Evidence for Relational Contracts in CEO Bonus Compensation

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Abstract

This paper investigates the structure of optimal incentive schemes in a stochastic environment and provides evidence consistent with the design of self-enforcing relational contracts. We show in a theoretical model that under relational contracting firms can credibly promise to pay chief executive officers (CEOs) larger bonuses in good states than in bad states, whereas under formal contracting firms offer the same bonus in both states of the world. Estimating an empirical model using ExecuComp data, we find that CEO annual bonuses are related to "luck" (idiosyncratic shocks and serially-correlated states) in a manner consistent with relational contracting.

JEL Classification: C73, D86, J41

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1 Introduction

One of the most controversial issues in CEO compensation is the historically weak link between CEO pay and firm performance (see, e.g., Murphy, 1999; Core et al., 2003, for surveys). In particular, Hall and Liebman (1998) show that existing pay-performance sensitivities are almost entirely driven by stock options and stock ownership, which leaves virtually no significant correlation between non equity-based compensation (e.g., salary and bonus) and firm performance. In recent years, a number of researchers have found that CEO cash compensation responds to factors, or luck, over which the managers have no control (e.g., Blanchard et al., 1994; Bertrand and Mullainathan, 2001; Oyer, 2004; Garvey and Milbourn, 2006; Bizjak et al., 2008).

Bebchuk and Fried (2003, 2004) prominently argued that pay-for-luck is inconsistent with the agency theoretic view but consistent with the hypothesis of managerial power. That is, the Informativeness Principle suggests that only those measures that provide information about the CEO's desired action should be used in the CEO's incentive contract (Shavell, 1979; Holmstrom, 1979). However, Bebchuk and Fried argue that excessive CEO power and a lack of arm's-length relationship with the board lead to inefficient forms of pay. In this paper, we argue that pay-for-luck can actually be consistent with efficient compensation under relational contracting, and present empirical ev idence supporting our argument.[1]

The key feature of relational contracting is that decisions on performance pay are ul-

[1] An alternative explanation of pay-for-luck is that the firm may want to adjust CEO pay for retention purposes in a way that is correlated with the CEO's outside options in the labor market (Oyer, 2004; Bizjak et al., 2008). However, Holmstrom (2005) suggests that increased demand is not likely to be the sole driver for the rise in CEO pay, but instead argues that dynamic models where commitment problems and implicit incentives arise should be examined.

timately a matter of firm discretion. Firms and workers often rely on relational contracts because complete, explicit contracts are costly to design and enforce (Kvaløy and Olsen, 2009). In a cross-sectional study, Gillan et al. (2009) found that roughly half of the S&P 500 CEOs work without an explicit employment contract. Certain arrangements that do exist regarding executive bonuses might appear at first glance to be entirely formal.[2] However, even if firms have in place a formal shareholder-approved bonus plan, the board can exercise discretion either in the performance metrics used or in judgments about whether certain performance standards have been achieved. For instance, "individual bonuses may be based in part on subjectively assessed individual performance [...] Alternatively, the boards of directors may make discretionary adjustments" (Murphy and Oyer, 2004: 2).[3]

A natural question that follows is whether relational contracting plays a role in executive compensation. Our approach is to construct a theoretical model that yields different predictions under explicit (formal) and implicit (relational) contracting and to test its predictions in an empirical analysis of CEO bonus pay. The basic theory of stationary relational contracts is well known (e.g., Bull, 1987; MacLeod and Malcomson, 1989; Baker et al., 1994; Levin, 2003; Malcomson, 2012). Relational contracts can be self-enforcing in the sense that, when the future value of the relationship is sufficiently large, both parties to the contract find it profitable to adhere to their implicit obligations, rather than engage in opportunistic behavior. In an employment model, this means that joint future surplus must overwhelm the firm's current temptation to renege on discretionary bonus payments promised to the

[2] For example, Murphy (1999) provides a detailed discussion of formula-based "80/120 plans," which are common, piecewise-linear contracts.

[3] The scope for discretion in executive bonuses is further articulated in the following observation by Murphy and Jensen (2012: 42): "sometimes these shadow plans have little or nothing to do with the performance criteria specified in the shareholder approved plans."

worker.

In a stationary environment with stochastic output shocks that are independent over time, it is difficult to empirically discriminate between formal and relational contracts, since both would imply that the bonus paid to a worker who succeeds should be constant over time. The intuitive reason under relational contracts is that one-off events over which managers have no control (i.e., "luck") only affect today's surplus and have no relevance to the future value of the relationship. Hence, pay-for-luck should be absent. The only difference between formal and relational contracts is that the bonus would be smaller when the firm's dynamic enforcement constraint binds; however, without knowing the counterfactual for a given firm, estimating the difference is not straightforward.

In fact, most existing studies measure luck as the portion of firm performance that can be predicted by exogenous price changes (e.g., oil prices and exchange rates) or average industry performance (see, e.g., Bertrand and Mullainathan, 2001), measures that tend to be correlated over time. Serial correlation means that the future value of the relationship is no longer independent of today's shock, which matters for relational contracting but not for formal contracting. Distinguishing between independent shocks and serially-correlated shocks (which we call "state") allows us to formulate a discriminating test between formal and relational contracts that we can then bring to the data.

More precisely, we consider a simple Markovian environment with two states of the world (good and bad). The state directly affects output and is positively correlated over time, the idea being that certain factors beyond the manager's control reflect business cycle effects that are persistent. Our main predictions concern how the sensitivity of bonus payments to the state varies with the contracting form. If the discount factor is sufficiently high, then both contracting forms imply a bonus for success that is constant across states. But if the discount factor is sufficiently low, relational contracting implies the bonus in the good state exceeds that in the bad state, whereas formal contracting implies the same bonus in both states. The intuition is that the low expected future value in the bad state increases the principal's temptation to renege under relational contracting.

Our results also suggest a negative correlation between pay-for-luck and performance. Looking across a large sample, the firms that offer a bonus that varies with the state should also have low discount factors and engage in relational contracting. These same firms will generate lower equilibrium effort and output than others. Nonetheless, their decision to condition the size of bonus payments on luck is efficient, given the dynamic enforcement constraint they face.

We investigate these predictions using a merged datafile drawn from ExecuComp, Compustat, and CRSP. We estimate an empirical model for executive bonuses that includes two types of "luck" on the right-hand side: an idiosyncratic "shock" that is independent over time, and a serially-correlated "state". Our measure of the shock is Extraordinary Items and Discontinued Operations (EIDO). Our measure of the state is either lagged values of sales growth or the part of lagged sales growth that is predicted by observable variables unrelated to CEO effort (e.g. lagged Gross Domestic Product (GDP) growth rate and a time trend), where using lags is intended to purge any influence of current effort. We verify that EIDO is indeed serially uncorrelated and that lagged or predicted sales growth measures are positively autocorrelated. One of the model's premises is that these two measures of luck positively affect the firm's profits. We find empirically that EIDO and lagged or predicted sales growth are indeed positively correlated with the firm's income.

To test the main theoretical predictions, we estimate a reduced-form bonus equation that expresses the amount of the CEO annual bonus as a function of uncorrelated and positively autocorrelated shocks. Our main hypotheses are that the effect of idiosyncratic shocks on the bonus is zero and that of the correlated state is positive, to the extent that relational contracting characterizes CEO bonus pay. Furthermore, since this relationship only holds for a sufficiently low discount factor, the empirical result should be stronger (and perhaps only detectable) for low values of a discount factor proxy. To identify a proxy for the discount factor we follow the macroeconomics literature by assuming that the firm's default probability – and hence the probability that the employment relationship ends – is increasing in financial leverage. Using leverage as a proxy for the (inverse) discount factor provides robust evidence that is consistent with our prediction.[4] That is, when the discount factor is low (as reflected by high values of leverage) the CEO's annual bonus payment is positively related to the state, which is consistent with relational contracting.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literatures. Section 3 describes the theoretical model, and Section 4 characterizes the optimal contracts. Section 5 explains the data set, and Section 6 presents estimation results. Section 7 concludes.

[4] A firm's financial leverage might also have a direct effect on the amount of the bonus the firm can credibly promise (Fahn et al., 2013). Our empirical specification nests this direct effect, and we find support for Fahn et al.'s prediction that debt weakens the firm's incentive to honor relational contracts. Our focus is different in that the firm's leverage affects the bonus through the interaction with state.

2 Related Literature

This study relates to an extensive literature on CEO compensation and firm performance (see, e.g., Murphy, 1999, for a survey). Whereas that literature focuses on the measurement of, and issues surrounding, the sensitivity of pay to performance, we focus on the empirical implications of relational versus formal contracting. To our knowledge, there are no prior studies that focus on empirically distinguishing between formal and relational contracting. Certain work has looked at the related question of discretion in executive compensation. For example, Murphy and Oyer (2004) derive a set of predictions regarding executive bonus payments and test their hypotheses using a cross-sectional survey data concerning 262 firms' annual bonus plans. They find that nearly two-thirds of the sample companies base bonuses in part on subjective assessments of individual performance but that 33 (14%) firms utilize no discretion in CEO bonus payouts.

