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Internal versus External CEO Choice and the Structure of Compensation Contracts

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Abstract

Any firm choosing a chief executive officer (CEO) faces a double problem: candidate selection and choice of a compensation scheme. We derive sufficient conditions where the unique optimal compensation scheme is a capped-bonus contract in a pure moral-hazard environment, while equity is used when the firm also faces adverse selection. Then, we provide a rationale for the simultaneous increases in CEO pay, use of equity in compensation, and external hiring of CEOs. Our results are consistent with empirical evidence that shows externally hired CEOs earn more than those internally hired and that externally hired CEOs get a higher fraction of their compensation equity based.

I. Introduction

The dramatic and unprecedented increase in chief executive officer (CEO) pay in the 1980s and 1990s (see Frydman (2007), Gabaix and Landier (2008)) led to questioning of the efficiency of CEO compensation packages. Following Jensen and Murphy's (1990) seminal paper, the debate concentrated first on the pay-performance sensitivity and then moved to the compensation level, given the observed widening gap between the pay level of executive officers and other employees.

However, another important change regarding CEOs took place over the same period: their working experience prior to being appointed as a CEO. Increasingly, boards of directors have hired CEOs from outside their firm, while in the 1960s and 1970s internal promotion was the standard. For example, in their long-run study of CEO turnover in the United States, Huson, Parrino, and Starks (2001) provide evidence that over the 1971–1976 period, only 15.3% of appointed

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CEOs were outsiders, while this proportion had reached 30% between the 1989–1994 period.

Two types of explanations have been proposed for this evolution in CEO appointment. First, improvement in corporate governance led to the evolution of the composition of boards of directors, outside directors being increasingly represented (see Huson et al. (2001), Hermalin (2005)). Second, the evolution of the economic environment influenced the type of skills required for the CEO job (Murphy and Zabojnik (2004), (2007), Frydman (2007)). In the words of Murphy and Zabojnik ((2004), p. 193), "Over the past three decades, general managerial skills (i.e., the skills transferable across companies, or even industries) became relatively more important for the CEO job, perhaps as a result of the steady progress in economics, management science, accounting, finance, and other disciplines which, if mastered by a CEO, can substantially improve his ability to manage any company."

In this paper, we propose a model of CEO choice that provides a rationale for the simultaneous increases in i) CEO pay, ii) use of equity in compensation schemes, and iii) hiring of CEOs externally, as a result of the evolution of the type of skills required for a CEO position.

Our model extends the current literature in the following way: Articles that have studied changes in CEO appointment also looked at the consequences on CEO pay *level* but ignored changes in the *structure* of the compensation contracts (see Hermalin (2005)). Conversely, articles that studied the evolution of pay levels and the structure of compensation contracts (see Edmans, Gabaix, and Landier (2009) and Edmans and Gabaix (2011) for recent contributions) did not address internal versus external hires. This paper aims to fill the gap between these two sets of articles.

Formally, we study a standard principal-agent model in which the risk-neutral shareholders of a firm need to appoint a new CEO, also assumed to be risk neutral. Managing a firm requires both firm-specific and general skills, and in each type, a manager is either high-skilled or low-skilled. Moreover, the CEO can exert one of two unobservable efforts. The firm runs projects, and higher skills translate into first-order stochastic dominance (FOSD) of the probability distribution of project values when a high effort is exerted. Two types of candidates are considered for the CEO position: an internal candidate with perfectly known skills and an external candidate with an unknown level of firm-specific skills.

We do not impose any cash constraint on the side of the principal. The only restrictions placed on the contract space are that the CEO has limited liability and contracts must be nondecreasing.[1] We allow for cash incentive functions of any shape and any type of equity-based compensation as long as the total reward remains above the limited liability level and is nondecreasing in performances.

