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The structure of CEO pay: pay-for-luck and stock-options *

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Abstract

We develop a stylized model of efficient contracting in which firms compete for CEOs. The optimal contracts are designed to retain and insure CEOs. The retention motive explains pay-for-luck in executive compensation, while the insurance feature explains asymmetric pay-for-luck. We show that the optimal contract can be implemented with stock-options based on a single performance measure which does not filter out luck. When the capacity to dismiss underperforming CEOs differs across firms, and the ability of different CEOs is more or less precisely estimated ex-ante, endogenous matching between CEOs and firms can explain the observed association between pay-for-luck and bad corporate governance. The model also predicts that an improvement in the governance of badly governed firms has spillover effects that increase CEO pay in all firms.

Keywords: CEO pay; corporate governance; pay-for-luck; stock-options.

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In recent years, CEO pay has attracted considerable attention, both in the popular press and in academic journals. This renewed interest was in part triggered by some puzzling observations such as the evidence that exogenous and contractible shocks to performance do nevertheless have an effect on CEO pay: this is the pay-for-luck phenomenon documented by Bertrand and Mullainathan (2001). In response to this and to other empirical findings inconsistent with standard principal-agent models, Bertrand and Mullainathan (2001) and Bebchuk and Fried (2004), among others, have proposed the managerial power or "skimming" hypothesis as an alternative paradigm. The subsequent literature has documented a number of "anomalies", which can be suggestive of corporate governance failures (Edmans and Gabaix (2009), Frydman and Jenter (2010)). In particular, the compensation base for CEO pay (the stock price without indexation) and the use of stock-options remain controversial.

This paper proposes a model in which CEO compensation contracts are designed to match the state-contingent reservation wages of CEOs determined in a market equilibrium. Our baseline model builds on Harris and Holmstrom (1982) and Oyer (2004). It can notably explain the compensation base of CEOs, and the use of stock-options. In particular, the optimal contract displays pay-for-luck, but only on the upside, so that pay-for-luck is asymmetric. When we extend the contractual environment to a matching model of CEOs and firms, we find that endogenous matching can explain the association between pay-for-luck and poor corporate governance (Bertrand and Mullainathan (2001)). In equilibrium, firms with bad governance employ CEOs whose contracts display more pay-for-luck. This result is reminiscent of Ackerberg and Botticini (2002) who show in the context of sharecropping contracts that endogenous matching can explain apparent discrepancies between theoretical predictions and empirical findings. We also generate a number of predictions which seem broadly consistent with the empirical evidence, and which suggest new interpretations for existing findings. We thus argue that models based on the market value of CEOs can not only explain the *level* of CEO pay (Gabaix and Landier (2008), Tervio (2008)), but also the *structure* of CEO pay.

As in Oyer (2004), we focus on the effect of a CEO's outside options on his compensation.

We consider a two-period relationship between a risk-neutral principal (shareholders) and a risk averse CEO with a state-contingent outside option that depends on signals on his unknown ability (as in Harris and Holmstrom (1982)) and on business conditions or "luck" (as in Oyer (2004)). We assume that the firm can commit to a long-term contract, but that the CEO cannot commit to work for the firm in the future. In this setting, we show that a risk averse CEO accepts a lower pay in the first period in exchange for insurance against a low reservation wage in the second period. This is possible because the firm can commit to pay an endogenously generated "minimum wage" in the second period. However, when the second period reservation wage exceeds this "minimum wage" the firm must adjust the pay of the CEO upward to retain him. Therefore, compensation will be downward rigid *and* sensitive to factors that affect the reservation wage of the manager (including luck) on the upside, so that pay-for-luck will be asymmetric (see Bertrand and Mullainathan (2001) and Garvey and Milbourn (2006) for the empirical evidence).

This optimal contract can be implemented using stock-options: stock options provide the required upside participation as well as the required downward protection. Intuitively, a positive shock to either CEO ability or business conditions raises both firm value and the market value of the CEO – to the extent that CEO talent or ability is transferable across firms. Stock-options are then optimal with downward wage rigidity as in Harris and Holmstrom (1982) and equity-based compensation as in Oyer (2004). This result contrasts with the arguments that it is inefficient to use stock-options for retention purposes[1] (Hall and Murphy (2003), Lazear (2004)), or to solve a principal-agent problem of effort provision (Hall and Murphy (2002), Dittmann and Maug (2007)). The model also predicts an increase in stock-options based compensation as general managerial skills become relatively more important than firm-specific skills, as was arguably the case in the 1980s and the 1990s (Murphy and Zabojnik (2004) and Frydman (2007)).

[1]According to Lazear (2004), "Worker retention is not a justification for awarding non-vested stock options (...) To the extent that the typical worker is more risk-averse than the outside suppliers of capital, non-vested pay should take the form of bonds rather than equity." According to Hall and Murphy (2003), "Options clearly provide retention incentives, but do they do so in the most efficient manner? (...) it is not obvious to us that retention incentives should optimally vary with company stock prices."

Our third main result concerns the link between pay-for-luck and corporate governance. We show that pay-for-luck will be stronger in firms with poor corporate governance. This result is obtained in a simple matching model of CEOs and firms, in which CEOs differ in the variance of their ability. We assume that dismissing a CEO and hiring a new one is costly, and that this cost differs across firms (see Taylor (2010)). Given that it is efficient to dismiss a CEO with low ability, we interpret a high cost of dismissal as an indicator of bad corporate governance.[2] The result can be explained as follows. With endogenous matching, firms with a high firing cost hire CEOs whose ability is more precisely estimated ex-ante ("safe CEOs"). In turn, contracts for CEOs with more precisely estimated ability display more pay-for-luck. This is because firm performance in the first period provides some information on the CEO's ability, which affects his reservation wage in the second period. But economic conditions ("luck") also affect the reservation wage of the CEO. Overall, firm performance is all the more informative about managerial ability that this ability is not precisely estimated ex-ante – think about young CEOs, or CEOs with a short tenure, for example. It follows that state-contingent pay puts a higher weight on firm performance (rather than luck) for CEOs whose ability is more uncertain. Thus, the model predicts that there will be more pay-for-luck in firms with bad governance.

As already noted for example in Murphy and Zabojnik (2004), the skimming hypothesis is hard to reconcile with the facts that, in the past decades, CEO pay increased *and* corporate governance improved. The results of the paper are consistent with this phenomenon – although many other factors such as an increase in the size of big American firms are behind the rise in CEO pay (Gabaix and Landier (2008)). Indeed, we show that an improvement in corporate governance, whether across the board or confined to the subset of badly governed firms, has a spillover effect that increases CEO pay in all firms. Intuitively, corporate governance heterogeneity softens competition for CEOs, and enables well-governed firms to earn rents. Improvements in governance improve the bargaining position of CEOs and reduce these rents. This is related to

[2]The variables used in Bertrand and Mullainathan (2001) – the existence of a large shareholder, CEO tenure, the board size, and the fraction of insider directors – can also be interpreted as proxies for the cost or difficulty of CEO dismissal. Note that the link between CEO turnover and corporate governance is not new – for example, in Hermalin and Weisbach (1998), the independence of the board of directors plays a key role in CEO turnover.

the work of Acharya and Volpin (2010) and Dicks (2012), who show that corporate governance in a firm may generate an externality and influence the compensation of CEOs in other firms. However, the externality that we identify does not affect Pareto efficiency and therefore does not call for a regulatory intervention. We also find that an across-the-board improvement in corporate governance leads to more forced CEO turnover, which is consistent with the evidence in Kaplan and Minton (2012). However, in our model, a firm-specific change in corporate governance does not necessarily have an effect on CEO turnover (because of a sorting effect), and it does not affect CEO pay. This distinction between the effects of economy-wide and firm-specific changes in governance should be relevant for future empirical studies.