Murphy and Oyer's (2004) findings are complementary to ours in the sense that whether firms and CEOs actually engage in relational contracting is an empirical question. Finding evidence that is generally consistent with relational contracts may shed new light on the recent debate on pay-for-luck; that is, CEOs are rewarded for good luck (positive industry performance) but not punished for bad luck (e.g., Bertrand and Mullainathan, 2001; Garvey and Milbourn, 2006). One viable explanation in a static model is that CEOs' outside option values are correlated with their firms' performance, so that firms adjust CEO pay for retention purposes (Oyer, 2004; Bizjak et al., 2008). In a dynamic framework, our results suggest that firms adjust CEO pay in response to the expected future value of the relationship.

Our empirical model for CEO bonuses includes a measure of the state of the world, which is lagged sales growth (and the component of lagged sales growth that nets out factors that may be related to CEO effort). The relationship between sales growth and executive compensation has also been explored in the literature. For example, Hallock and Oyer (1999) present evidence that in addition to being rewarded for current performance, CEOs are rewarded in year t for year $t+1$ increases in earnings. They also show that fourth-quarter sales growth is a particularly good predictor of the following fiscal year's earnings growth. Therefore, the most recent observations on sales growth should receive the most weight in an executive's compensation contract. Whereas Hallock and Oyer focus on determining whether executives have incentives to shift sales from one fiscal quarter to another, our focus is on the role of sales growth as a persistent state variable that can be used to empirically detect the use of relational contracts (versus formal contracts) according to our theoretical model.

Although our theoretical model describes stationary contracts, the literature has increasingly considered nonstationary relational contracts. Some of the significant factors that lead to nonstationarity include the agent's limited liability and the principal's private information. For instance, Fong and Li (2012) show that limited liability can lead to backloading of the agent's utility, but that the optimal contract will be quasi-stationary when surplus is sufficiently high. Chassang (2010), Halac (2012), Li and Matouschek (2012) and Yang (2013) show that the dynamics of relational contracts can involve nonstationary phases when the principal has private information on its action, outside option, and costs of paying the agent, or when the agent's ability is private information. The main reason for the nonstationary phase is related to learning.[5]

Our simple principal-agent model generates testable predictions, but it does not incor-

[5] We comment on the implications of uncertain information in our model at the end of Section 4.

porate private information, and we do not consider non-stationary contracts. While undoubtedly important in general, nonstationarity may be of lesser concern for CEOs who have successfully reached the top of their career ladders, and who interact with the board frequently, potentially diminishing informational asymmetries.

Empirical evidence on relational contracting has been in scant supply in the literature. Most of the existing evidence comes from inter-firm (supply) relationships rather than intra-firm (employment) relationships (e.g., McMillan and Woodruff, 1999; Banerjee and Duflo, 2000; Johnson et al., 2002; Lafontaine and Slade, 2012). These papers are mainly focused on showing that relational contracts can substitute for formal institutions like courts and help sustain long-term relationships in many developing countries. Existing evidence on relational employment contracts has been almost exclusively experimental (e.g., Brown et al., 2004; Fehr et al., 2009; Camerer and Linardi, 2010), and has focused on capturing features of competitive labor markets rather than testing the implications of principal-agent relationships.[6]

3 The Model

Consider a repeated relationship between a principal and an agent, both of whom are risk-neutral. Time has an infinite horizon with discrete periods indexed by $t = 1, 2, \ldots$. In each period t, the agent chooses effort $e_t \in [0, 1]$ and produces output $x_t \in R_+$. Given e_t, the

[6] For instance, Brown et al. (2004) conduct experiments, where firms offer prepaid wages to workers and workers can exert noncontractible effort. Relational contracting is operationalized by attaching ID numbers to all firms and workers, allowing firms to make private offers to a particular worker each period. They show that repeated interactions in the absence of third-party enforcement can lead to more efficient outcomes than one-shot interactions. However, there is no discretionary payment (i.e., bonus) at the end of period, and the rationale for cooperation centers around reciprocity, so we believe that the experimental framework is complementary to our study.

agent incurs an effort cost $C(e_t)$, with $C(0) = 0$, $C'(0) = 0$, $C'(e) \geq 0$, $C''(e) > 0$, $C'''(e) \geq 0$, and $\lim_{e \to 1} C'(e) = \infty$. The agent's effort choice is not observed by the principal.

The agent's effort generates stochastic output, $x_t \in \{x_F + \Delta_t + \epsilon_t, x_S + \Delta_t + \epsilon_t\}$, where $x_S > x_F > 0$, Δ_t is the state of the world, and ϵ_t is a random (idiosyncratic) shock with mean zero. We say that the agent succeeds if $x_t = x_S + \Delta_t + \epsilon_t$ and that he fails if $x_t = x_F + \Delta_t + \epsilon_t$ in a given period t. The probability of success, $p(e_t) \equiv p(x_t = x_S + \Delta_t + \epsilon_t | e_t)$, is increasing in effort, and we assume that $p(0) = 0$, $p'(e) > 0$, $p''(e) < 0$, $p'''(e) \leq 0$.

Output x_t is observable to both the principal and the agent, but it may not be verifiable by a third party. If x_t is verifiable, then the principal can use formal contracting. If x_t is unverifiable, however, the principal must rely on relational contracting, as described below. Both the principal and agent discount future payoffs at rate $\delta \in (0, 1)$, which can be interpreted as the probability that the relationship continues in the following period.

There are two possible states of the world, and these are positively correlated over time. The state evolves according to a Markov process: $\Delta_t = \{-\Delta, \Delta\}$, where $0 < \Delta < x_F$, and $P(\Delta_{t+1} = \Delta_t) = \theta \in (1/2, 1)$. We say that the period-t state is good if $\Delta_t = \Delta$ and that it is bad if $\Delta_t = -\Delta$. Both states are *a priori* equally likely, i.e. $P(\Delta_1 = \Delta) = P(\Delta_1 = -\Delta) = 1/2$. Random shocks are independently and identically distributed with mean zero on $[-\epsilon, \epsilon]$, where $0 < \epsilon < x_F - \Delta$.

The timing of the game is as follows. At $t = 0$, the principal offers the agent a contract B that specifies payment at the end of each period $t \geq 1$, conditional on the history of previous play. The principal can commit to these payments when output is verifiable (formal contracting) but not when it is unverifiable (relational contracting). At the start of any period $t \geq 1$, the state Δ_t and the shock ϵ_t are publicly revealed. The agent chooses effort e_t, after which output x_t is realized and publicly revealed. The principal then makes the payment specified under B, or possibly reneges on this payment under relational contracting, and the period ends. Play then continues to period $t+1$.

We focus on stationary Markov Perfect equilibria where, on the equilibrium path, period-t payments and strategies depend only on x_t, Δ_t, and ϵ_t. We can therefore write $B = (b_{SG}(\epsilon_t), b_{FG}(\epsilon_t), b_{SB}(\epsilon_t), b_{FB}(\epsilon_t))$, where b_{SG} and b_{FG} denote, respectively, the bonuses for success and failure when the state is good, and b_{SB} and b_{FB} denote the bonuses for success and failure when the state is bad. These bonuses may also depend on the value of the contemporaneous shock, ϵ_t. We assume limited liability so that $B \geq 0$, and we also assume trigger strategies, where reneging on a payment specified by B causes the productive relationship to end (Abreu, 1988). That is, the agent chooses zero effort in all subsequent periods, and the principal offers zero bonus.

4 Theoretical Results

Markov strategies are independent of time because the state, but not time, affects current and future payoffs. Suppose that the period-t state is good, i.e. $\Delta_t = \Delta$. Then given contract B, effort choice e_t, and shock ϵ_t, the principal's expected period-t profits are $\pi_G(B, e) + \epsilon_t$, where

$$\pi_G(B, e) = p(e)(x_S + \Delta - b_{SG}(\epsilon_t)) + (1 - p(e))(x_F + \Delta - b_{FG}(\epsilon_t)), \quad (1)$$

and the agent's expected period-t payoff is

$$u_G(B, e) = p(e)b_{SG}(\epsilon_t) + (1 - p(e))b_{FG}(\epsilon_t) - C(e). \quad (2)$$

Suppose instead that the period-t state is bad, i.e. $\Delta_t = -\Delta$. Then expected period-t profits are $\pi_B(B, e) - \epsilon_t$, where

$$\pi_B(B, e) = p(e)(x_S - \Delta - b_{SB}(\epsilon_t)) + (1 - p(e))(x_F - \Delta - b_{FB}(\epsilon_t)), \tag{3}$$

and the agent's expected period-t payoff is

$$u_B(B, e) = p(e)b_{SB}(\epsilon_t) + (1 - p(e))b_{FB}(\epsilon_t) - C(e). \tag{4}$$

For any $t' \geq t$, define $P_{t',t} \equiv P(\Delta_{t'} = \Delta_t)$, the probability that the period-t' and period-t states are the same. $P(\Delta_{t+1} = \Delta_t) = \theta$ implies that $P_{t',t}$ can be defined recursively by

$$P_{t',t} = \theta P_{t'-1,t} + (1 - \theta)(1 - P_{t'-1,t}), \tag{5}$$

for $t' \geq t + 1$, with $P_{t,t} = 1$. Given that $\theta \in (1/2, 1)$, the correlation between states $\Delta_{t'}$ and Δ_t is positive and decreasing in the time lag, $t' - t$: $1/2 < P_{t',t} < P_{t'-1,t}$ for all $t' \geq t+1$, with $\lim_{t' \to \infty} P_{t',t} = 1/2$. Furthermore, it is straightforward to establish that $P_{t',t}$ is increasing in θ.

