big(\omega(b_1) - \varepsilon + b_1 p^*(b_1) - c\big(p^*(b_1)\big)\Big)\,,$$

which entails that the firm could have implemented the target $\widetilde{p}$ using the contract $\langle \omega(b_1) - \varepsilon, b_1 \rangle$, which costs less than y_0: the contract $\langle \omega(b_1) - \varepsilon, b_1 \rangle$ is a profitable deviation, contradicting the supposition that $\langle w_0, b_0 \rangle$ would be offered in equilibrium. The result follows *reductio ad absurdum*. ■

Proof of Lemma 5: Suppose that $\langle w, b \rangle$ is a contract offered in equilibrium. Suppose, contrary to the first claim of the lemma, that there exist $\widetilde{p}'$ and $\widetilde{p}''$, $\widetilde{p}'' > \widetilde{p}' \geq p^*(b)$, such that (2) is an equality both when $\widetilde{p} = \widetilde{p}'$ and when $\widetilde{p} = \widetilde{p}''$. Because $bp - c(p)$ is a strictly concave function of p with a unique maximizer, $p^*(b)$, it must be that

$$b\widetilde{p}'' - c(\widetilde{p}'') < b\widetilde{p}' - c(\widetilde{p}')\,.$$

That insight leads to the contradictory chain:

$$\begin{aligned}(1-\gamma)\Big(w + bp^*(b) - c\big(p^*(b)\big)\Big) &= w + b\widetilde{p}'' - c(\widetilde{p}'') < w + b\widetilde{p}' - c(\widetilde{p}') \\ &= (1-\gamma)\Big(w + bp^*(b) - c\big(p^*(b)\big)\Big)\,.\end{aligned}$$

That $\widehat{p}(\cdot,\cdot)$ is differentiable in each argument follows immediately from the implicit function theorem.

Differentiating (2) with respect to w yields

$$1 + \Big(b - c'\big(\widehat{p}(b,w)\big)\Big)\frac{\partial \widehat{p}(b,w)}{\partial w} = 1 - \gamma\,.$$

Because $\widehat{p}(b,w) > p^*(b)$, the expression in the largest parentheses is negative, from which it follows that $\partial \widehat{p}(b,w)/\partial w > 0$.

Differentiating (2) with respect to b yields

$$\widehat{p}(b,w) + \Big(b - c'\big(\widehat{p}(b,w)\big)\Big)\frac{\partial \widehat{p}(b,w)}{\partial b} = (1-\gamma)p^*(b)$$

---

[43] The derivative of

$$(1-\gamma)\Big(\omega(b) + bp^*(b) - c\big(p^*(b)\big)\Big)$$

with respect to b is, using the envelope theorem,

$$(1-\gamma)\big(p^*(b) - \widetilde{p}\big)\,.$$

At $b = b_0$, the sign of the derivative is negative because $\widetilde{p} > p^*(b_0)$ in equilibrium.

(utilizing the envelope theorem on the righthand side). It follows, given $\widehat{p}(b,w) > p^*(b) \geq (1-\gamma)p^*(b)$, that $\partial\widehat{p}(b,w)/\partial b > 0$. ■

Proof of Proposition 1: Let $y(b,w)$ denote the firm's expected cost (the CEO's expected compensation) in equilibrium given contract $\langle w,b\rangle$. From Lemmas 3 and 5:

$$y(b,w) = c\big(\widehat{p}(b,w)\big) + (1-\gamma)\Big(w + bp^*(b) - c\big(p^*(b)\big)\Big)\,. \tag{40}$$

The firm's (board's) seeks to maximize

$$\widehat{p}(b,w)g - y(b,w)\,. \tag{41}$$

The firm either faces a binding constraint (limit or cap) on bonuses, in which case its only degree of freedom is to adjust w, or it faces no such constraint, in which case, given Lemma 4, $w=0$ and it adjusts b only. Using (40), the relevant derivative of (41) is

$$\Big(g - c'\big(\widehat{p}(\bar{b},w)\big)\Big)\frac{\partial\widehat{p}(\bar{b},w)}{\partial w} - (1-\gamma) \tag{42}$$

in the first case and

$$\Big(g - c'\big(\widehat{p}(b)\big)\Big)\frac{d\widehat{p}(b)}{db} - (1-\gamma)p^*(b) \tag{43}$$

in the second. Given Lemma 5 and the fact that $g - c'(p) \leq 0$ for all $p \geq p^*(g)$, it follows from (42) or (43), as appropriate, that the firm can never find it profit-maximizing to choose a contract such that $\widehat{p}(b,w) \geq p^*(g)$.[44] It follows that, in equilibrium, $\widehat{p}(b,w) < p^*(g)$, which establishes the first claim.