The assumption at the core of our analysis that retention is an important determinant of CEO compensation has been tested in the literature. Gabaix and Landier (2008) find strong empirical support for a model in which the level of CEO pay is jointly determined in a competitive market by the distribution of CEO talent and firm size (see also Tervio (2008)). Lazear (2004) and Oyer and Schaefer (2005) emphasize the limitations of the incentives-based explanation for the adoption of variable pay and broad-based stock-options plans, respectively. Rajgopal, Shevlin and Zamora (2006) present evidence that CEO pay is structured to match the state-contingent outside employment opportunities of managers. Taylor (2012) studies the response of CEO pay to good and bad news about CEO ability, and finds that the data is consistent with the model of Harris and Holmstrom (1982). The present paper contributes to this growing literature which shows that both the level and the form of CEO pay can be explained by retention motives and changes in reservation wages.

Our paper also obviously contributes to the literature on pay-for-luck. Pay-for-luck is not predicted by the standard moral hazard model of efficient contracting with a risk averse agent: if a worker's pay must be variable for incentive purposes, then the informativeness of the performance measure should be maximized (Holmstrom (1979)), so that it is optimal to filter out exogenous shocks to performance. Hoffmann and Pfeil (2010) and Noe and Rebello (2012) show that pay-for-luck can nevertheless arise in a dynamic principal-agent model. In a calibration,

Dittmann, Maug, and Spalt (2011) find that pay-for-luck is not very costly to the firm. Gopalan, Milbourn, and Song (2009) and Feriozzi (2010) propose some alternative hypotheses to explain asymmetric pay-for-luck, related respectively to strategy choice and the implicit incentives emanating from the threat of bankruptcy. By contrast, this paper and the models of Oyer (2004) and Himmelberg and Hubbard (2000) show that pay-for-luck can be driven by changes in the reservation wages of CEOs, as determined in a competitive labor market.

This paper is also the first to explain both asymmetric pay-for-luck and the association between pay-for-luck and corporate governance as the equilibrium outcome of a simple contracting model. This is important: according to the seminal paper of Bertrand and Mullainathan (2001), these two aspects of pay-for-luck rather than pay-for-luck per se provide supporting evidence for a skimming model of executive pay. These results have obvious policy implications. If the evidence related to "anomalies" such as pay-for-luck implies a corporate governance failure – that would affect a majority of large American firms and have wide ranging consequences, of which pay-for-luck would merely be a symptom – then it provides the grounds for a regulatory intervention, and a substantial change in firm governance. However, if the evidence related to pay-for-luck can be comprehensively explained by a simple model of efficient contracting, then it is unclear whether such measures are necessary.

Section 1 presents the model. Section 2 derives the optimal compensation contract, for any given firm-manager match. Section 3 describes the relevant performance measure for managerial compensation, and introduces stock-options. Section 4 describes the matching equilibrium. Section 5 discusses the empirical implications of the results. Section 6 concludes. All proofs are in the Appendix.

1 The model

We consider a two-period economy in which firms compete for CEOs.

Firms are risk neutral and maximize their expected profits. In both periods, the gross profits

(before compensation of the manager) of a firm depend on three factors: its CEO's ability a, business conditions $\tilde{L}$, and an unobservable idiosyncratic shock $\tilde{\epsilon}_t$. We assume that the gross profits of the firm in period t, for $t \in \{1, 2\}$, are realized at the end of the period and write as:[3]

$$\pi_t = (\alpha + s_t a + \tilde{\epsilon}_t)\tilde{L}. \tag{1}$$

where $s_t > 0$. A notable implication is that an exogenous shock to business conditions (L) also affects the value of CEO talent or ability.

We assume that $\tilde{\epsilon}_t$ is normally distributed with mean zero and variance σ_ϵ^2, and independent from other random variables for any $t \in \{1, 2\}$. We assume that $\tilde{L}$ is a random variable with positive support, which is also independent from other random variables, and we denote by $G(\cdot)$ the c.d.f. of L.

We will use the notation $\tilde{L}$ to denote the random variable $\tilde{L}$, and the notation L to denote its realization at the end of period 1, which is observable and contractible. We will refer to L as "luck", since it represents a shock which is not under the control of the CEO but which nevertheless has an effect on firm value and on the CEO's productivity (see below).

The variable s_t represents the accumulated experience and firm-specific skills of the CEO. Following Murphy and Zabojnik (2004), we let $s_t = 1$ if the CEO worked for the firm in period $t-1$, and $s_t = \gamma \in (0, 1)$ otherwise (the evidence in Taylor (2012) is consistent with the hypothesis that $\gamma < 1$). This makes CEO turnover intrinsically costly. Note that if general skills predominate, then s approaches one, in which case managerial skills are more easily transferable, and CEOs are more easily replaceable.

The ability a of a CEO is normally distributed with mean $\bar{a} > 0$ and variance σ_a^2, but it is unknown ex-ante (including to the CEO). CEOs are risk averse with utility function $u(\cdot)$ ($u' > 0$, $u'' < 0$). We assume a limited supply of CEOs. Firms without CEOs can be run

[3]This specification relies on strong evidence from Gabaix and Landier (2008) that the dollar effect of CEO "talent" on firm value is increasing in firm value, and that the data is consistent with a constant returns to scale hypothesis, i.e., a multiplicative structure as in (1).

by managers. There is an infinite supply of managers, whose expected ability is normalized to zero.[4] As is apparent in (1), realized profits in the first period are informative about CEO ability. Firms will update their beliefs about CEOs' ability and use this information for their second period decisions.

For any firm, the net profits in any period are the gross profits (henceforth "profits") net of compensation costs. Both gross profits and net profits are observable and contractible. For simplicity, we assume a zero interest rate and no time discounting. Firms pay out their net profits realized over period 1 and 2 to shareholders at the end of the second period.

Crucially, we assume that a firm can commit to a long-term contract, but a CEO cannot. While firms can and do propose enforceable long-term contracts to their employees, constraints on involuntary servitude prevent employees from forgoing (ex-ante) the option to quit a job. This one-sided-commitment assumption is natural and was introduced in Harris and Holmstrom (1982), and Holmstrom and Ricart i Costa (1986). We also assume that a manager can neither save nor borrow, so that he does not transfer income from one period to another.[5]

Two types of contracts are feasible. Any firm can propose a spot contract to a manager or CEO at the beginning of the first period, and a spot contract to a manager or CEO at the beginning of the second period. In this case, the employment of the first period manager/CEO terminates at the end of the first period. Alternatively, the firm can propose a long-term contract to a CEO at the beginning of the first period.[6] This contract specifies the wage that the firm commits itself to pay the CEO in periods 1 and 2.