First, we compare the contracts offered to internal and external candidates. The firm faces a pure moral-hazard problem when considering an internal candidate. We derive conditions under which the optimal contract is *uniquely* a capped-bonus contract. By this we mean, a contract such that the compensation is flat

[1] In this respect, we follow Innes (1990) or Palomino and Prat (2003).

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(i.e., independent of the performance) below a first threshold, and above a second threshold the compensation is also flat.

When considering external candidates, due to the asymmetric information about their firm-specific skills, the shareholders face both moral-hazard and adverse-selection problems. We derive (sufficient) conditions under which it is optimal for the principal to offer equity (stocks or stock options) as part of the optimal contractual arrangement, even if optimal contracts are uniquely capped-bonus contracts in the pure moral-hazard case. Formally, the firm offers a menu of contracts, one of them including equity, the other being a pure capped-bonus contract. A high-skill agent selects the contract with equity, while a low-skill agent selects the pure capped-bonus contract.

Equity is never an optimal compensation tool in the pure moral-hazard case, while it is a component of an optimal compensation package if the firm also faces adverse selection. This is because in a pure moral-hazard case, whatever the quality of the agent, the principal aims at providing incentives to exert effort at the lowest possible cost. Given our assumption of nondecreasing compensation, it is then optimal for the principal to provide salary increases only at firm-value levels for which the likelihood that effort has been exerted is the highest. If a very high output is more likely to be due to luck rather than very high effort, and so additional rewards should not be given,[2] there exists a firm value beyond which compensation is flat (as a function of the firm value). Hence, the unique optimal contract is a capped-bonus contract.

When the firm also faces adverse selection, the situation is different. FOSD implies that any contract such that a low-skill agent exerts effort implies that a high-skill agent also exerts effort. Therefore, the principal looks for the cheapest contract that achieves effort exertion by *both* types of agents. As in the pure moral-hazard case, this is achieved with a capped-bonus contract. However, FOSD also implies that there is room for the design of compensation contracts composed of equity (either stocks or options) that i) give the same expected compensation to a high-skill agent as the above-mentioned bonus contract and ii) is not chosen by a low-skill agent (hence implying that the adverse-selection constraints for the low-skill agent are satisfied).

Finally, we study the conditions under which one type of equity (stocks or options) can be used for pure-equity compensation. In general, for given performance probability distributions (with high or low skills), the larger the difference in expected compensation generated by skills for a given pure-equity contract, the more likely it is that this contract is an equilibrium contract. Option-based contracts are then more likely to be optimal contracts than pure stock-based contracts, given the additional flexibility provided by the choice of the exercise price in the design of the performance-compensation relationship.

Then, turning to the optimal CEO choice, we show that as the importance of general skills increases relative to firm-specific skills, the hiring of external candidates increases, and so does the use of equity in compensation contracts and the average CEO compensation level. The rationale for this result is the

[2] A very high output is more likely to be due to luck rather than effort if the optimal effort is capped and the monotone likelihood ratio property (MLRP) does not hold.

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following: First, when hiring an external candidate, the firm faces additional constraints (i.e., adverse-selection constraints). As a consequence of these additional constraints, the firm must leave some extra informational rent to an externally hired CEO in order to reach the same effort level.[3] Hence, externally hired CEOs receive higher compensation than internally hired ones. However, as the economic environment evolves from one in which firm-specific skills dominate to one in which general skills dominate, recruiting an outsider becomes more profitable, relative to an internal candidate, in terms of expected project cash flows. If this additional value generated by an external candidate exceeds the extra cost, then i) external candidates are hired. As a consequence, ii) equity is used in compensation contracts, and iii) the compensation level of CEOs increases.