Since shocks have mean zero, the present discounted value of expected profits as of a period t when the state is good is $\Pi_G(B, e_G, e_B) + \epsilon_t$, where

$$\Pi_G(B, e_G, e_B) = \sum_{t=1}^{\infty} \delta^{t-1} \Big(P_{t,1}\pi_G(B, e_G) + (1 - P_{t,1})\pi_B(B, e_B) \Big), \tag{6}$$

with $\pi_G(B, e_G)$ given by (1) and $\pi_B(B, e_B)$ given by (3).[7] Similarly, the present discounted value of expected profits as of a period t when the state is bad is $\Pi_B(B, e_G, e_B) + \epsilon_t$, where

$$\Pi_B(B, e_G, e_B) = \sum_{t=1}^{\infty} \delta^{t-1} \Big((1 - P_{t,1}) \pi_G(B, e_G) + P_{t,1} \pi_B(B, e_B) \Big). \tag{7}$$

Given a stationary contract and unobservable effort, the agent's optimal effort choice in any period t will only depend on the incentives offered in that particular period. Since both states are *a priori* equally likely, and shocks have mean zero, the principal's program under formal contracting can be written as

$$\max \ \Pi = \frac{1}{2}\Pi_G(B, e_G, e_B) + \frac{1}{2}\Pi_B(B, e_G, e_B), \text{ subject to} \tag{8}$$

$$e_G(B) = \arg\max_{e \in [0,1]} \ u_G(B, e), \tag{9}$$

$$e_B(B) = \arg\max_{e \in [0,1]} \ u_B(B, e), \tag{10}$$

$$B = (b_{SG}(\epsilon_t), b_{FG}(\epsilon_t), b_{SB}(\epsilon_t), b_{FB}(\epsilon_t)) \geq 0. \tag{11}$$

Under relational contracting, the principal is faced with a credibility constraint: he must have an incentive to actually pay each bonus specified under B when called upon to do so. Given trigger strategies, the optimal way for the principal to renege on a bonus is to withhold it completely, so the benefit of reneging is equal to the size of the bonus. The cost of reneging is the expected future profits lost from ending the productive relationship. This means that

[7] The notation makes explicit the fact that effort, e_G, in the good state may differ from effort, e_B, in the bad state.

the principal's program under relational contracting includes the following constraints:

$$\max\{b_{SG}(\epsilon_t), b_{FG}(\epsilon_t)\} \leq \delta\Big(\theta\Pi_G(B, e_G, e_B) + (1-\theta)\Pi_B(B, e_G, e_B)\Big), \tag{12}$$

$$\max\{b_{SB}(\epsilon_t), b_{FB}(\epsilon_t)\} \leq \delta\Big((1-\theta)\Pi_G(B, e_G, e_B) + \theta\Pi_B(B, e_G, e_B)\Big). \tag{13}$$

where both the cost and benefit from reneging may depend on the current state.

Note that the value of the shock, ϵ_t, does not enter into the principal's objective function (8), nor does it enter into any of constraints (9), (10), (11), (12), or (13). It follows immediately that the bonuses prescribed under the optimal contract are independent of ϵ_t; that is, $B = (b_{SG}(\epsilon_t), b_{FG}(\epsilon), b_{SB}(\epsilon_t), b_{FB}(\epsilon_t)) \equiv (b_{SG}, b_{FG}, b_{SB}, b_{FB})$.

We begin with a lemma that simplifies the principal's program.

Lemma 1 *Under both formal and relational contracting, the principal never pays a positive bonus in a period where the agent fails:* $b_{FG} = b_{FB} = 0$.

The intuition for Lemma 1 is straightforward. For any given effort level, offering a positive bonus for failure increases the principal's expected payout. It also makes success relatively less attractive for the agent, which reduces his incentive to exert effort. This leads the principal to set the payment for failure as low as possible, which under limited liability is equal to zero. In particular, this means that the optimal contract can be written as $B = (b_{SG}, 0, b_{SB}, 0)$. To ease notation, we henceforth drop the subscript S and write $b_G = b_{SG}$ and $b_B = b_{SB}$. Similarly, the optimal effort level only depends on the contract through the bonus for success in that particular state, that is, $e_G(B) = e_G(b_G)$ and $e_B(B) = e_B(b_B)$.

Finally, Lemma 1 also implies that under relational contracting, credibility constraints

(12) and (13) reduce to

$$b_G \leq \delta\Big(\theta\Pi_G(b_G, b_B, e_G, e_B) + (1-\theta)\Pi_B(b_G, b_B, e_G, e_B)\Big), \tag{14}$$

$$b_B \leq \delta\Big((1-\theta)\Pi_G(b_G, b_B, e_G, e_B) + \theta\Pi_B(b_G, b_B, e_G, e_B)\Big). \tag{15}$$

We now present a second lemma that will be useful in proving later results. It shows that the optimal effort level is increasing in the size of the bonus but at a decreasing rate.[8]

Lemma 2 *Let $I \in \{G, B\}$. Then $b_I \geq 0$ implies $0 \leq e_I(b_I) < 1$, where the inequality is strict for all $b_I > 0$. Moreover, $e_I(b_I)$ is unique, with $e_I'(b_I) > 0$ and $e_I''(b_I) < 0$.*

The following proposition states our main result, where superscripts f and r denote optimal bonuses under formal and relational contracting.

Proposition 1 *If output is verifiable, then the principal will choose formal contracting and offer the same bonus in both states: $b^f \equiv b_G^f = b_B^f > 0$. If output is nonverifiable so that contracting is relational, then the principal will offer a different bonus in each state if and only if the discount factor is sufficiently low: for any $\theta \in (1/2, 1)$, there exists $\delta_0 \in (0, 1)$ such that $0 < b_B^r < b_G^r \leq b_f$ for all $\delta \in [0, \delta_0)$ and $b_G^r = b_B^r = b^f$ for all $\delta \in [\delta_0, 1]$.*

The principal knows that a large bonus will generate high effort, which increases expected output and increases profits. However, a large bonus also increases the expected payment to the agent, which decreases profits. The principal takes into account these two opposing effects in setting the optimal bonus that gives marginal profits of zero. Marginal profits are

[8] Of course, under relational contracting, effort will only be positive if the promised bonus is credible.

independent of the state, since the state does not affect the relationship between bonus and effort, or the relationship between effort and success or failure. It follows that under formal contracting, the principal will offer the same bonus b^f in both states of the world.

The difference under relational contracting is that the principal faces a commitment problem. He would like to offer the same profit-maximizing bonus as under formal contracting, but he must actually have an incentive to pay this bonus when the agent succeeds. Reneging on a promised bonus increases immediate profits. However, it also decreases expected future profits, as the agent stops working and the productive relationship ends. This means the bonus b^f will not be credible under relational contracting if it exceeds the discounted value of expected future profits, which happens if the discount factor is sufficiently low.

In this case, the principal can credibly promise a larger bonus in the good state than in the bad state, since immediate profits are higher in the good state, and states are positively correlated over time. The principal will then set $b_B^r < b_G^r$ under relational contracting. Total profits are lower than under formal contracting, since marginal profits are strictly positive, but the principal cannot credibly commit to pay a larger bonus. The driving force behind this result is clearly the correlation of states over time. That is, it can be readily shown that as the realization of the future state becomes independent of the current state (i.e., $P(\Delta_{t+1} = \Delta_t) = \theta \to 1/2$), the bonus paid in each state becomes identical ($\lim_{\theta \to 1/2} b_B^r = \lim_{\theta \to 1/2} b_G^r$) because future profits have little relation to the current state.

We now describe further how the optimal bonuses depend on the discount factor.

Proposition 2 *Consider the optimal bonuses b^f, b_G^r, and b_B^r, as given by Proposition 1. Then b^f is independent of δ, whereas b_B^r and b_G^r are increasing in δ whenever $b_B^r < b^f$,*

$b_G^r < b^f$.