At the beginning of the second period, any CEO can resign, in which case he forgoes his contractual second period payment, but earns his reservation wage, which will be endogenously determined. A firm can dismiss a CEO who has not resigned at a cost K, with $K \geq 0$, and hire a new CEO (or a manager) on the spot market. The parameter K represents the cost

[4]The ability of managers could also be random, the main results would not change. This formulation simplifies the algebra. It also implies that managers do not accumulate firm-specific skills.

[5]As in Harris and Holmstrom (1982) and Holmstrom and Ricart i Costa (1986), the optimal contract is such that the saving restriction is inconsequential.

[6]We show in the next section that we can ignore long-term contracts for managers, as they can be replicated by a sequence of spot contracts.

of involuntary CEO turnover in a given firm. This assumption is grounded in the evidence that involuntary CEO turnover is indeed costly (Taylor (2010)). The cost of involuntary CEO turnover reflects unmodelled but important factors such as the cost of coordination problems which impede internal governance, the cost of the severance package that an entrenched CEO may obtain, or the disruptive effect of a disorderly or lengthy dismissal procedure.[7]

We also assume that there is a market for each firm's shares at the beginning of the second period, following the realization of the luck shock $\tilde{L}$, where stock prices are established by competitive and risk neutral investors. We denote by V the (endogenously determined) market value of a given firm at the beginning of the second period.

The analysis of the model is in two steps. We first solve for optimal contracts for an exogenously given match of firms and CEOs, by taking the reservation utility of CEOs as given. Then, in section 4, we study the endogenous matching of firms and CEOs; the reservation utilities at the beginning of the first period are then determined in a market equilibrium.

2 Optimal contracts

Consider a firm with firing cost K matched with a CEO with variance of ability σ_a^2 and reservation utility over periods 1 and 2 denoted by $\bar{U}$. We first consider the market for the CEO at the beginning of period 2, after information about his ability and about business conditions has been realized, and then solve backwards for the optimal contract in period 1.

[7]Taylor (2010) finds that the cost of involuntary CEO turnover consists of two components: the direct cost to the firm, and the personal cost to the board, which includes directors' ties to the CEO, their effort, and a lower probability of nomination at other boards. In our model, we only consider the direct cost in terms of firm profits for simplicity, but our results would be robust to a more general interpretation of K that includes the personal cost to the board. Indeed, the value of the firm derived in section 3 only matters for managerial compensation purposes when the CEO is not dismissed (so that K is irrelevant), and the dismissal rule derived in (5) would remain the same (the only difference is that (4) would not be interpreted narrowly as firm profits, but as the objective function of the board, which would then include the personal cost of dismissal).

2.1 Spot market in period 2

Managers are in unlimited supply, they have zero ability and a reservation wage of zero.[8] Their first and second period compensation under either a spot or a long-term contract is therefore zero.

The updated expected ability $\hat{a}$ of a CEO after first-period profits π_1 and the luck shock L have been observed is calculated using Bayes' rule:

$$\hat{a} = \frac{1}{\gamma} \frac{\gamma^2 \sigma_a^2 (\pi_1 / L - (\alpha + \gamma \bar{a})) + \sigma_\epsilon^2 \gamma \bar{a}}{\gamma^2 \sigma_a^2 + \sigma_\epsilon^2}. \tag{2}$$

Note that $\hat{a}$ is independent of L. We will denote by $F_{\hat{a}}$ and $f_{\hat{a}}$ the c.d.f and p.d.f of $\hat{a}$ before the realization of π_1 and L. In the second period, a firm can choose to hire a manager with zero ability on a spot contract for a zero wage, in which case its expected profits are αL. Firms can also compete for a CEO with updated expected ability $\hat{a}$. All other firms with vacant positions are only willing to pay up to $\gamma \hat{a} L$ to hire this CEO, which corresponds to the additional profits generated by a given CEO relative to a zero-ability manager. Competition between firms drives the second period reservation wage of a CEO with updated expected ability $\hat{a}$ to $W_2(\hat{a}, L) = \gamma \hat{a} L$. Because of the assumption of one-sided commitment, any given CEO with $\hat{a}$ can earn this wage in the second period, whether he entered a spot contract or a long-term contract in the first period. It follows that a firm which employed a CEO in the first period only needs to match this reservation wage to retain him in the second period. Note that because of the imperfect transferability of managerial skills across companies ($\gamma < 1$), the market value of CEOs does not fully adjust to ability or luck shocks: any given firm would be willing to pay up to $\hat{a} L$ to retain its CEO in the second period.

[8] In this section, we assume that the reservation wage of managers is zero. In section 4, this will be derived endogenously.

2.2 The dismissal rule

We now consider a firm which entered into a long-term contract with a given CEO. We will show that this firm dismisses its CEO at the beginning of the second period when his updated expected ability is lower than a threshold.

The expected second period profits of a firm which does not dismiss its CEO at the beginning of the second period are

$$(\alpha + \hat{a})L - w_2, \tag{3}$$

where w_2 denotes the (as yet undetermined) compensation of the CEO in the second period under his contract. The expected second period profits of a firm which dismisses its CEO at the beginning of the second period and hires either a new CEO or a manager on the spot market are:

$$\alpha L - K - w_2, \tag{4}$$

where w_2 is again the second period compensation of the dismissed CEO. Comparing the expressions in (3) and (4) yields the optimal firing rule: a firm will dismiss its CEO at the beginning of the second period if and only if

$$\hat{a} < -\frac{K}{L}. \tag{5}$$

Dismissing a CEO under a long-term contract is optimal if the updated expected ability of the CEO in place is lower than a threshold. This threshold is decreasing in the cost K of changing the CEO, and increasing in the luck shock L. The ability of the CEO matters all the more that L is high, since firms profits are multiplicative in a and L.

The dismissal cost creates some inefficiencies in the market for CEOs. There are two sources of inefficiencies: the direct cost K incurred in case of dismissal, and the fact that some CEOs remain in place despite their low ability.

2.3 The optimal long-term contract

A long-term contract consists in a first-period wage w_1 and a second period state-contingent wage $w_2(\hat{a}, L)$ that potentially depends on the observed variables L and $\hat{a}$ (through π_1). The firm chooses the contract to minimize the total expected cost of compensation subject to two types of participation constraints. First, the state-contingent participation constraints guarantee that the firm matches the reservation wage of the CEO in the second period state-by-state. Second, the first-period participation constraint guarantees that the CEO accepts the long-term contract at the beginning of the first period – which is the case when the expected utility associated with the contract exceeds his reservation utility $\bar{U}$.

As seen before, the dismissal decision is independent of the contract; it only depends on the information on L and a received at the end of the first period. The dismissal cost in turn does not affect the optimal long-term contract.[9]

The optimal long-term contract solves the following optimization problem:

$$\min_{\langle w_1, w_2(\hat{a},L)\rangle} w_1 + E[w_2(\hat{a}, L)] \tag{6}$$

$$\text{subject to} \qquad w_2(\hat{a}, L) \geq W_2(\hat{a}, L) \qquad \text{for all } \hat{a}, L \tag{7}$$

$$u\left(w_1\right) + E[u\left(w_2(\hat{a}, L)\right)] \geq \bar{U} \tag{8}$$

where $\bar{U}$ denotes the reservation level of utility of the CEO over two periods at the beginning of the first period.