Not only do our results provide a rationale for the simultaneous increases in CEO pay, use of equity in compensation contracts, and external hiring of CEOs; they are also consistent with several other pieces of empirical evidence. First, our results concerning the presence of both cash bonuses and equity in optimal compensation schemes are consistent with empirical evidence provided by Murphy (1999) and with studies released by consultancies showing that in some countries, cash bonuses are an important component of variable pay (see Table 1). Second, the result concerning higher compensation levels for externally hired CEOs is consistent with the results of Murphy and Zabojnik (2007), who document that the premium for external hires is about 15.3%. Third, the result that equity is only used in contracts for external agents is consistent with the empirical evidence provided by Gillan, Hartzell, and Parrino (2009), who show that externally hired CEOs have a higher fraction of their total remuneration that is stock based.

TABLE 1

Variable Pay as a Percentage of Annual Basic Compensation for CEOs Worldwide

Source: Towers Perrin's *Worldwide Total Remuneration Report 2005–2006*.

	1998		2005	
Country	Bonus	Equity	Bonus	Equity
Argentina	32	16	39	32
Australia	30	4	32	16
Belgium	27	8	40	30
Canada	35	28	50	85
China (Hong-Kong)	29	24	37	14
France	19	30	36	66
Germany	27	0	90	50
Italy	30	11	35	50
Japan	16	0	14	25
Mexico	26	2	42	39
Netherlands	24	17	55	40
Singapore	36	22	32	123
Spain	28	0	44	40
Sweden	20	0	25	20
Switzerland	28	6	50	65
United Kingdom	22	38	30	50
United States	39	97	51	171

[3]Formally, this is due to the fact that the adverse-selection constraints are not satisfied at the optimal contract for a low-quality agent in the pure moral-hazard case.

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The organization of this paper is as follows: Section II reviews the related literature. Section III presents the model. In Section IV, we derive the optimal contract for the internal candidate in a pure moral-hazard environment. In Section V, we turn to the derivation of the optimal contract for an external candidate, hence considering a setting in which the principal faces both moral-hazard and adverse-selection problems. Section VI studies the optimal CEO choice and how a change in the economic environment in which the firm operates may change the structure and level of CEO pay. Finally, Section VII concludes. All proofs are in the Appendix.

II. Related Literature

Our article is related to two aspects of CEO compensation that have often been studied separately. First, the optimal structure of CEO compensation, which deals with pay-performance sensitivity, and second, the level of CEO compensation. In a principal-agent framework, the first issue is related to incentive compatibility (IC) constraints, while the second issue is related to participation and limited liability constraints.

A. Optimal Structure for CEO Compensation Packages

Innes (1990) establishes the optimality of bonus contracts in the context of a principal-agent problem with moral hazard on effort and limited liability.

Then, focusing on efficiency, Park (1995) and Kim (1997) show, in a pure moral-hazard setting, that a discrete bonus associated to a performance standard may lead to first-best agent effort.[4] Oyer (2000) extends the result of Park (1995) and Kim (1997) and shows that, when the participation constraints are not binding, a bonus scheme can be preferable to any other mechanism. Our article extends Oyer's result to a heterogeneous-agent framework with adverse selection on the side of the principal.

Lazear (2000) compares equity and bonus plans as compensation devices in the presence of heterogeneous agents. He derives conditions under which equity is an optimal selection device. The main difference between Lazear's analysis and ours is that Lazear considers a unique contract for both types of agents, whereas we assume that the principal is allowed to offer a menu of contracts. Moreover, we show that mixing a bonus plan and equity can be an optimal strategy for a firm.

The preference for equity with respect to bonus plans has also been established by Dittmann and Yu (2009), who show that when the principal wishes to provide a risk-averse agent with risk-taking and effort incentives, an optimal contract can be obtained with a base salary, stocks, and options awarded in the money. In the same vein, Edmans and Gabaix (2011) show that if value-enhancing actions undertaken by the CEO also increase firm risk, the optimal contract is convex

[4]The optimality of bonuses in compensation packages is also derived by Holmström and Tirole (1993). However, their definition of a bonus is different from ours. In their model, a bonus is a fixed share of the short-run profit, independent of the profit level. In particular, it means that this bonus i) can be negative (when the firm has made losses) and ii) is not capped.