The optimal bonus under formal contracting is chosen to maximize immediate profits, which are independent of discounting or of the future state. In contrast, the credibility constraint under relational contracting depends on δ and θ through the discounted value of expected future profits. When the discount factor is very low, the principal must offer a similar bonus in both states, since only a small bonus can be credible (in fact, zero bonus as $\delta \to 0$). An increase in δ allows the principal to credibly increase both b_B^r and b_G^r. Proposition 1 shows that these bonuses are identical when δ becomes sufficiently large, which means that the difference in compensation across states is nonmonotonic in the discount factor.

We have presented a simple model to derive testable implications on the difference between formal and relational contracts. Although we have made several simplifying assumptions, we believe that our results would be robust to alternative assumptions. For instance, suppose players were initially uncertain about the value of θ and held prior beliefs over $(1/2, 1)$. If the period-t state is good, then players will update their beliefs about θ towards 1, which drives up expected future profits, loosens the credibility constraint, and allows for a larger bonus. If the period-t state is bad, then players will update their beliefs about θ towards $1/2$, which drives down expected future profits, tightens the credibility constraint, and only allows for a smaller bonus. Hence, in any period t, we would still expect the bonus to be larger if the state is good than if it is bad, but now bonuses would change over time as players continue updating their beliefs. In the long run, beliefs would tend to the true value of θ with probability one, and bonus payments would tend to b_G^r and b_B^r from the above analysis as well.

5 Data

The executive compensation data used for the empirical analysis come from the Standard & Poor's Execucomp database for the period 1993–2011. Our sample comprises current constituents of all S&P 500 (large cap), S&P 400 (mid cap) and S&P 600 (small cap) companies.[9] We focus on individuals identified as CEOs for each firm. The Execucomp database contains an indicator for the executive who served as CEO for all or most of the year (i.e., CEOANN); however, this variable often has missing entries, and the CEO designation sometimes changes in a somewhat arbitrary fashion between co-CEOs and between chairman and CEO, etc. Our solution was to check for irregular data patterns, verify the executives' career profiles using online sources such as businessweek.com and forbes.com, and make necessary corrections.

The data include individual executives' age and the date individuals became chief executive officers (i.e., BECAMECEO), from which we calculated each CEO's tenure.[10] Compensation data are collected from each firm's annual proxy (DEF 14A) and include the CEO's salary, bonus, equity-based compensation, and other components. Consistent with our theoretical model, we focus on executive annual bonus payments. Hence, our primary dependent variable is executive i's year-t bonus, which we denote by $BONUS_{it}$. Due to the SEC rule change (FAS 123(R)), ExecuComp made some important changes in the reporting format for some variables as of 2006. For our purposes, the most important change was that an-

[9] Compustat does not show historical constituents. Thus, our sample includes new entries but not dropouts.

[10] Wherever the BECAMECEO entry was missing, we searched the executive's career profile from the previously mentioned source. Importantly, the ExecuComp database resets (overwrites) the BECAMECEO variable when the same individual becomes a CEO more than once for various reasons. We did not reset the CEO tenure whenever we found such cases.

nual bonuses were mostly reported as Non-Equity Incentive Plan Compensation as of 2006, meaning that the bonus variable equals zero for most cases starting in 2006. Therefore, from 2006 forward our bonus measure is defined to include non-equity incentive pay.[11]

After eliminating firms for which only a couple of years' data are observed, we have an unbalanced panel of 1490 firms by 19 years. We then obtain each firm's financial information from the Compustat annual industrial file and match that information with the compensation data. All financial variables in the raw data are measured in nominal values (e.g., compensation, income, and balance sheet items), and we convert these to real values (in 2005 dollars) using the GDP deflator. Following the literature (e.g., Bertrand and Mullanaithan, 2001), we use income before extraordinary items as our measure of executive i's year-t performance and denote it by $PERF_{it}$.

Our model includes ϵ_{it}, an idiosyncratic shock to executive i's period-t performance. We measure the shock using the sum of extraordinary items and discontinued operations, which we denote by $EIDO_{it}$. The factors included in $EIDO$ represent financial occurrences that are rare and unexpected. Such items would typically not factor into an evaluation of the future prospects of a company because the events are seen as one-time shocks that should have no bearing on the future. They are therefore considered irregular items that are separately reported on income statements. Examples could include natural disasters and adjustments arising from accounting changes.

In principle, $EIDO$ should be serially uncorrelated. In practice, some serial correlation

[11] As Florin et al. (2010) note, "[s]trictly speaking, the bonus as listed in the table is formula-based pay beyond cash salary. On the other hand, non-equity incentive compensation can be both short-term or long-term pay that is based on some pre-set criteria (based on performance) whose outcome is uncertain [...] both can be considered a type of bonus."

might occur either because the events themselves are autocorrelated (e.g., an unexpected hurricane on a particular segment of the coast might be the harbinger of a broader climatic shift that makes that segment more hurricane prone in the future than it was in the past) or because of reporting errors (e.g., management might purposely misclassify an ordinary, recurring expense transaction as an extraordinary item or discontinued operation to make the numbers for continuing operations on the income statement look better).

Our model also includes Δ_{it}, the state, which is persistent (i.e., positively autocorrelated over time). Any variable that is persistent and observed to economic agents at the time executive actions are determined and bonuses are decided will suffice for our purposes. The variable we use to capture the period-t state is $SALESCHGPOS_{t-1}$, defined to be 1 if $SALES_{t-1} - SALES_{t-2} > 0$, where $SALES_t$ denotes period-t sales revenue. Our use of lagged $SALESCHGPOS$ as a measure of the state requires discussion given that sales growth has also been used in the literature as a measure of executive performance. As previously mentioned, Hallock and Oyer (1999) argued that since the CEO's goal is to increase the firm's scale, sales growth can be thought of as CEO performance.

Our view is that although sales growth belongs on the right-hand side of an executive compensation equation (e.g., Murphy, 1985; and many subsequent studies), it is not an ideal measure of CEO performance from the standpoint of our theory.[12] Suppose that in each of years $t-10$, $t-9, \ldots, t$, company sales remain at 100. Then company sales jump

[12]Murphy (1985: 22) explains the rationale for including sales growth (and also the level of sales) on the right-hand side of an executive compensation equation as follows: "In addition to stock performance, firm size or growth may yield information relevant for determining levels of managerial effort. Indeed, several theories of managerial production suggest that compensation should be partially determined by firm size or growth, reflecting the quantity of resources controlled by the individual executive and the scope of managerial responsibilities. For comparisons with previous literature, we have chosen sales and percentage change in sales as proxies for firm size and growth."

to 500 in year $t+1$, and from year $t+2$ forward they remain at 499. Thus, $SALESCHG_{it-9} = SALESCHG_{it-8} = \ldots = SALECHG_{it} = 0$ whereas $SALESCHG_{it+1} \simeq 161$ and $SALESCHG_{it+2} = SALESCHG_{it+3} = \ldots \simeq -0.2$, where $SALECHG_{it}$ is the log-difference of sales multiplied by 100. Using sales growth to capture CEO performance would imply a huge drop in performance between years $t+1$ and $t+2$ and would also suggest that CEO performance in years $t+2$ forward is lower than it was for the decade preceding year $t+1$, and both conclusions seem unwarranted.

Although $SALESCHGPOS$ is not ideal as a measure of CEO performance, a potential concern from using it to measure the state in our model is that the state, Δ_t, is not a function of CEO actions, whereas sales growth from one year to the next could partially reflect those actions. We address this concern in two ways. First, in our statistical models for the year-t executive bonus, we include only lagged values of $SALESCHGPOS$ on the right-hand side. The rationale is that even if sales growth from years $t-2$ to $t-1$ contains some information regarding CEO effort, this would be past effort and therefore irrelevant from the standpoint of our theoretical model. All that we require to test our theoretical predictions is a serially correlated variable that affects CEO performance, that is observed to economic agents at the time of their decisions, and that is exogenous (as a consequence of being pre-determined) as of the current year t.

Second, we also consider an alternative measure of the state: we use the predicted values from individual regressions (one for each firm in the sample), each of which has the following form: $SALESCHG_t = \gamma_0 + \mathbf{Z}_t\boldsymbol{\gamma} + \omega_t$, where $\mathbf{Z}_t$ is a vector of time-varying covariates measuring factors that are observable to economic agents in year t, that affect sales growth, and that are unrelated to CEO effort. We then compute a binary variable equaling 1 if the lagged predicted value is positive and zero otherwise. Note that the residual, ω_t, is the unexplained part of sales that can be attributed (in part) to CEO effort. Measuring the state using predicted values nets out these effort-based components that are embedded in ω_t. In the results we report, $\mathbf{Z}_t$ contains a linear time trend and the real GDP growth rate between years $t-2$ and $t-1$.[13]

The final variable needed to address our model empirically is a measure of the discount factor, δ_{it}. Recall that in the theoretical model there is a critical threshold for the discount factor, beyond which the bonus is insensitive to the state both for formal and relational contracts. Only when the discount factor is below the threshold does a difference emerge between the two contract forms. We therefore need a proxy to identify low values of δ_{it}. We rely on the probability of default: The greater the likelihood of default, the less weight the economic agents place on future payoffs when making current decisions. Although the likelihood of default depends on a number of factors, one such factor that clearly affects the likelihood and that is observed in the data is leverage; that is, high leverage increases the default risk (Crosbie and Bohn, 2003). We therefore use the measure $LEVERAGE_{it}$ as an empirical proxy for $(1-\delta_{it})$.[14]

[13] A downside to this robustness check as compared to our main results that use lagged $SALESCHGPOS$ as the state variable is that the residual, ω_t, likely contains more than just CEO effort, so by subtracting ω_t we are potentially netting out too much, including some information that is persistent and observed to the economic agents and that should be included in the measure of the state.