Fix a γ and let $\langle w,b\rangle$ be the contract the board offers in equilibrium. Assume expected profit is positive. Hence, w or b or both are positive. Suppose γ increases to γ'. Observe, fixing $\widetilde{p} = \widehat{p}(b,w)$, that the lefthand side of (2) is unchanged, while the righthand side falls. It follows that the firm can reduce b or w slightly so that (2) continues to hold at the previously fixed target $\widetilde{p}$. It follows that the firm's expected equilibrium profit must be greater when the CEO's discount factor is γ' than when it is γ. ■

Proof of Lemma 8: Maximizing (1) with respect to p reveals

$$p^*(b) = \begin{cases} 0\,, \text{ if } b \leq c'(0) \\ {c'}^{-1}(b)\,, \text{ if } c'(0) < b < c'(1) \\ 1\,, \text{ if } c'(1) \leq b \end{cases}\,, \tag{44}$$

[44] When $w=0$, it must be that $p^*(b) > 0$ if $\widehat{p}(b) > 0$. To see this, suppose not: the righthand side of (2) is then zero; hence, from Lemma 3, $b\widehat{p}(b) - c\big(\widehat{p}(b)\big) = 0$. Because $\widehat{p}(b) > 0$ and $bp - c(p)$ is strictly concave in p, it follows that $bp - c(p) > 0$ for any $b \in \big(0, \widehat{p}(p)\big)$, which contradicts the claim that $p^*(b) = 0$.

So $b \leq c'(0)$ implies $p^*(b) = 0$, which entails $u(b) = 0$. It is, thus, sufficient to show $u(b) > 0$ if $b > c'(0)$. Because $c'(\cdot)$ is strictly increasing, it follows from (44) that $p^*(b) > 0$ if $b > c'(0)$. We thus have for $b > c'(0)$:

$$u(b) = \int_0^{p^*(b)} \big(b - c'(p)\big)dp > 0\,,$$

where the inequality follows because (1) is a strictly concave optimization program. So $u(b) = 0$ for all $b \leq c'(0)$ and $u(b) > 0$ for all $b > c'(0)$. It follows that $\underline{b} = c'(0)$. ■

Proof of Lemma 9: Because $\tau(p)$, $p \neq \widetilde{p}$, is relevant only off the equilibrium path, it matters only for the CEO's incentive constraint, expression (14). If (14) holds for an arbitrary $\tau(p)$, it holds if $\tau(p) = 0$. Moreover, relaxing that constraint would permit the board to reduce $\tau(\widetilde{p})$, which would both be directly beneficial and relax the credibility condition; hence, the board must be weakly better off setting $\tau(p) = 0$ for $p \neq \widetilde{p}$ than setting any other value for $\tau(p)$. ■

Proof of Lemma 11: The first claim is immediate from (31).

Given Assumption 1, for any $b \in (0, g)$, $p^*(b) > 0$ implying that $(g-b)p^*(b) > 0$. Because the board can guarantee itself at least that profit by setting $\widetilde{p} = p^*(b)$ and $\tau(p) \equiv 0$, in which case (31) is $(g - b)p^*(b) > 0$, we know that maximizing (31) entails $\widetilde{p} > 0$.

The problem of maximizing (31) is unaffected if that expression is multiplied by θ; henceforth, considered it to have been so scaled. It is readily verified the expression is concave in b and $\widetilde{p}$; hence, in what follows, first-order conditions are sufficient as well as necessary. Because $b < g$, maximizing (31) with respect to b yields the first-order condition[45]

$$(1 - \theta)\widetilde{p} - p^*(b) \leq 0\,, \tag{45}$$

with an inequality only if $b = 0$. Observe that $b = 0$ can be a solution only if $\theta = 1$ given we know $p^*(b) > 0$ if and only if $b > 0$.