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(i.e., contains stock options). Our model differs from those of Dittmann and Yu (2009) and Edmans and Gabaix (2011) in that it does not feature risk-taking incentives.

Adopting a behavioral perspective, Hall and Liebman (1998) suggest that stock options are preferred to bonus plans because they are "a less visible vehicle for paying CEO than salary and bonuses." Our model differs from Hall and Liebman's approach, as we consider fully rational agents.

Another large body of literature focuses on the efficiency of stock-option plans relative to restricted stock plans. The common feature of most of these articles is that they focus on the standard insurance-incentive trade-off; that is, they study under what conditions stock options are more efficient than stocks at providing effort incentives at minimum risk in a pure moral-hazard setting (see, e.g., Dittmann and Maug (2007)). Furthermore, the contracting space is often restricted to equity-based incentive tools and, therefore, bonus contracts are ruled out by assumption (Aseff and Santos (2005), Dittmann and Maug (2007), Choe (2006), Armstrong, Larcker, and Su (2010), Kadan and Swinkels (2008), and Stoughton and Wong (2009)).

Some authors use alternative frameworks to provide a rationale for the use of stock options rather than stocks. O'Reilly, Crystal, and Main (1988) and Bebchuk and Fried (2003) consider that agents have rent-seeking concerns. De Meza and Webb (2007) and Dittmann, Maug, and Spalt (2010) show that stock options can be optimal if CEOs exhibit loss aversion. Finally, Oyer (2004) and Oyer and Schaefer (2005) advocate that granting stock options is a way of attracting optimistic managers.

Our article offers a different perspective. First, we assume that agents are fully rational (unlike the above-mentioned behavioral models). Second, we assume that managers are heterogeneous and that firms suffer from a lack of information regarding managers' abilities. Hence, by allowing for *both* adverse selection and moral hazard, we show that several types of compensation packages may coexist in equilibrium, some of them being pure capped-bonus contracts, others being either pure-equity contracts (either options or stocks) or mixing bonus and equity. Moreover, we show that, among pure-equity contracts, pure option contracts are more likely to be equilibrium contracts relative to pure stock contracts. This is due to the fact that options offer more flexibility in the design of the contract (thanks to the choice of the exercise price) and are more likely to satisfy both the IC and adverse-selection constraints of the maximization problem.

B. On Compensation Levels

As evidence provided by Frydman and Saks (2010) shows, CEO compensation was almost flat between the end of World War II and the mid-1970s. It then rose dramatically in the 1980s and 1990s. Much of the debate on the efficiency of CEO compensation was then fueled by the observed pay raise in this latter period. Several explanations have been offered for this increase in CEO compensation.

Murphy and Zabojnik (2004), (2007) and Frydman (2007) suggest that the transformation of the environment in which firms operate increased the value of general skills relative to firm-specific skills. As a consequence, competition

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between firms to hire the most talented agents increased, leading to increases in the external filling of CEO vacancies and in the compensation of agents with the highest general skills.

Our model borrows from these articles, since our starting point is that firm-specific and general skills are required to run a firm. Additionally, a shift in the relative importance of those two types of skills occurred in the recent past, as general skills have become more important. However, there are two main differences between our model and those of Murphy and Zabojnik (2004), (2007) and Frydman (2007). First, in our model, agents' bargaining power does not increase as the shift occurs. Still, we find that CEO compensation increases as the external hiring of CEOs increases. Second, we also study the *structure* of the compensation contract and show that the external hiring of CEOs is accompanied by the use of equity in compensation contracts.

Hermalin (2005) studies how CEO monitoring by boards of directors influences CEO appointment (i.e., internally vs. externally) and compensation levels. He shows that through greater board diligence, more external candidates become CEOs, tenure durations shorten, and compensation levels increase. The main difference between Hermalin's article and ours is that when studying compensation schemes, we assume that the firm faces both moral hazard and adverse selection.[5] The results in our model show that the optimal contract is performance based. As a consequence, we can study the structure of the compensation contract and show that several types of compensation tools are used in equilibrium.