[14] $LEVERAGE$ is defined to equal $(DLTT + DLC)/(DLTT + DLC + CEQ)$, where $DLTT$ and DLC are the book value of long-term debt and debt in current liabilities, respectively. CEQ is the market value of common/ordinary equity, which is calculated by multiplying the closing stock price and the number of shares outstanding.

6 Empirical Analysis

Our goal in the empirical analysis is to model the variation in executive bonuses over time and across firms, as a function of idiosyncratic "shocks" and the persistent "state" (i.e., two different types of "luck") to show evidence for or against relational contracts as opposed to formal contracts.

Table 1 presents summary statistics for the variables in our main analysis. We begin by investigating whether our measure of the shock (i.e., $EIDO$) is serially uncorrelated as required by the theoretical model. Panel A of Table 2 presents an autocorrelation matrix for $EIDO_t$ and its first three lags. These results confirm that $EIDO$ is a good measure of idiosyncratic shocks; the variable is positively correlated only in adjacent years, and even those correlations are all below 0.03. Our model also requires that the measure of state (i.e., $SALESCHGPOS$) be positively autocorrelated. Panel B of Table 2 presents an autocorrelation matrix for $SALESCHGPOS_t$ and its first three lags. As required by the theory, the state variable is positively autocorrelated, with correlations in adjacent periods exceeding 0.21 and with correlations as far as three periods apart remaining statistically significant at the five percent level with a magnitude exceeding 0.05.

Our theoretical model posits that the idiosyncratic shock and the persistent state both have positive direct effects on output, or CEO performance. Therefore, we first estimate the following CEO performance equation:

$$PERF_{it} = \alpha_0 + \alpha_1 EIDO_{it} + \alpha_2 SALESCHGPOS_{it-1} + \mathbf{X}_{it}\boldsymbol{\alpha} + \theta_i + u_{it},$$

where $\mathbf{X}_{it}$ includes age, age squared, tenure, tenure squared, and year dummies, and where θ_i is a firm fixed effect. As seen in column 1 of Table 3, the estimates of α_1 and α_2 are both positive and significant at the five percent level, suggesting that both the idiosyncratic shock and the persistent state are positively related to CEO performance.

Turning next to the predictions on bonus compensation, we start with the following linear bonus equation:

$$BONUS_{it} = \beta_0 + \beta_1 EIDO_{it} + \beta_2 SALESCHGPOS_{it-1} + \mathbf{X}_{it}\boldsymbol{\beta} + \lambda SALARY_{it} + \phi_i + \varepsilon_{it},$$

where again $\mathbf{X}_{it}$ includes age, age squared, tenure, tenure squared, and year dummies, and where ϕ_i is a firm fixed effect. We include the CEO's base salary on the right-hand side because salary and bonus can be expected to positively covary, though omitting salary from the model does not change our results of interest.

Note that our specification differs from what is typically seen in the executive compensation literature. That is, we do not include the (endogenous) executive performance measure on the right-hand side of the compensation equation. A common objective in the executive compensation literature is to measure pay-for-performance sensitivities, that is, the slope of a performance measure in a total compensation regression. In contrast, consistent with our theoretical model, our dependent variable is the executive's bonus rather than total compensation. Further, our objective is to measure the effect of stochastic "luck" (both idiosyncratic and persistent) on the bonus. Thus, our bonus equation can be interpreted as a reduced form in which the performance equation has been substituted for the (endogenous) CEO performance appearing on the right-hand side of the bonus equation.

First, our theoretical model predicts $\beta_1 = 0$ in the bonus regression. Second, if the bonus equation happens to be estimated on a sample for which the discount factor, δ_{it}, is low, then our theoretical model predicts $\beta_2 = 0$ if the data-generating process is characterized by formal contracts and $\beta_2 > 0$ if it is characterized by relational contracts. Results are displayed in column 1 of Table 4 and reveal $\beta_2 > 0$, consistent with relational contracts. However, the result that $\beta_1 > 0$ is at odds with the theory, and we discuss potential reasons for this result at the end of the section.

If the sample includes observations for which the discount factor is high, then the preceding test may fail to produce evidence of $\beta_2 > 0$ even if the data-generating process is characterized by relational contracts. This leads us to consider the following interactive bonus specification:

$$\begin{aligned} BONUS_{it} \;&=\; \beta_0 + \beta_1 EIDO_{it} + \beta_2 SALESCHGPOS_{it-1} + \beta_3 (SALESCHGPOS_{it-1} \times \\ &\quad LEVERAGE_{it}) + \beta_4 LEVERAGE_{it} + \mathbf{X}_{it}\boldsymbol{\beta} + \lambda SALARY_{it} + \phi_i + \varepsilon_{it}. \end{aligned}$$

Since high leverage implies a high default risk and therefore a low value of δ_{it}, our model predicts $\beta_2 + \beta_3 LEVERAGE_{it} = 0$ under formal contracting and $\beta_2 + \beta_3 LEVERAGE_{it} > 0$ under relational contracting. Results from the interactive bonus model are displayed in column 2 of Table 4. The estimate of β_2 is statistically insignificant, though the estimate of β_3 is positive and significant. Whereas the marginal effect of $SALESCHGPOS$ was 165 in the linear model of column 1, it varies considerably with leverage in the interactive model of column 2. When evaluated at 0.04 (the 25^{th} percentile of the $LEVERAGE$ distribution) the marginal effect is only 22.5, whereas when evaluated at 0.52 (the 90^{th} percentile of the

$LEVERAGE$ distribution) the marginal effect is about 313. Given our theoretical model, these results can be interpreted as consistent with relational contracts, though again the result $\beta_1 = 0$ is at odds with the theory.

Another interesting result from the interactive bonus model is that the coefficient of $LEVERAGE$ is negative and significant, suggesting that companies pay considerably lower bonuses when the default risk is high. As noted earlier, a firm's financial leverage might directly affect the amount of the bonus the firm can credibly promise (Fahn et al., 2013). Our result that the coefficient of $LEVERAGE$ is negative and significant is consistent with Fahn et al.'s prediction that debt weakens the firm's incentive to honor relational contracts. One might think that a firm's leverage is an endogenous choice variable. However, Graham et al. (2013) show that there is little relation between executive compensation and leverage in the aggregate.[15]

Since the financial and utilities industries are frequently excluded from estimation samples in the finance literature, we excluded those observations and found that our results are insensitive to that change in sample. Our main analysis is based on the entire sample that combines S&P 500 (large cap), S&P 400 (mid cap), and S&P 600 (small cap) companies. We also repeated the analysis within each of those three subsamples. In each of them we found that our main result concerning the marginal effect of $SALESCHGPOS$ on the bonus (and how it varies with $LEVERAGE$) remained qualitatively unchanged. We also tried including additional dummies for different ranges of values of sales growth, as opposed

[15]Specifically, Graham et al. (2013: 4) find that "both the level and performance sensitivity of executive compensation was largely constant from the end of World War II through the mid-1970s – precisely when leverage ratios underwent their largest change. Only after 1980 did executive pay experience a significant increase in amount and sensitivity to performance, precisely as corporate leverage stabilized and began a slight decline."

to simply a binary indicator for whether sales growth is positive. Again, our results were qualitatively unchanged, though in specifications that included larger numbers of dummies not all of them were statistically significant.

Since $SALESCHGPOS_{t-1}$ is predetermined in the $BONUS_t$ equation, the fact that the state variable may be affected by CEO effort (which is not the case in our theoretical model) should not be a problem given that the variable is unaffected by year-t effort. Nonetheless, as a further robustness check we computed the $SALESCHGPOS_{t-1}$ dummy based on the predicted values from the regressions discussed earlier, repeating all of our analyses with this new state variable. Panel C of Table 2 displays the autocorrelation matrix for the new state variable. The autocorrelations are considerably higher than those in Panel B, ranging from 0.61 to 0.67 for adjacent periods and reaching 0.38 even for the correlation three periods apart.

Column 2 of Table 3 reveals positive and statistically significant coefficients on $EIDO_t$ and (the alternative measure of) $SALESCHGPOS_{t-1}$, consistent with the theory. Columns 3 and 4 of Table 4 display results from the linear and interactive bonus regressions. The results qualitatively match those from the first two columns of Table 4 that are based on the actual measure of $SALESCHGPOS_{t-1}$.