Proposition 1. The optimal long-term contract is characterized by a first period wage of w_1^* *and a second period wage of*

$$w_2^\star(\hat{a}, L) = \max\{w_1^*, \gamma \hat{a} L\}. \tag{9}$$

[9] A firm dismisses its CEO if and only if $\hat{a} < -\frac{k}{L}$. The participation constraint (7) is binding only when $\hat{a} \geq \frac{w_1^*}{\gamma L} \geq 0$. But in cases when the firm dismisses its CEO, $\hat{a}$ is negative so that (7) cannot be binding. It follows that the dismissal decision does not affect the contract.

The value of w_1^* is determined by the first period participation constraint, and depends on the value of the outside option $\bar{U}$.

A long term contract is fully determined by the first-period wage w_1^*. The second period wage is equal to w_1^*, unless the participation constraint in (7) binds given $\hat{a}$ and L, in which case the second period wage is equal to the reservation wage $W_2(\hat{a}, L)$, which is larger than w_1^*. At this stage, we do not specify how this state-contingent payment is implemented. Notice that, even though firing a CEO is costly in our model, there is no rent extraction in equilibrium, since the first period wage of the CEO adjusts so that he is at his reservation level of utility. On the contrary, in Kuhnen and Zwiebel (2008), firing costs make rent extraction possible.

The advantage of a long-term contract over a sequence of spot contracts is that the firm can partially insure the CEO against a bad state of the world (in terms of estimated ability and business conditions). As long as the expected dismissal cost is not too large, a long-term contract dominates a sequence of spot contracts. This is because a long-term contract allows to partially insure the CEO in the second period. In the remainder of the paper, we assume that this is the case.[10]

Finally, it should be noted that the firm could simply commit to paying the manager the fixed wage w_1^* in periods 1 and 2, and adjust his pay at the beginning of the second period depending on $\hat{a}$ and L. While this is certainly possible, this would not be optimal with a renegotiation or transaction cost, no matter how small. Indeed, even with an arbitrarily small renegotiation cost, the long-term contract described in this section would strictly dominate the contract described above in this paragraph. By contrast, in Oyer (2004), with an arbitrarily small renegotiation cost, it will always be optimal to use spot contracts instead of long-term contracts.

[10]This assumption can be microfounded by assuming that σ_a^2 and K are sufficiently low.

2.4 Characteristics of the optimal contract

The optimal long-term contract displays three interesting features.

First, as in Harris and Holmstrom (1982), the risk averse CEO is insured by the firm: should his second period reservation wage fall below w_1^*, the firm will nevertheless pay w_1^* in the second period. In this case, this payment will either take the form of a fixed wage, or of a severance payment, in case the CEO is dismissed at the beginning of the second period. Thus, because of the risk aversion of the CEO and of the ability of the firm to commit, it is inefficient to punish the CEO for "failure". The cost of this insurance is a first period wage w_1^* lower than what the CEO could obtain on the spot market. That is, the CEO pays an insurance premium in the first period to be insured against adverse realizations of his reservation wage in the second period.[11]

Otherwise, if the reservation wage of the CEO in the second period is above w_1^*, the firm matches it to retain him. The CEO cannot be fully insured by the firm (with a constant wage in the second period) because he cannot commit in the first period to work for the firm in the second period. To summarize, the optimal contract features downside protection, with a downward rigid second period wage for insurance purposes, and upside participation for retention purposes. The assumption of one-sided commitment is crucial for this result.

Second, the compensation of the CEO in the second period depends on business conditions, or "luck" (L). The reason is the same as in Oyer (2004): compensation adjusts to the level required to retain the CEO, and this level in turn depends on business conditions.

Third, pay for luck is asymmetric. Indeed, the pay of the CEO is sensitive to luck (at the margin) if and only if the luck shock is sufficiently positive:

Proposition 2. The optimal contract displays asymmetric pay-for-luck. For any given value of $\hat{a}$*,*

$$\frac{dw_2^\star}{dL} = \gamma\hat{a} > 0 \text{ if } L > \underline{L} \qquad \text{and} \qquad \frac{dw_2^\star}{dL} = 0 \text{ if } L < \underline{L}, \tag{10}$$

[11] They stem from two sources: updating of beliefs regarding the CEO's ability, and the luck shock. In Harris and Holmstrom (1982), the only source of uncertainty relates to the updating of beliefs on the agent's ability.

$$\text{where} \qquad \underline{L} \equiv w_1^*/\gamma\hat{a}.$$

This result highlights that, with an optimal contract, the CEO is "rewarded for good luck", but he is not symmetrically "penalized for bad luck": pay-for-luck is asymmetric. This is due to the insurance against adverse states of the world (including bad luck) provided by the optimal contract to a risk averse CEO.

3 Implementation with stock-options

In the optimal contract, the second period compensation of a CEO depends on his expected ability $\hat{a}$ and on the luck shock L. In this section, we show that the optimal long-term contract can be implemented by giving the CEO a fixed wage and stock-options. We also discuss how the optimal compensation contract depends on the parameters of the model.

We first show that the optimal second-period compensation of the CEO can be expressed as a function of firm value at the beginning of the second period and the luck shock. In a competitive market for firm shares with risk neutral shareholders, firm value at the beginning of the second period is:

$$V = \pi_1 - w_1 + E[\pi_2|\pi_1, L] - w_2(\hat{a}, L) = \pi_1 - w_1^* + (\alpha + \hat{a})L - \max\{w_1^*, \gamma\hat{a}L\}, \qquad (11)$$

if $\hat{a} > -\frac{K}{L}$. Otherwise, the incumbent CEO is dismissed at the beginning of the second period, with a compensating payment of w_1^*, while the new CEO receives a fixed wage, so that firm value does not matter for compensation purposes.

Substituting for $\pi_1 = V + w_1^* - (\alpha + \hat{a})L + \max\{w_1^*, \gamma\hat{a}L\}$, in (2) and isolating $\hat{a}$, we get:

$$\begin{aligned} w_2^\star(\hat{a}, L) &= w_1^* \text{ if } \gamma\hat{a}L \leq w_1^*, \\ w_2^\star(\hat{a}, L) &= \gamma\hat{a}L = \left(\frac{\gamma^2\sigma_a^2 + \sigma_\epsilon^2}{\gamma^2\sigma_a^2} + \frac{1-\gamma}{\gamma}\right)^{-1}\left(V + w_1^* - 2\alpha L + \gamma\bar{a}L\left(\frac{\sigma_\epsilon^2}{\gamma^2\sigma_a^2} - 1\right)\right) \text{ otherwise.} \end{aligned}$$

That is,

$$w_2^\star(\hat{a}, L) = \max\{w_1^*, \psi(w_1^* + V + \eta L)\}, \tag{12}$$

$$\text{where} \qquad \psi \equiv \left(\frac{\gamma^2\sigma_a^2 + \sigma_\epsilon^2}{\gamma^2\sigma_a^2} + \frac{1-\gamma}{\gamma}\right)^{-1} \qquad \text{and} \qquad \eta \equiv \gamma\bar{a}\left(\frac{\sigma_\epsilon^2}{\gamma^2\sigma_a^2} - 1\right) - 2\alpha. \tag{13}$$

Notice that $\psi \in (0, 1)$.