Our results are also related to those of Giannetti (2011), who studies the compensation contract offered to a CEO who may have incentive to develop either firm-specific skills or general skills, with this latter type of skills increasing the probability of being offered a job in another company. One of the main findings is that it can be optimal to offer unrestricted stocks or stock options (rather than restricted stocks) to a manager with strong incentives to acquire general skills. However, only equity-based contracts are considered in Giannetti's model.

Gabaix and Landier (2008) consider a model in which CEOs have different levels of managerial talent and are matched to firms competitively. They show that CEO equilibrium pay increases with both the size of their firm and the size of the average firm in the economy. Edmans et al. (2009) and Edmans and Gabaix (2011) extend this work by considering the structure of the compensation contract, CEOs being risk neutral in the former article and risk averse in the latter. If CEOs are risk neutral, then, as in Gabaix and Landier's paper, the total pay level is determined by the agent's marginal productivity. Hence, pay levels are entirely determined by talent, not by incentive considerations, which only affect the division of total pay into cash and stock components. Conversely, if CEOs are risk averse, incentive considerations influence both the pay level and the pay structure. One of the main differences between these three models and ours is that they assume firms have perfect information about CEO candidates' skills, while we assume there is asymmetric information about the quality of an external CEO candidate. As a consequence, in the models of Gabaix and Landier (2008), Edmans et al. (2009),

[5] In Hermalin (2005), the CEO receives a flat wage determined only by the participation constraint being binding.

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and Edmans and Gabaix (2011), the choice between appointing an outsider or an insider as CEO is not an issue.

Finally, another argument put forward for the increase in CEO pay is entrenchment: CEOs use captive boards of directors to deal themselves large increases in pay at the expense of shareholders (see Bebchuk and Fried (2003)). As already mentioned, our model does not rely on CEO bargaining power. In our model, CEOs extract rents only through asymmetric information (either about their action or skill levels).

III. The Model

We consider a principal-agent model building upon the models of Murphy and Zabojnik (2004), (2007), Frydman (2007), and Hermalin (2005).

The Firm. Risk-neutral shareholders of a firm (the principal) delegate its management to a CEO (the agent).[6] This management requires two types of skills: general skills that are transferable across firms and firm-specific skills that are not transferable. In each type of skills, an agent is either high-skilled (H) or low-skilled (L). An agent is then described by a pair $(i,j) \in \{H,L\} \times \{H,L\}$, i and j corresponding to general and firm-specific skills, respectively.

The firm has one ongoing project in which value v is the realization of a random variable $\tilde{v}$ and belongs to an interval $[\underline{v}, \bar{v})$, where $\underline{v} \geq 0$ and $\bar{v}$ could be $+\infty$.

The probability distribution of $\tilde{v}$ depends on the magnitude of the effort $e \in \{e_l, e_h\}$ exerted by the agent and his skill levels. Whenever the agent exerts a low effort ($e = e_l$), the probability distribution of $\tilde{v}$ is $Q(\cdot)$, independently of the skills of the agent. In contrast, when a high effort is exerted by the agent ($e = e_h$), the probability distribution of $\tilde{v}$ is type dependent. For an agent of type (i,j) choosing $e = e_h$, the probability distribution of $\tilde{v}$ is $P_{ij}(\cdot)$. Exerting a high effort e_h involves a nonpecuniary cost c, whereas a low effort (e_l) is costless. We denote $p_{ij}(\cdot)$ and $q(\cdot)$ the probability densities associated to $P_{ij}(\cdot)$ and $Q(\cdot)$, respectively (i.e., $P_{ij}(w) = \int_{\underline{v}}^{w} p_{ij}(v)dv$ and $Q(w) = \int_{\underline{v}}^{w} q(v)dv$). We also denote $\mathrm{E}_{ij}(v|e_h)$ the expected value generated by agent of type (i,j) when an effort is exerted and $\mathrm{E}(v|e_l)$ the expected value generated by any type of agents when a low effort is exerted. Probability distributions and expected values are assumed to be continuously differentiable and finite, respectively. The value of the firm is then defined as being the value of the project net of compensation expenses.