A potential concern is that the GDP growth rates that are used to predict the alternative measure of $SALESCHGPOS_{t-1}$ are based on calendar year and are not tailored to each firm's fiscal-year-end month, whereas the data from firms is based on fiscal years (with end months that are not always in December). We do not see this as a concern given that in the prediction regressions we used lagged GDP growth to predict sales growth. However, as a further check we restricted the sample to those firms having fiscal years ending on December

31. The results from these estimations qualitatively match those we have already discussed.

Both the linear and interactive bonus models show a positive and statistically significant marginal effect of $EIDO$ even though our theory predicts a value of zero. This result suggests that pay-for-luck in our data is partly driven by features that are not capture in the model. One possibility is that firms are liquidity constrained and use part of any unexpected cash flow to award CEO bonuses. Another possibility is that CEOs might have bargaining power that allows them to claim a share of any windfall profits. If pay-for-luck were due only to liquidity constraints, then the impact of the serially-correlated state on the bonus payment should not depend on the discount factor, since all that matters is current cash flow. If instead pay-for-luck were due only to bargaining power, then the impact of the state on the bonus payment should be largest for firms with high discount factors, who are likely to remain solvent and for whom the current state has a large impact on expected future profits. Neither alternative explanation is consistent with the positive interaction we find between leverage and state, which suggests a central role for relational contracting.

7 Conclusion

We have presented a simple model in which formal and relational contracts yield a different prediction for how bonus payments respond to "luck" (as measured both by a persistent state and by a time-independent shock). Given that differentiating theoretical prediction, our main focus in the empirical work was on finding evidence for or against relational contracting in CEO compensation. Drawing on a large sample of publicly-traded companies, and using reasonable proxies for the state and shock variables, we found evidence consistent with relational contracting in the payment of CEO bonuses. Hence, our findings shed new light on the debate on the pay-for-luck phenomenon. That is, the reason why firms seem to reward CEOs for luck is that the expected future value of the employment relationship is larger in a good state of the world than in a bad state, so that the firm's credibility to pay bonuses as well as the CEO's incentive to exert effort are higher in good states. The approach we have developed can also be applied to establish the empirical relevance of relational contracting for other (non-executive) worker groups.

8 Appendix

Proof of Lemma 1. By (2) and (9), the agent's optimal choice of effort in the good state is

$$\begin{aligned} e_G(B) &= \underset{e\in[0,1]}{\arg\max}\ p(e)b_{SG} + (1-p(e))b_{FG} - C(e), \\ &= \underset{e\in[0,1]}{\arg\max}\ p(e)(b_{SG} - b_{FG}) - C(e). \end{aligned} \tag{16}$$

By (4) and (10), the agent's optimal choice of effort in the bad state is

$$\begin{aligned} e_B(B) &= \underset{e\in[0,1]}{\arg\max}\ p(e)b_{SB} + (1-p(e))b_{FB} - C(e), \\ &= \underset{e\in[0,1]}{\arg\max}\ p(e)(b_{SB} - b_{FB}) - C(e). \end{aligned} \tag{17}$$

Consider two contracts, $b = (b_{SG}, b_{FG}, b_{SB}, b_{FB})$ and $B' = (b'_{SG}, 0, b'_{SB}, 0)$, with $b'_{SG} = b_{SG} - b_{FG}$ and $b'_{SB} = b_{SB} - b_{FB}$. By (16) and (17), the contracts result in identical effort provision in both states: $e_G(B) = e_G(B')$ and $e_B(B) - e_B(B')$.

Clearly, $b_{FG} > 0$ implies $b_{SG} > b'_{SG}$. Moreover, (1) shows that $\pi_G(B,e)$ is strictly decreasing in b_{SG} and in b_{FG}. Hence, $b_{FG} > 0$ implies $\pi_G(B,e) < \pi_G(B',e)$, so that B' yields higher profits than B in the good state. Similarly, $b_{FB} > 0$ implies $b_{SB} > b'_{SB}$, and (3) shows that $\pi_B(B,e)$ is strictly decreasing in b_{SB} and in b_{FB}. Hence, $b_{FB} > 0$ implies $\pi_B(B,e) < \pi_B(B',e)$, so that B' yields higher profits than B in the bad state.

It then follows from (6) and (7) that both $\Pi_G(B) < \Pi_G(B')$ and $\Pi_B(B) < \Pi_B(B')$ whenever $b_{FG} > 0$ or $b_{FB} > 0$. Hence, the optimal formal contract that solves (8), subject to (9), (10) and (11), must have $b_{FG} = b_{FB} = 0$. Moreover, the credibility constraints (12) and (13) are stricter under B than under B' whenever $b_{FG} > 0$ or $b_{FB} > 0$, so the optimal relational contract must also have $b_{FG} = b_{FB} = 0$. ■

Proof of Lemma 2. Let $I = G$, where the proof is entirely analogous for $I = B$. By Lemma 1, (2) reduces to

$$u_G(b_G, e) = p(e)b_G - C(e).$$

$C''(e) > 0$ and $p''(e) < 0$ imply $\frac{\partial^2}{\partial e^2} u_G(b_G, e) < 0$, so that $\arg\max_{e \in [0,1]} u_G(b_G, e)$ is unique. The first-order condition is

$$p'(e_G)b_G - C'(e_G) = 0, \tag{18}$$

and the second-order condition is

$$p''(e_G)b_G - C''(e_G) < 0.$$

If $b_G = 0$, then (18) reduces to $C'(e_G) = 0$. It therefore follows from $C'(0) = 0$ that $e_G(0) = 0$. If instead $b_G > 0$, then $p'(0) > 0$ and $C'(0) = 0$ mean that (18) is violated at $e_G = 0$. Moreover, (18) must be violated at $e_G = 1$, since $p'(1)$ is finite and $\lim_{e \to 1} C'(e) = \infty$. Taken together, this implies $e_G(b_G) \in [0, 1)$, with $e_G(b_G) \in (0, 1)$ for $b_G > 0$.

Differentiating both sides of (18) with respect to b_G yields

$$p'' e'_G(b_G) b_G + p' - C'' e'_G(b_G) = 0 \tag{19}$$

where we drop the arguments for p', p'' and C'' for ease of exposition. Rearranging gives

$$e'_G(b_G) = \frac{p'}{C'' - p'' b_G},$$

which is strictly positive by $p' > 0$ and by the second-order condition. Now differentiating (19) with respect to b_G yields

$$p'''(e'_G(b_G))^2 b_G + p'' e''_G(b_G) b + 2p'' e'_G(b_G) - C'''(e'_G(b_G))^2 - C'' e''_G(b_G) = 0,$$

and rearranging gives

$$e''_G(b_G) = \frac{(p''' b_G - C''')(e'_G(b_G))^2 + 2p'' e'_G(b_G)}{C'' - p'' b_G}.$$

The numerator is negative by $p''' \leq 0$, $C''' \geq 0$, $p'' < 0$ and $e'_G(b_G) > 0$. The denominator is positive by the second-order condition, so that $e''_G(b_G) < 0$. ■

Proof of Proposition 1. Relational contracting only differs from formal contracting through additional constraints (14) and (15). It follows immediately that the principal will engage in formal contracting whenever it is feasible, so whenever output is verifiable.

By (18), the optimal effort in the good state is defined by $p'(e_G)b_G - C'(e_G) = 0$. Similarly, the optimal effort in the bad state is defined by $p'(e_B)b_B - C'(e_B) = 0$. Effort does not depend directly on the state but only on the bonus offered for success, so we can write $e(b) \equiv e_G(b) = e_B(b)$, where $b \geq 0$.

By (6) and (7), $\Pi = \frac{1}{2}\Pi_G + \frac{1}{2}\Pi_B$ is increasing in π_G and π_B. Applying Lemma 1 to (1) yields

$$\pi_G(b) = p(e(b))(x_S - x_F - b) + x_F + \Delta, \tag{20}$$

and applying Lemma 1 to (3) yields

$$\pi_B(b) = p(e(b))(x_S - x_F - b) + x_F - \Delta. \tag{21}$$

The principal's first-order condition for b is therefore the same in both states, $\pi'(b) = 0$, or

$$\frac{d}{db}\big(p(e(b))\big)(x_S - x_F - b) - p(e(b)) = 0. \tag{22}$$

We know that $\frac{d^2}{db^2}p(e(b)) < 0$, since $p''(e) < 0$ holds by assumption and $e''(b) < 0$ holds by Lemma 2. This implies $\pi''(b) < 0$, so that $b^f \equiv b^f_G = b^f_B = \arg\max_{b \geq 0}\ \pi_G(b) = \arg\max_{b \geq 0}\ \pi_B(b)$ is uniquely defined by (22). Moreover, $p'(e) > 0$, $e'(b) > 0$ and $p(0) = e(0) = 0$ imply $p(e(0)) = 0$ and $\frac{d}{db}p(e(b)) > 0$. It follows from (22) that $\pi'(0) = \frac{d}{db}\big(p(e(0))\big)(x_S - x_F) - p(e(0)) > 0$, so that $b^f > 0$.