We now specify how the optimal contract described in Proposition 1 can be implemented with stock-options on a measure which is constructed to incorporate both changes in firm value and luck. Consider the measure $P(V, L)$, constructed as

$$P(V, L) = V + \eta L. \tag{14}$$

Then the state-contingent payment $w_2^\star(\hat{a}, L)$ in (9) can be implemented by making payments to the agent contingent on the measure P:

$$w_2^\star(\hat{a}, L) = \max\{w_1^*, \psi w_1^* + \psi P(V, L)\}. \tag{15}$$

This immediately leads us to this important result that establishes the optimality of stock-options as an instrument for CEO retention:

Proposition 3. The state-contingent optimal payment in (15) may be implemented by giving the CEO a fixed wage w_1^* and ψ stock-options based on the performance measure $P(V, L) = V + \eta L$ with exercise price $\kappa = \frac{w_1^*(1-\psi)}{\psi}$, which vest at the beginning of the second period, after the resignation and dismissal decisions, and expire before the end of the second period.

Stock-options vest after one period precisely because, to be an optimal compensation instrument, their value must depend on the factors that affect the CEO reservation wage in period 2, namely estimated CEO ability $\hat{a}$ and business conditions L, which are unknown at the beginning of period 1. In addition, the vesting period of stock-options is such that a CEO who resigns at

the beginning of the second period cannot exercise them. The options of a dismissed CEO are out-of-the-money and therefore worthless, so that it does not matter whether or not a dismissed CEO can exercise his options.

We summarize notable comparative static results in this corollary:

Proposition 4. The stock-options compensation plan has the following comparative statics properties:

(i) The performance measure P is not independent of luck: $\frac{d}{dL}P(V,L) \neq 0$.

(ii) The sensitivity of the performance measure to luck is increasing in the variance of the idiosyncratic shock $\tilde{\epsilon}$: $\frac{d\eta}{d\sigma_\epsilon^2} > 0$.

(iii) The sensitivity of the performance measure to luck is decreasing in the variance of the CEOs ability: $\frac{d\eta}{d\sigma_a^2} < 0$.

(iv) The sensitivity of the performance measure to luck is decreasing in the relative importance of general managerial skills: $\frac{d\eta}{d\gamma} < 0$.

(v) The amount of stock options granted is increasing in the relative importance of general managerial skills: $\frac{d\psi}{d\gamma} > 0$.

The stock-options are not completely indexed: the luck shock L is not fully filtered out of the measure P. Intuitively, this is because the reservation wage of the CEO in the second period depends not only on $\hat{a}$ but also on L. Furthermore, the degree of pay-for-luck relative to pay-for-performance (or pay-for-ability), which is measured by η, is increasing in σ_ϵ^2, and decreasing in σ_a^2: there will be more pay-for-luck relative to pay-for-performance when firm value V is a noisy measure of CEO ability a, and when the initial uncertainty on the ability of the CEO is low, which is intuitive. This suggests that pay-for-luck will be relatively strong for old CEOs or CEOs with a long tenure (whose σ_a^2 tends to be low). On the contrary, young CEOs or CEOs with a short tenure should be less paid for luck, all else equal. In the limit, as the ratio $\frac{\sigma_\epsilon^2}{\sigma_a^2}$ tends to infinity, η also tends to infinity, and state-contingent remuneration only depends on luck.

The quantity ψ of stock-options given to the CEO is an increasing function of γ, which

measures the relative importance of general managerial skills as opposed to firm-specific skills. This is because a rise in γ increases the transferability of CEOs across firms, so that it increases the sensitivity of a CEO's market value to firm value. This in turn implies that more stock-options should be granted in order to match the reservation wage of the CEO state-by-state. To the extent that general skills did indeed become progressively more important in the 1980s and the 1990s, as argued by Murphy and Zabojnik (2004) and Frydman (2007), then our model can explain why CEOs received increasing amounts of stock-options over this period (Frydman and Jenter (2010), figure 2). This prediction is also consistent with the evidence in Cunat and Guadalupe (2009) that higher foreign competition – which is their words "could be an additional reason why general skills are more important" – is associated with more performance-related pay.

It is noteworthy that the CEO is not more exposed to risk with this long-term contract than he would be with a sequence of spot contract – he is even less exposed to risk with the long-term contract because of the embedded insurance.[12] Here our results differ from Oyer's (2004). In Oyer, there is a trade-off between exposing the CEO to risk (by indexing his pay on some variable which is imperfectly correlated with his reservation wage) and incurring renegotiation or transactions costs with interim re-contracting. We also differ from standard models of moral hazard, where the optimal contract is the outcome of a trade-off between exposing the agent to a noisy measure of his effort and providing incentives for effort.

4 Competition for CEOs and matching equilibrium

In section 2, we derived the optimal contract with exogenous reservation utilities. We now introduce competition between firms for available CEOs to endogenize the reservation utilities

[12]Indeed, the CEO is only exposed to variations in his reservation wage – on the upside. Firm value V consists of two components: some exogenous shocks which can be filtered out (here represented by L), and the "pure measure of performance", i.e., firm profits once exogenous influences (such as L) have been removed. Since the beliefs on the CEO's ability are updated based on this "pure measure of performance", any residual noise in this measure will *also* affect the updated beliefs on the CEO's ability, and therefore his reservation wage.

of CEOs in the first period. We also extend the model to incorporate matching between CEOs and firms.[13] This enables us to address the negative correlation between pay-for-luck and measures of corporate governance documented by the literature on pay-for-luck. This empirical fact is at the root of the skimming theory, which states that CEOs "set their own pay" in badly governed firms (Bertrand and Mullainathan (2001)).

We do not model the competitive process explicitly, but we identify the stable matching between firms and CEOs. We assume that CEOs are on the short side of the market, i.e., there is a limited supply of "talented" CEOs, so that the outside option will be determined by the stability of matching: no unmatched firm should be willing to propose a contract to a matched CEO that he would accept.

4.1 A matching model of CEOs and firms

We now assume that different firms have different costs K of CEO dismissal (see Taylor (2010) for the empirical evidence). This cost can be viewed as a measure of (bad) governance. In general, corporate governance measures the extent to which the firm is managed in the interests of the providers of funds. In our model, the only relevant differences across firms are the estimated ability of the CEO at the beginning of the second period and the cost of CEO dismissal. Since all CEOs have the same expected ability ex-ante, the extent to which a firm can dismiss a CEO with low estimated ability at the beginning of the second period and hire a more able CEO or manager instead is therefore a measure of good governance. This is captured by the cost K. Accordingly, we will henceforth refer interchangeably to the cost of dismissal or to governance, bearing in mind that we consider corporate governance only insofar as it matters for involuntary CEO turnover.

We also assume that the ex-ante variance of CEO ability σ_a^2 differs across CEOs. As in the baseline model, there are no information asymmetries: for any given CEO, the value of

[13]Other matching models between managers and firms in the CEO compensation literature include Gabaix and Landier (2008), Edmans, Gabaix, and Landier (2009), and Acharya, Gabarro, and Volpin (2011).