The first-order condition with respect to $\widetilde{p}$ can be rewritten as

$$\widetilde{p} = p^*\big(\theta g + (1 - \theta)b\big)\,. \tag{46}$$

The final claim is immediate from (46) given $g > b$. ■

Lemma A.2. *Suppose that the* CEO *is a short-run player or, equivalently, wholly myopic (i.e., assume $\gamma = 0$). Assume the* CEO*'s disutility-of-action function, $c(p)$, equals $p^2/2$. Then the following are true:*

(i) A board limited to using formal contracts only, but without a cap on bonuses, will set $b_{\text{FC}} = g/2$;

[45] Recall, by the envelope theorem, $u'(b) = p^*(b)$.

(ii) *maximum possible expected profit using formal contracts only,* π^*_{FC}*, is* $g^2/4$*;*

(iii) *if the cap on bonuses is* $\bar{b} < g/2$*, then the cap binds for a board limited to formal contracts and* $\pi_{\text{FC}} = (g - \bar{b})\bar{b}$*; and*

(iv) $\pi^0_{\text{FC}} = 0$.

In addition, if the board has quality $\theta \in (0, 1]$*, then:*

(v) *Under the (hybrid) contract that maximizes expected per-period profit (ignoring the credibility condition* (32)*), the board sets*

$$\widetilde{p} = \frac{g}{2-\theta}\,,\ b = \frac{g(1-\theta)}{2-\theta}\,,\ \text{and } \tau(\widetilde{p}) = \frac{g^2\theta}{2(2-\theta)^2}\,; \tag{47}$$

(vi) *the credibility condition* (32) *is slack in equilibrium if*

$$\delta \geq \frac{g^2\theta}{2\left(g^2 - \pi_{\text{FC}}(2-\theta)^2\right)}\,;\ \text{and} \tag{48}$$

(vii) *if the credibility condition* (32) *binds in equilibrium (i.e., expression* (48) *fails to hold), then the (hybrid) contract offered in equilibrium is*

$$\widetilde{p} = \frac{g + \sqrt{\delta\theta\left(g^2/2 - \pi_{\text{FC}}(2-\delta\theta)\right)}}{2-\delta\theta}\,, \tag{49}$$

$$b = \frac{g(1-\delta\theta) - \sqrt{\delta\theta\left(g^2/2 - \pi_{\text{FC}}(2-\delta\theta)\right)}}{2-\delta\theta}\,,\ \text{and} \tag{50}$$

$$\tau(\widetilde{p}) = \frac{\delta\left(g\left(g(2+\delta\theta) + 4\sqrt{\delta\theta\left(g^2/2 - \pi_{\text{FC}}(2-\delta\theta)\right)}\right) - 4\pi_{\text{FC}}(2-\delta\theta)\right)}{2(2-\delta\theta)^2}\,. \tag{51}$$

Moreover, if the credibility condition binds in equilibrium, then $\widetilde{p}$ *is less than its value in* (47) *and* b *is greater than its value in* (47)*.*

Proof: Given the assumed functional form, it is readily verified that $p^*(\zeta) = \zeta$. Because the CEO is wholly myopic, there are no efficiency-wage effects (consider expression (2) above); hence, $w = 0$ in any formal contract. In addition, a board limited to formal contracts but otherwise unconstrained will set b to maximize

$$p^*(b)(g-b) = gb - b^2\,. \tag{52}$$

The solution is $b = g/2$, which establishes result (i). Inserting that value into (52) yields result (ii). Expression (52) is strictly concave in b, so if $\bar{b} < g/2$, the constraint binds. Substituting the constraint yields (iii) and (iv).

From the proof of Lemma 11, expressions (45) and (46) yield, respectively

$$(1-\theta)\widetilde{p}-b=0 \text{ and } \widetilde{p}=\theta g+(1-\theta)b\,.$$

Solving for $\widetilde{p}$ and b yield the first two equalities in (47). Expression (30) implies

$$\tau(\widetilde{p})=\frac{1}{\theta}\Big(\underbrace{\frac{b^2}{2}}_{u(b)}-\big(b\widetilde{p}-\underbrace{\frac{\widetilde{p}^2}{2}}_{c(\widetilde{p})}\big)\Big)\,, \tag{53}$$

which yields the third equality in (47) once $\widetilde{p}$ and b have been substituted for. Hence, (v) is proved. Straightforward algebra reveals that per-period expected profit under the contract given in (47) is

$$\frac{g^2}{4-2\theta}\,. \tag{54}$$

Hence, the credibility condition is slack if

$$-\underbrace{\frac{g^2\theta}{2(2-\theta)^2}}_{\tau(\widetilde{p})}+\frac{\delta}{1-\delta}\frac{g^2}{4-2\theta}\geq\frac{\delta}{1-\delta}\pi_{\text{FC}}\,.$$

Solving for δ yields (48) and establishes (vi).