Under the relational contracting, the principal faces additional constraints (14) and (15), given by

$$b_G \leq \delta\Big(\theta\Pi_G(b_G, b_B) + (1-\theta)\Pi_B(b_G, b_B)\Big),$$

and

$$b_B \leq \delta\Big((1-\theta)\Pi_G(b_G, b_B) + \theta\Pi_B(b_G, b_B)\Big),$$

with effort $e(b_G)$ and $e(b_B)$ in the good and bad state, respectively. By (6) and (7), write

$$\Pi_G(b_G, b_B) = \Big(\sum_{t=1}^{\infty}\delta^{t-1}P_{t,1}\Big)\pi_G(b_G) + \Big(\sum_{t=1}^{\infty}\delta^{t-1}(1-P_{t,1})\Big)\pi_B(b_B), \tag{23}$$

and

$$\Pi_B(b_G, b_B) = \Big(\sum_{t=1}^{\infty}\delta^{t-1}(1-P_{t,1})\Big)\pi_G(b_G) + \Big(\sum_{t=1}^{\infty}\delta^{t-1}P_{t,1}\Big)\pi_B(b_B). \tag{24}$$

We showed above that $\pi_G(b)$ and $\pi_B(b)$ are both strictly concave and attain their maximum at $b^f > 0$. It follows that both functions are strictly increasing for all $b \in [0, b_f)$ and strictly decreasing for all $b > b_f$. Hence, for any b_B, we have $\frac{\partial}{\partial b_G}\Pi_G(b_G, b_B) > 0$ and $\frac{\partial}{\partial b_G}\Pi_B(b_G, b_B) > 0$ for all $b_G \in [0, b^f)$; $\frac{\partial}{\partial b_G}\Pi_G(b_G, b_B) < 0$ and $\frac{\partial}{\partial b_G}\Pi_G(b_G, b_B) < 0$ for all $b_G > b^f$; $\frac{\partial}{\partial b_G}\Pi_G(b^f, b_B) = 0$ and $\frac{\partial}{\partial b_G}\Pi_B(b^f, b_B) = 0$. Similarly, for any b_G, we have $\frac{\partial}{\partial b_B}\Pi_G(b_G, b_B) > 0$ and $\frac{\partial}{\partial b_B}\Pi_B(b_G, b_B) > 0$ for all $b_B \in [0, b^f)$; $\frac{\partial}{\partial b_B}\Pi_G(b_G, b_B) < 0$ and $\frac{\partial}{\partial b_B}\Pi_B(b_G, b_B) < 0$ for all $b_B > b^f$; $\frac{\partial}{\partial b_B}\Pi_G(b_G, b^f) = 0$ and $\frac{\partial}{\partial b_B}\Pi_B(b_G, b^f) = 0$.

Taken together, it follows that neither $b_G > b^f$ nor $b_B > b^f$ can be optimal, since marginally reducing either bonus would increase Π_G and Π_B and loosen (14) and (15). It also follows that, for given b_B, the optimal bonus in the good state, $b_G(b_B)$ is the minimum of b^f and the unique value of b_G for which (14) binds. Similarly, for given b_G, the optimal bonus in the bad state, $b_B(b_G)$ is the minimum of b^f and the unique value of b_B for which (15) binds. The optimal bonus pair (b^r_G, b^r_B) is defined by $b_G(b_B(b^r_G)) = b^r_G$ and $b_B(b_G(b^r_B)) = b^r_B$.

Without loss of generality, we can restrict both $b_G(b_B)$ and $b_B(b_G)$ to a domain of $[0, b^f]$. The function $b_G(b_B)$ is continuous, with range $[b_G(0), b_G(b^f)]$, where $b_G(0) > 0$ and $b_G(b^f) \leq b^f$. We also have $b'_G(b_B) \geq 0$ and $b''_G(b_B) \leq 0$, where the inequalities are strict if and only if b_B satisfies $b_G(b_B) < b^f$. Similarly, the function $b_B(b_G)$ is continuous, with range $[b_B(0), b_B(b^f)]$, where $b_B(0) > 0$ and $b_B(b^f) \leq b^f$. We have $b'_B(b_G) \geq 0$ and $b''_B(b_G) \leq 0$, where the inequalities are strict if and only if b_G satisfies $b_B(b_G) < b^f$.

Define the correspondence $f(b_G)$ as the inverse of $b_G(b_B)$: $f(b_G(b_B)) = b_B$. In (b_B, b_G) space, $f(b_G)$ is the reflection of $b_G(b_B)$ about the 45 degree line, $b_B = b_G$. Hence, the correspondence is continuous, with domain $[b_G(0), b_G(b^f)]$, range $[0, b^f]$, with $f(b_G(0)) = 0$, and with $f'(b_G) > 0$ and $f''(b_G) > 0$ on $[b_G(0), b_G(b^f))$. Note that the correspondence may be set valued at $b_G(b^f)$, where $f(b_G(b^f)) = [\lim_{b_B \to b^{f-}} f(b_G(b_B), b^f]$.

Given continuity and their respective domain and range, there exists some $b^r_G \in (0, b^f]$ for which $b_B(b^r_G) = f(b^r_G)$, so where the curves intersect. Moreover, since $b_B(b_G)$ is increasing and concave while $f(b_G)$ is increasing and convex, this point of intersection is unique and defines the optimal bonus pair: $b^r_B \equiv b_B(b^r_G) = f(b^r_G) > 0$.

We will have $b^r_B < b^r_G$ if and only if $b_B(b_G)$ intersects the 45 degree line before $f(b_G)$ does: that is, if $b_B(b) = b$ implies $f(b) < b$. Since $f(b_G)$ is the inverse of $b_G(b_B)$, an equivalent condition is that $b_B(b) = b$ implies $b_G(b) > b$. Similarly, we will have $b^r_B = b^r_G$ if and only if $b_B(b) = b$ implies $b_G(b) = b$.

When $b = b_G = b_B$, the credibility constraint in the good state (14) reduces to

$$b \leq \delta\Big(\theta\Pi_G(b) + (1-\theta)\Pi_B(b)\Big), \tag{25}$$

and the credibility constraint in the bad state (15) reduces to

$$b \leq \delta\Big((1-\theta)\Pi_G(b) + \theta\Pi_B(b)\Big). \tag{26}$$

By definition, $b_G(b)$ and $b_B(b)$ are the minimum of b^f and of the value of b for which (25) and (26) bind, respectively. Hence, we must show the following: (i) if there exists $b \in (0, b^f)$ for which (26) binds, then (25) holds strictly at b (so that $b^r_B < b^r_G$), and (ii) if (26) holds strictly for all $b \in (0, b^f)$, then (25) holds strictly as well (so that $b^r_B = b^r_G = b^f$). From (25), (26) and $\theta > 1/2$, it is sufficient to show that $\Pi_G(b) > \Pi_B(b)$ for all $b \in (0, b^f)$, where

$$\Pi_G(b) = \Big(\sum_{t=1}^{\infty}\delta^{t-1}P_{t,1}\Big)\pi_G(b) + \Big(\sum_{t=1}^{\infty}\delta^{t-1}(1-P_{t,1})\Big)\pi_B(b),$$

and

$$\Pi_B(b) = \Big(\sum_{t=1}^{\infty}\delta^{t-1}(1-P_{t,1})\Big)\pi_G(b) + \Big(\sum_{t=1}^{\infty}\delta^{t-1}P_{t,1}\Big)\pi_B(b)\Big).$$

Recall that $P_{t,1} > 1/2$. Moreover, comparing (20) and (21) shows that $\pi_G(b) > \pi_B(b)$, since $\Delta > 0$. Thus, we can conclude that $\Pi_G(b) > \Pi_B(b)$.

To complete the proof, note that $\Pi_G(b)$ and $\Pi_B(b)$ are increasing without bound in δ.

Define $\delta_0 \in (0,1)$ as the value of δ for which (26) binds at $b = b^f$. Then (26) holds strictly for all $b \in (0, b^f)$ if and only if $\delta \in [\delta_0, 1]$. We therefore have $b_B^r < b_G^r$ for all $\delta \in (0, \delta_0)$ and $b_B^r = b_G^r = b^f$ for all $\delta \in [\delta_0, 1]$. ■

Proof of Proposition 2. Under formal contracting, the optimal bonus b^f is defined by first order condition (22), which is independent of δ. It follows that b^f is independent of δ.