σ_a^2 is common knowledge, but neither the firms nor the CEO observe a. We denote by $A_f = \{K_1, K_2, ...K_n\}$ the set of firms with $K_1 < K_2 < ... < K_n$. Likewise, we denote by $A_c = \{\sigma_1^2, \sigma_2^2, ..., \sigma_l^2, \sigma_{l+1}^2, ...\sigma_p^2\}$ the set which comprises l CEOs, with $a = \bar{a}$ and $\sigma_1^2 < \sigma_2^2 < ... < \sigma_l^2$, and $p - m$ managers, with $a = 0$ and $\sigma_k^2 = 0$ for $k > l$, where $l < n < p - l$.

Following Roth and Sotomayor (1989), the matching process can be defined as a matching function $\mu : A_f \cup A_c \to A_f \cup A_c$ such that $\mu(K_i) \in A_c \cup \{K_i\}$ for all K_i, $\mu(\sigma_i^2) \in A_f \cup \{\sigma_i^2\}$, for all $\sigma_i^2 \in A_c$, and $\mu(K_i) = \sigma_j^2$ if and only if $\mu\left(\sigma_j^2\right) = K_i$ for all $\left(K_i, \sigma_j^2\right) \in A_f \times A_c$. An equilibrium is defined by a matching function indicating which type of firm employs which type of manager in equilibrium, and equilibrium long-term contracts. A firm is unmatched if $\mu(K_i) = K_i$, similarly a CEO or manager is unmatched if $\mu(\sigma_i^2) = \sigma_i^2$

The first condition for equilibrium is that the matching function be consistent, i.e., each manager is matched with only one firm. The second condition is that no firm can break its match and improve its expected profit by proposing a contract to an already matched CEO (manager) that would prefer that contract. The model corresponds to a matching model with nontransferabilities, as studied in Legros and Newman (2007). They derive sufficient conditions on the Pareto frontiers generated by a match that ensure positive or negative assortative matching. In our setup, the equilibrium is characterized by negative assortative matching:

Proposition 5. Consider a matching μ associated with optimal contracts. This matching is stable if and only if the $n - l$ firms with the highest K are matched with managers, and there is negative assortative matching between the l CEOs and the l firms with the lowest Ks: $\mu(K_l) = \sigma_1^2$, $\mu(K_{l-1}) = \sigma_2^2$, ..., $\mu(K_1) = \sigma_l^2$.

The negative matching comes from the fact that, for any fixed set of reservation utilities, a negatively assorted matched firm-CEO pair will generate more surplus. The intuition is that a firm which can dismiss its CEO at a lower cost will be matched with a relatively more "risky" CEO. Clearly, it is more likely that the estimated ability of a more risky CEO (with

a higher σ_a^2) will fall below the firing threshold of any firm (which is necessarily negative). To minimize the costs of dismissals and the costs of inefficient continuation of CEOs with low ability, it is more efficient to match a risky CEO with a firm with a low K, i.e., a good corporate governance, according to our interpretation. Heterogeneity among firms and CEOs and the resulting matching equilibrium that we described has important implications, that we study in the next two subsections.

It is noteworthy that the link between pay-for-luck and poor corporate governance is created by the endogenous matching and not by the governance differences. For example, two firms with different Ks but with identical CEOs would offer identical compensation packages. However, in the stable matching equilibrium, these two different firms are matched with CEOs of different types that require different contracts.

The reservation utility of CEOs and the wages associated with their optimal contracts are determined in the equilibrium of the matching process. In particular, the wage of CEO σ_1 matched with with firm with cost K_l is such that if firm with cost K_{l+1} was to attract CEO σ_1, it would make zero profit, which the profit it gets by hiring a manager. This condition pins down the wage that firm K_l need to give to its CEO, and also determines the profits of that firm. The wage of CEO 2 and the profits of firm $l-1$ are similarly determined by the condition that firm l can not hire CEO 2 and make a profit higher than it gets by proposing the contract proposed to CEO 1 as determined previously.

4.2 Pay-for-luck and governance

The matching equilibrium and the associated contracts can explain the Bertrand and Mullainathan (2001) finding that firms with bad corporate governance use contracts that display more pay for luck. Indeed, firms with different types of governance design optimal long-term contracts for different types of CEOs. Consequently, it is in principle possible that the observed differences in CEO pay across firms with different types of governance are explained by differences in CEO characteristics. Specifically, in a matching equilibrium, firms with a higher cost

of CEO dismissal (or worse governance) are matched with CEOs whose ability is more precisely estimated ("safe CEOs"), i.e., with a lower σ_a^2. But we know from Proposition 4 that pay-for-luck is decreasing in σ_a^2. Therefore, the equilibrium is such that there is more pay-for-luck in firms with bad governance. The following Proposition makes this reasoning formal:

Proposition 6. (i) The second period reservation wage is relatively more sensitive to luck than to performance for CEOs whose ability is more precisely estimated ex-ante:

$$\frac{dw_2^\star(\hat{a}, L)}{dL} \Big/ \frac{dw_2^\star(\hat{a}, L)}{dV} \qquad \text{is (weakly) decreasing in } \sigma_a^2. \tag{16}$$

(ii) Firms with bad corporate governance offer contracts that display more pay-for-luck than firms with good corporate governance.

The higher the cost of CEO dismissal, the more a firm pays its CEO for luck rather than for performance.

To take an extreme example to develop the intuition, suppose that the ability of a given CEO is known: $\sigma_1^2 = 0$. Since $\hat{a} = \bar{a}$ with probability one, the second period reservation wage of this CEO is only contingent on future business conditions, or "luck" (L). On the contrary, the second period reservation wage of a CEO with an unknown ability ($\sigma_a^2 > 0$) depends both on future business conditions, and on the updated expected ability of this CEO following his performance in the first period. In the former case, all the variability in the second period pay of the CEO will be attributable to luck. In the latter case, it will be attributable both to luck and to the updating of beliefs on the CEO's ability. In a matching equilibrium, the first CEO will be hired by the firm with the highest cost of dismissal, and he will be exclusively paid for luck (firm performance net of luck is not informative about the CEO's ability, it is pure noise and will be filtered out of the contract). On the contrary, the other CEO will be paid both for luck and for performance.

4.3 Corporate governance spillovers

The matching model that we propose also generates corporate governance spillovers, whereby an improvement in governance in a subset of firms has spillover effects that increase CEO compensation in these firms and in firms with a better governance.

Proposition 7. If K_i diminishes for $i \in \{j, \ldots, n\}$, with $K_j \leq K_l$ without changing the ranking of firms on this dimension, then CEO compensation increases in the set of firms with cost of dismissal $\{K_1, \ldots, K_l\}$}.

In equilibrium, the expected profits of any given firm are constrained by the competition for CEOs. More precisely, the difference in expected profits between any given firm which employs a CEO and the next firm with a higher cost of CEO dismissal is increasing in the wedge in the cost of CEO dismissal between these two firms. Lower costs of CEO dismissal in a subset of firms reduce this wedge and therefore reduce expected profits in this subset of firms (except for firms which employ managers), and increase the compensation of their CEOs. It follows that these firms will be willing to bid higher to hire CEOs employed by firms with lower costs of CEO dismissals. In equilibrium, CEO pay must therefore increase in all firms with a better governance. In particular, an improvement in the quality of governance of badly governed firms (for example because of the widespread adoption of best practices) triggers an across-the-board increase in CEO pay.