The Lagrangian for optimizing expected per-period profit with respect to $\widetilde{p}$ and b given constraint (32) is equivalent to

$$(1+\lambda)\left((g-b)\widetilde{p}+\frac{1}{\theta}\Big(\big(b\widetilde{p}-c(\widetilde{p})\big)-u(b)\Big)\right)-\lambda(1-\delta)(g-b)\widetilde{p}\,,$$

where λ is the Lagrange multiplier. The first-order conditions with respect to $\widetilde{p}$ and b are, respectively,

$$(1+\lambda)\left((g-b)+\frac{1}{\theta}(b-\widetilde{p})\right)-\lambda(1-\delta)(g-b)=0 \text{ and} \tag{55}$$

$$(1+\lambda)\left(-\widetilde{p}+\frac{1}{\theta}(\widetilde{p}-b)\right)-\lambda(1-\delta)(-\widetilde{p})=0\,. \tag{56}$$

For future reference observe the (55) implies

$$(g-b)+\frac{1}{\theta}(b-\widetilde{p})>0 \tag{57}$$

if $\lambda>0$. Adding (55) and (56) yields

$$0=(1+\lambda)(g-b-\widetilde{p})-\lambda(1-\delta)(g-b-\widetilde{p})=(1+\delta\lambda)(g-b-\widetilde{p})\,.$$

It follows that $b=g-\widetilde{p}$. Consequently, (57) implies

$$\widetilde{p}<\frac{g}{2-\theta} \text{ and } b>\frac{g(1-\theta)}{2-\theta}\,. \tag{58}$$

This establishes the "moreover" part of (vii). Substituting $b = g - \widetilde{p}$ into (32) and simplifying both sides yields:

$$\frac{4g\widetilde{p} - 2(2-\theta)\widetilde{p}^2 - g^2}{2\theta} = (1-\delta)\widetilde{p}^2 + \delta\pi_{\text{FC}}\,. \tag{59}$$

Observe that the lefthand side of (59) is expected per-period profit. Observe that (59) is a quadratic expression in $\widetilde{p}$ and will, thus, generically have two roots. Because the righthand side of (59) is increasing in $\widetilde{p}$, it follows that the larger root must correspond to the largest possible expected per-period profit. That root is given by (49). Using $b = g - \widetilde{p}$ yields (50). Inserting those values for b and $\widetilde{p}$ into (53) yields (51). ■

Proof of Proposition 10: Part (i): The cutoff value is the righthand side of (48) in Lemma A.2. The derivative of that with respect to θ is

$$\frac{g^2\left(g^2 - (4-\theta)^2\pi_{\text{FC}}\right)}{2\left(g^2 - (2-\theta)^2\pi_{\text{FC}}\right)^2}\,, \tag{60}$$

which has the same sign as $g^2 - (4-\theta^2)\pi_{\text{FC}}$, which, by Lemma A.2(ii), cannot be less than

$$g^2 - (4-\theta^2)\frac{g^2}{4} = \theta^2\frac{g^2}{4} > 0\,.$$

Hence, (60) is positive, as was to be shown.

Part (ii): If the credibility condition doesn't bind, then the result is immediate from Lemma A.2(v): the ratio $(1-\theta)/(2-\theta)$ is decreasing in θ. If the credibility condition does bind, then differentiating (50) in Lemma A.2 with respect to θ yields

$$-\delta\frac{2\sqrt{2}(g^2 - 4\pi_{\text{FC}}) + \delta\theta\sqrt{2}(g^2 + 4\pi_{\text{FC}}) + 4g\sqrt{\delta\theta\left(g^2 - (4-2\delta\theta)\pi_{\text{FC}}\right)}}{4(2-\delta\theta)^2\sqrt{\delta\theta\left(g^2 - (4-2\delta\theta)\pi_{\text{FC}}\right)}}\,. \tag{61}$$

From Lemma A.2(ii), $g^2 \geq 4\pi_{\text{FC}}$. It follows that (61) is negative.