It remains to show that b_B^r and b_G^r are increasing in δ whenever $b_B^r < b^f$ and $b_G^r < b^f$. In the proof of Proposition 1, we defined $f(b_G)$ as the inverse of $b_G(b_B)$, with $f'(b_G) > 0$ and $f''(b_G) > 0$ on $[b_G(0), b_G(b^f))$. Recall that $b_B'(b_G) > 0$ and $b_B''(b_G) < 0$ for all b_G satisfying $b_B(b_G) < b^f$. We showed that the optimal bonus pair is given by the unique point where $b_B(b_G)$ and $f(b_G)$ intersect: $b_B^r = b_B(b_G^r) = f(b_G^r)$.

By (23) and (24), both $\Pi_G(b_G, b_B)$ and $\Pi_B(b_G, b_B)$ are strictly increasing in δ, so the right-hand-sides of (14) and (15) are strictly increasing in δ as well. This implies $\frac{\partial}{\partial \delta} b_B(b_G) > 0$ for any b_G satisfying $b_B(b_G) < b^f$, and $\frac{\partial}{\partial \delta} f(b_G) < 0$ on $[b_G(0), b_G(b^f))$.

Differentiating both sides of $b_B(b_G^r) = f(b_G^r)$ with respect to δ gives

$$\frac{\partial b_B}{\partial \delta} + \frac{\partial b_B}{\partial b_G} \frac{d b_G^r}{d \delta} = \frac{\partial f}{\partial \delta} + \frac{\partial f}{\partial b_G} \frac{d b_G^r}{d \delta},$$

or equivalently

$$\frac{d b_G^r}{d \delta} = \frac{\frac{\partial b_B}{\partial \delta} - \frac{\partial f}{\partial \delta}}{\frac{\partial f}{\partial b_G} - \frac{\partial b_B}{\partial b_G}}, \tag{27}$$

where the right-hand-side of (27) is evaluated at $b_G = b_G^r$. We know that $\frac{\partial b_B}{\partial \delta} > 0$ and $\frac{\partial f}{\partial \delta} < 0$ whenever $b_G^r < b^f$ and $b_B^r < b^f$. Moreover, we must have $\frac{\partial f}{\partial b_G} > \frac{\partial b_B}{\partial b_G}$ when evaluated at

b_G^r, since $b_B(b_G)$ is concave, $f(b_G)$ is convex, and (b_G^r, b_G^r) is their unique point of intersection. It follows from (27) that $\frac{db_G^r}{d\delta} > 0$, which in turn implies $\frac{db_B^r}{d\delta} = \frac{\partial b_B}{\partial \delta} + \frac{\partial b_B}{\partial b_G}\frac{db_G^r}{d\delta} > 0$. ■

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Table 1

DESCRIPTIVE STATISTICS

	Mean	SD
$BONUS_{it}$	1037.359	1885.46
$SALARY_{it}$	712.138	394.103
$PERF_{it}$	0.038	0.562
$EIDO_{it}$	-0.465	404.581
$SALESCHGPOS_{it-1}$	0.737	0.440
$SALESCHGPOS_{it-1}$ (predicted)	0.867	0.339
$LEVERAGE_{it}$	0.221	0.206
AGE_{it}	55.924	7.620
$TENURE_{it}$	8.209	8.109

NOTE. – Sample size is 24,919 firm-years. Years cover 1993-2011. All monetary variables are measured in 2005 U.S. dollars, converted via the GDP deflator.

Table 2

PANEL A: AUTOCORRELATION MATRIX FOR *EIDO*

	$EIDO_{it}$	$EIDO_{it-1}$	$EIDO_{it-2}$	$EIDO_{it-3}$
$EIDO_{it}$	1.000			
$EIDO_{it-1}$	0.027*	1.000		
$EIDO_{it-2}$	0.006	0.027*	1.000	
$EIDO_{it-3}$	0.007	0.006	0.026*	1.000

NOTE. – * indicates correlation is statistically significantly different from zero at the 5% level.

PANEL B: AUTOCORRELATION MATRIX FOR *SALESCHGPOS*

	$SALESCHGPOS_{it}$	$SALESCHGPOS_{it-1}$	$SALESCHGPOS_{it-2}$	$SALESCHGPOS_{it-3}$
$SALESCHGPOS_{it}$	1.000			
$SALESCHGPOS_{it-1}$	0.217*	1.000		
$SALESCHGPOS_{it-2}$	0.070*	0.210*	1.000	
$SALESCHGPOS_{it-3}$	0.051*	0.084*	0.232*	1.000

NOTE. – * indicates correlation is statistically significantly different from zero at the 5% level.

PANEL C: AUTOCORRELATION MATRIX FOR (PREDICTED) *SALESCHGPOS*

	$SALESCHGPOS_{it}$	$SALESCHGPOS_{it-1}$	$SALESCHGPOS_{it-2}$	$SALESCHGPOS_{it-3}$
$SALESCHGPOS_{it}$	1.000			
$SALESCHGPOS_{it-1}$	0.607*	1.000		
$SALESCHGPOS_{it-2}$	0.462*	0.673*	1.000	
$SALESCHGPOS_{it-3}$	0.379*	0.463*	0.659*	1.000

NOTE. – * indicates correlation is statistically significantly different from zero at the 5% level. $SALESCHGPOS_{it}$ equals 1 if the the predicted value for year t from an individual regression for the i^{th} firm is positive, and equals 0 otherwise, where the regression for firm i takes the following form: $SALESCHG_t = \gamma_0 + \mathbf{Z}_t\boldsymbol{\gamma} + \omega_t$, where $\mathbf{Z}_t$ includes the first lag of real GDP growth, a linear time trend, and a constant.

Table 3

CEO PERFORMANCE REGRESSIONS

	(1)	(2)
	$PERF_{it}$	$PERF_{it}$
$EIDO_{it}$	0.006	0.006
	(0.002)***	(0.002)***
$SALESCHGPOS_{it-1}$	16.753	
	(1.903)***	
$SALESCHGPOS_{it-1}$ (predicted)		18.009
		(2.569)***
AGE_{it}	2.154	1.971
	(1.562)	(1.492)
$(AGE_{it})^2$	-2.346	-2.178
	(1.382)*	(1.320)*
$TENURE_{it}$	0.224	0.300
	(0.370)	(0.354)
$(TENURE_{it})^2$	0.849	0.672
	(1.128)	(1.077)
Constant	-1.675	1.902
	(43.943)	(41.982)
Sample Size	N = 18,511	N = 19,117

NOTE. – Both specifications include year dummies and firm fixed effects. Standard errors are in parentheses below each estimate. Statistical significance at the 10%, 5%, and 1% levels denoted by *, **, and ***. Dependent variable, $PERF_{it}$, is income before extraordinary items. $SALESCHGPOS_{it-1}$ (predicted), used in model (2), is computed as described in the note to Table 2, Panel C. All coefficients and standard errors are multiplied by 1000 for easier reading.

Table 4

CEO BONUS REGRESSIONS

	(1)	(2)	(3)	(4)
	$BONUS_{it}$	$BONUS_{it}$	$BONUS_{it}$	$BONUS_{it}$
$EIDO_{it}$	0.076	0.069	0.076	0.069
	(0.024)***	(0.024)***	(0.024)***	(0.024)***
$SALESCHGPOS_{it-1}$	165.425	-2.451		
	(27.525)***	(41.069)		
$SALESCHGPOS_{it-1} \times LEVERAGE_{it}$		604.068		
		(124.233)***		
$SALESCHGPOS_{it-1}$ (predicted)			121.806	-126.123
			(37.482)***	(56.503)**
$SALESCHGPOS_{it-1} \times LEVERAGE_{it}$ (pred.)				845.427
				(155.722)***
$LEVERAGE_{it}$		-1885.230		-2196.837
		(139.139)***		(168.533)***
$SALARY_{it}$	1.100	1.108	1.253	1.257
	(0.060)***	(0.060)***	(0.058)***	(0.058)***
AGE_{it}	-26.416	-22.798	-11.589	-10.070
	(22.573)	(22.462)	(21.801)	(21.689)
$(AGE_{it})^2$	21.365	18.025	10.033	8.924
	(19.965)	(19.866)	(19.279)	(19.181)
$TENURE_{it}$	17.834	17.666	12.448	12.326
	(5.394)***	(5.369)***	(5.2005)**	(5.179)**
$(TENURE_{it})^2$	-33.061	-31.136	-20.592	-20.676
	(16.379)**	(16.301)*	(15.788)	(15.711)
Constant	1202.062	1551.748	492.942	990.369
	(634.983)*	(632.449)**	(612.833)	(611.599)
Sample Size	N = 18,323	N = 18,300	N = 18,929	N = 18,906

NOTE. – All specifications include year dummies and firm fixed effects. Standard errors are in parentheses below each estimate. Statistical significance at the 10%, 5%, and 1% levels denoted by *, **, and ***. Dependent variable, $BONUS_{it}$, is the year-t bonus for firm i's CEO in 2005 dollars. $SALESCHGPOS_{it-1}$ (predicted), used in models (3) and (4) is computed as described in the note to Table 2, Panel C.