This result can explain the fact that CEO pay rose as corporate governance improved in the U.S. (Holmstrom and Kaplan (2001), Murphy and Zabojnik (2004)). This fact is not explained by the skimming hypothesis, which would predict the opposite.

By contrast, it is noteworthy that a firm-specific change in K does not affect CEO pay in the firm in question. This is because $w_2^\star$ is not affected by K, while $w_1^\star$ is only affected by K to the extent that the reservation utility $\bar{U}$ of the CEO depends on K (because of (8), which is binding in equilibrium). But by definition, the reservation utility of the CEO is unrelated to firm-specific

factors, so that it does not depend on the cost of dismissal K of the firm. Incidentally, a model of managerial power would tend to make a different prediction. For example, in the model of Kuhnen and Zwiebel (2008), CEOs "receive further compensation for their entrenchment." Given that changes in governance are often either correlated with other factors or not firm-specific, the related empirical evidence is scarce. This said, Cunat, Gine, and Guadalupe (2012) identify a firm-specific exogenous shock to governance, and find that the effect on the level of CEO pay is statistically insignificant – even though the effects on other firm-specific variables are large. This is in line with the prediction of our model that CEO pay is unrelated to *firm-specific* corporate governance.

5 Other predictions and empirical implications

In this section, we confront other predictions of the model to further empirical evidence.

Bertrand and Mullainathan (2001) find that "governance correlates very little with pay for performance, only with pay for luck."[14] This is also predicted by our model. Indeed, the sensitivity of pay-for-performance to σ_a^2 is zero, while the sensitivity of pay-for-luck to σ_a^2 is proportional to the sensitivity of η to σ_a^2, which is strictly negative. That is, the model does not predict any cross-sectional variation in pay-for-performance across firm-CEO matches.

Even though we do not explicitly derive predictions on this dimension in our simple two-period model, there are reasons to believe that σ_a^2 will decrease over the tenure of a CEO, as his ability becomes more precisely estimated. An implicit prediction of our model is therefore that pay-for-luck should increase with CEO tenure. This is all the more interesting that Bertrand and Mullainathan derive a similar prediction with the skimming model: their hypothesis is that CEOs with a longer tenure are more entrenched, so that they can extract more monetary benefits in the form of asymmetric pay-for-luck. In addition, the variance of CEO ability is not related

[14] As discussed in section 4, governance in our model is related to the cost of CEO dismissal, and the measures of governance used in Bertrand and Mullainathan (2001) can also be viewed as measures of the cost of CEO dismissal.

to pay-for-performance in our model, so that we expect no relationship between tenure and pay-for-performance. As is made clear in Bertrand and Mullainathan, the data suggest that there is indeed a positive relationship between tenure and pay-for-luck, but no relationship between tenure and pay-for-performance.[15] These two predictions, which are empirically validated, are common to the skimming hypothesis and the efficient contracting model.

This being said, Bertrand and Mullainathan also find that the positive relationship between tenure and pay-for-luck holds only for firms without a large shareholder on the board (with a large shareholder on the board, the relationship is not statistically significant). The skimming hypothesis can explain this, whereas our model of efficient contracting cannot.[16]

The model does not generate any cross-sectional prediction regarding the frequency of firm-CEO separations depending on a measure of corporate governance. On the one hand, firms with bad corporate governance will tend to hire CEOs with a more precisely estimated ability, which tends to reduce bad surprises and the associated forced turnover. On the other hand, CEOs whose ability is more precisely estimated may be older, and therefore closer to retirement, which tends to increase voluntary turnover. A priori, it is not clear which effect will dominate, which can explain why Kaplan and Minton (2012) find no statistically significant relationship between CEO turnover and corporate governance in the cross-section. On the contrary, with an across-the-board improvement in governance which leaves the ranking of firms on this dimension unchanged, there is no sorting effect. Therefore, only the direct effect of a lower dismissal cost on the probability of dismissal operates, and the model predicts that an across-the-board improvement in governance leads to more forced CEO turnover. This is again consistent with

[15]Garvey and Milbourn (2003) also find that relative performance evaluation, which consists in filtering out one type of exogenous shock, namely the market index, is stronger for younger CEOs. They interpret this finding as evidence that firms tend to let older (and more wealthy) CEOs hedge against market fluctuations themselves, since they are better able to do so than young CEOs.

[16]Obviously, this does not mean that no model of efficient contracting can explain this feature of the data. For example, the model of CEO discretion of Gromb, Burkart and Panunzi (1997) predicts that a CEO who is less monitored by shareholders (which will typically be the case with a large shareholder on the board) will take more initiatives. On the contrary, a CEO who is closely monitored by shareholders will tend to manage the firm more conservatively. All else equal, this suggests that the updating on CEO ability will tend to be much faster in the former case: this model would thus predict a stronger (positive) relationship between tenure and pay-for-luck for firms with a large shareholder on the board.

the evidence in Kaplan and Minton (2012).

According to Frydman (2007) and Frydman and Saks (2010), CEO pay was stable and pay dispersion across executives was low from the 1930s to the 1970s, which was not the case in the following decades. The predictions of our model are consistent with these patterns. Indeed, firm-specific skills predominantly mattered in the past, i.e., γ was low, while general skills have become more useful in the last couple of decades, so that γ increased (Frydman (2007)). In our model, with a low γ, CEO skills are not easily transferable, and the market for CEOs is such that CEO pay is largely unresponsive to CEO performance. That is, CEO pay is relatively stable over time. If in addition there is not much dispersion in the *expected* ability of CEOs ex-ante (i.e., before their performances are realized), then the dispersion of CEO pay across firms will be low. Note that this is true even if the *actual* dispersion of abilities across CEOs is important and is at least partly learned ex-interim. This is because the first period wage $w_1^\star$ depends on the expected CEO ability $\bar{a}$, while the second period wage will deviate from this level only to the extent that γ is substantial.[17]

6 Conclusion

This paper proposes a principal-agent model of efficient contracting which focuses on the implications of changes in the market value of CEOs for their compensation base and the functional form relating their performance to their compensation. It can explain the use of stock-options in managerial compensation, and the main empirical regularities associated with the pay-for-luck phenomenon. In particular, CEO pay is downward rigid and pay-for-luck is asymmetric because of the insurance given by the firm to a risk-averse CEO. In addition, when the cost of CEO dismissal varies across firms and the abilities of different CEOs are more or less precisely estimated ex-ante, the equilibrium matching between CEOs and firms is such that pay-for-luck is

[17]Note that Murphy and Zabojnik (2004) and Frydman (2007) relate the increase in the relative importance of general skills to the level of CEO pay and CEO turnover, whereas our model also relates it to the structure of CEO compensation (as shown in section 3, a higher γ is associated with more stock-options) and the pay-performance sensitivity (which is increasing in γ).

relatively more important in firms with a high cost of CEO dismissal, which can be interpreted as an indicator of bad governance. We also find that an improvement in the governance of badly governed firms will have spillover effects that increase CEO pay in all firms. Our results contribute to a large recent literature which shows that the efficient contracting paradigm can actually explain a number of apparent anomalies (Edmans and Gabaix (2009)). The predictions of the model on a variety of dimensions are broadly consistent with the existing empirical evidence, but future work could specifically test some new hypotheses.