Part (iii): If the credibility constraint does not bind, then it follows from Lemma A.2(v) that the CEO's expected utility is

$$\frac{g^2(1-\theta)}{2(2-\theta)^2}\,,$$

the derivative of which with respect to θ is

$$-\frac{g^2\theta}{2(2-\theta)^3} < 0\,.$$

For the case in which the credibility constraint binds, the constraint (*i.e.,* expression (32)) implies that the CEO's expected utility is

$$\begin{aligned}\mathbb{E}V = g\widetilde{p} - (1-\delta)(g-b)\widetilde{p} - \delta\pi_{\text{FC}} - c(\widetilde{p}) &= g\widetilde{p} - (1-\delta)\widetilde{p}^2 - \delta\pi_{\text{FC}} \\ &= g\widetilde{p} - \frac{3-2\delta}{2}\widetilde{p}^2 - \delta\pi_{\text{FC}}\,, \end{aligned}\tag{62}$$

where the second equality follows from Lemma A.2(vii) and the third from the functional-form assumption. Because the righthand side of (48) is, given Lemma A.2(ii), never less than

$$\frac{2}{4-\theta}\,, \tag{63}$$

which in turn cannot be less 2/3, it follows that $3 > 2\delta$ if the credibility constraint binds. Observe that the derivative of (62) is negative if

$$\widetilde{p} > g\frac{1}{3-2\delta}\,.$$

Given Lemma A.2(ii),

$$\widetilde{p} \geq g\frac{2+\delta\theta}{4-2\delta\theta}\,.$$

For δ less than (63) (*i.e.,* satisfying the necessary condition for the credibility constraint to bind), it can be shown that

$$\frac{2+\delta\theta}{4-2\delta\theta} > \frac{1}{3-2\delta}\,;$$

hence, in sum, the derivative of (62) is negative evaluated at the equilibrium value of $\widetilde{p}$. Part (iii) will therefore follow if $\partial\widetilde{p}/\partial\theta > 0$. Calculations reveal

$$\frac{\partial\widetilde{p}}{\partial\theta} = \delta\frac{2\sqrt{2}(g^2-4\pi_{\text{FC}})+\delta\theta\sqrt{2}(g^2+4\pi_{\text{FC}})+4g\sqrt{\delta\theta\left(g^2-(4-2\delta\theta)\pi_{\text{FC}}\right)}}{4(2-\delta\theta)^2\sqrt{\delta\theta\left(g^2-(4-2\delta\theta)\pi_{\text{FC}}\right)}} > 0\,,$$

where the sign follows from Lemma A.2(ii).

Part (iv): As noted in the proof of part (iii), if there is no restriction on bonuses (*i.e.,* $\pi_{\text{FC}} = \pi^*_{\text{FC}}$), then the credibility constraint, expression (32), is slack if δ is not less than (63). Suppose that δ is in the range given by (33). Observe from Lemma A.2(i) that

$$b_{\text{FC}} = \frac{g}{2} > \frac{g(1-\theta)}{2-\theta} \equiv \bar{b}\,;$$

hence, limiting $b \leq \bar{b}$ is a binding constraint. If that cap is imposed, then straightforward algebra reveals that the *credibility* constraint is slack for all $\delta \geq 1/2$. By Lemma A.2(v), a bonus of $\bar{b}$ is optimal absent the credibility constraint. Moreover, expected profits are lower if the credibility constraint binds than if it does not. It thus follows that the above cap on bonuses raises expected per-period profit as was to be shown.

Part (v): If the credibility constraint binds, then, using (32), expected per-period utility equals

$$(1-\delta)(g-b)\widetilde{p}+\delta\pi_{\text{FC}} = (1-\delta)\widetilde{p}^2+\delta\pi_{\text{FC}}\,,$$

where the equality follows from Lemma A.2(vii). Imposing a cap of

$$\bar{b} = \frac{g(1-\theta)}{2-\theta}$$

provides, from (54), a benefit of

$$\frac{g^2}{4-2\theta} - (1-\delta)\widetilde{p}^2 - \delta\pi^*_{\mathrm{FC}}\,.$$

The derivative of that expression with respect to θ is

$$\frac{g^2\left(8-4\delta(8-5\theta+2\theta^2)+\delta^3\theta(16-16\theta+3\theta^2)+\delta^2(32-48\theta+30\theta^2-4\theta^3)\right)}{2(2-\theta)^2(2-\delta\theta)^3}\,,$$

which is positive for all δ less than (63). ■

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