We do not claim that our model integrates all the factors which are relevant for CEO compensation. In particular, we ignored the incentives aspect of the problem. This said, the ability of the model to explain many important stylized facts suggests that the often overlooked retention motive might be an important determinant of the structure (not just the level) of CEO compensation. Given that matching models can explain important features of CEO compensation, future work could build on this and other contributions (e.g., Gabaix and Landier (2008)) to develop a unified model of CEO pay which jointly explains the level and the structure of CEO compensation. This would enable us to better understand how the interplay between competition and retention affects optimal compensation schemes.

7 References

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8 Appendix

Proof of proposition 1

The optimal long-term contract solves the following optimization problem:

$$\min_{\langle w_1, w_2(\hat{a},L)\rangle} w_1 + \int\int w_2(x,y) dF_{\hat{a}}(x)\, dG(y) \tag{17}$$

$$w_2(\hat{a}, L) \geq W_2(\hat{a}, L) \qquad \text{for all } \hat{a}, L \tag{18}$$

$$u(w_1) + \int\int w_2(x,y) dF_{\hat{a}}(x)\, dG(y) \geq \bar{U} \tag{19}$$

where $\bar{U}$ denotes the reservation level of utility of the CEO over two periods at the beginning of the first period.

The first-order conditions with respect to w_1 and $w_2(\hat{a}, L)$ are respectively:

$$1 - \mu u'(w_1) = 0 \tag{20}$$

$$1 - \lambda(\hat{a}, L) / \left(f_{\hat{a}}(\hat{a})\, g(L)\right) - \mu u'(w_2(\hat{a}, L)) = 0 \qquad \text{for all } \hat{a}, L, \tag{21}$$

where $\lambda(\hat{a}, L)$ and μ are respectively the (nonnegative) Lagrange multipliers associated with the constraints (18) and (19), where $\lambda(\hat{a}, L) \geq 0$ satisfy the complementary slackness condition:

$$\lambda(\hat{a}, L)(W_2(\hat{a}, L) - w_2(\hat{a}, L)) = 0 \qquad \text{for all } \hat{a}, L. \tag{22}$$

Since the second-order conditions for minimization are satisfied, this immediately yields the form of the optimal long-term contract. The second period wage is equal to the reservation wage if the reservation wage is larger than the first-period wage or, it is equal to the first-period wage.■

Proof of Proposition 4:

The comparative static results follow immediately from the performance measure P and the

optimal contract as defined in proposition 3.

Proof of Proposition 5:

We will use the condition in proposition1-ii in Legros and Newman (2007) to prove that a stable matching satisfies Negative Assortative Matching (NAM), that is firms with better corporate governance match with riskier CEOs.

For that consider two firms with firing costs $K > K^{'}$ and two CEOs indexed by risk $\sigma^2 < \sigma^{'2}$.

Consider the long term contracts offered by the firm with high costs of firing to both types of CEOs that lead to the same profit for the firm. To prove NAM, we just need to show that if the firm with low firing cost proposes long term optimal contracts to the CEOs that give them as much as the contracts proposed by the high cost firm, it would make larger profits when it proposes a contract to the risky CEO.

First, note that the expected utility of a CEO for a given long term contract depends only on w_1^*. This means that the low cost firm would propose the same long term contract as the high cost firm if it needs to ensure the same expected utility to the CEO.

The CEO is fired if the estimated ability of the current CEO is too low compared to the average ability of a new CEO. The dismissal condition is: $\hat{a} \leq -K/L$.

The extra profit of a firm with low dismissal costs that proposes the same contract as a firm with high firing costs is thus given by $\left(K - K^{'}\right) > 0$ when $\hat{a} < -K/L$ and is equal to $\left(\hat{a}/L - K^{'}\right) \geq 0$ when $-K/L \leq \hat{a} \leq -K^{'}/L$. When $\sigma^2 < \sigma^{'2}$, we have that $\Phi_{\sigma}\left(-K^{'}/L\right) > \Phi_{\sigma^{'}}\left(-K^{'}/L\right)$ for $a < \bar{a}$. Given that $-K^{'}/L < \bar{a}$, and that $\Phi_{\sigma}\left(-K/L\right)$ increases as σ^2 increases, we get the result of negative assortative matching integrating over L. ■

Proof of Proposition 6:

(i)Either $W_2 < w_1^*$, in which case $\frac{dw_2}{dL} = 0$ and $\frac{dw_2}{dV} = 0$, so that $\frac{\frac{dw_2}{dL}}{\frac{dw_2}{dV}}$ is independent of σ_a^2. Or $W_2 \geq w_1^*$, in which case $\frac{dw_2}{dL} = \psi\eta$ and $\frac{dw_2}{dV} = \psi$, so that $\frac{\frac{dw_2}{dL}}{\frac{dw_2}{dV}} = \eta$, which is positive and decreasing in σ_a^2.

(ii) is a direct consequence of the negative matching and (i).■

Proof of Proposition 7:

Suppose that the ranking of costs of dismissals at different firms is such that $K_1 < K_2 < \ldots < K_l < \ldots < K_n$. Likewise, suppose that the ranking of CEOs is such that $\sigma_1 < \sigma_2 < \ldots < \sigma_l$.

According to proposition 5, firm l is matched with CEO 1, firm $l - i$ is matched is with CEO i, and firm 1 is matched with CEO l. We consider a decrease in the firing costs K_n to K_j, $(j < l)$ with no change in the order of firms. This means that the matching after the decrease in cost will remain unchanged.

Consider firm l. Before the changes in cost, the contract it was offering to its CEO was designed in order to make firm $l+1$ indifferent between attracting CEO 1 and hiring a manager, that is to ensure that firm $l+1$ would make negative expected profit by giving a better offer to CEO 1. Similarly, the contract of CEO 2 offered by firm $l-1$ is designed so that firm l makes the same expected profit with the optimal contract it offers CEO 1 and the expected profit it would make by attracting CEO 2.

When K_j decreases, the firing rule of firm j changes independently of the contracts and firm j's profit increases. As in the proof of proposition 5, this increase in expected profit is larger when the firm employs a CEO with higher σ.

Consider again the situation of firm l. Since the firing cost of firm $l+1$ has decreased, it needs to increase the wage it offers its CEO to make sure firm $l+1$ is still indifferent between hiring a manager or competing for CEO 1. So, firm l's cost of firing has decreased, which increases its expected profit relatively more when its employs riskier CEOs, and the wage it offers CEO 1 has increased to react to the competition of firm $l+1$. These two facts make it more attractive for firm l to try to compete for CEO 2 relative to CEO 1. In response, firm $l-1$ needs to adjust the contract it offers to CEO 2 by increasing the first-period wage of its CEO to make sure that firm l can not attract CEO 2. We can see that this process leads to an increase in the wage of all CEOs to maintain the negative matching.