We make the following assumptions regarding the probability distributions:

Assumption 1. The probability distributions when exerting a high effort (P_{ij}, $i,j = H,L$) dominate the probability distribution when exerting a low effort (Q) in the sense of FOSD.

Assumption 2. The probability distributions P_{Hj} and P_{iH} $(i,j = H,L)$ dominate the probability distributions P_{Lj} and P_{iL}, in the sense of FOSD, respectively.

[6] Shareholders are taken to be investors with funding but without either the time or the skills to run the firm.

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Finally, we define the function

$$CLR_{ij}(v) \equiv 1 - \frac{1 - Q(v)}{1 - P_{ij}(v)} \tag{1}$$

as the "cumulated" likelihood ratio (CLR) function. It defines the relative incremental probability that an agent of type (i,j) reaches at least a project value v when exerting a high level of effort rather than a low one. As discussed later, the CLR function will play an important role in our analysis, since we do not restrict our attention to families of probability distributions satisfying the MLRP.

CEO Candidates. There are two types of candidates: insiders (or internal candidates), who are either current or former employees of the firm; and outsiders (or external candidates), who have never been employees of the firm. All candidates are risk neutral with a reservation utility normalized to 0.

The information of the shareholders about candidates' skills depends on whether they are insiders or outsiders. If the candidate is an insider, shareholders have perfect knowledge of both her firm-specific and general skills. Conversely, if considering an outsider, shareholders have perfect knowledge of the general skills of the candidate, but not about her firm-specific skills. Shareholders believe that the candidate has high firm-specific skills with probability $\theta \in (0,1)$, and low firm-specific skills with probability $1-\theta$.

We additionally assume that there is a large pool of outsiders so that the firm can always find a candidate with a high level of general skills. Therefore, external candidates considered by the firm are of quality (H,H), with probability θ, and of quality (H,L), with probability $1-\theta$. In a symmetric way, we assume that there is always an internal candidate with high firm-specific skills, so that the internal candidate is either of type (H,H) or (L,H).

On their side, candidates are assumed to have perfect knowledge of their own skills. This assumption may seem extreme, in particular that external candidates have perfect knowledge of their level of firm-specific skills. However, our results still hold as long as outsiders are better informed than the shareholders about their skills.[7]

The Contracts. Though the effort exerted by a CEO is not observable, the realized project value is observed. Therefore, the effort level chosen by the appointed CEO can be influenced by the compensation contract he is offered. Assuming that CEOs have limited liability normalized here at 0, a compensation contract is then defined as a mapping $t(\cdot)$ from $[\underline{v},\bar{v})$ to $[0,+\infty)$ that specifies the transfer $t(v)$ the CEO receives if the project value v is realized.

Following Innes (1990) and Palomino and Prat (2003), we impose that the reward scheme be nondecreasing in outcome. The reason for this assumption is that whenever the contract is nonmonotonic and the realized performance falls in a subset of performance levels for which the compensation scheme is decreasing, the manager has incentives to sabotage performance.[8] Implicitly, it entails that

[7] In a situation in which firm-specific skills are acquired on the job, external candidates know better than the shareholders whether they are fast or slow learners. Our model describes the case in which a fast learner acquires firm-specific skills immediately, while a slow learner never does.

[8] See Innes (1990) for more on reward schemes.

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the manager can manipulate the value of the project downward at no personal cost. Considering that the reward scheme must be nondecreasing eliminates such concerns for manipulation. Finally, we also make the technical assumption that a feasible contract has a finite number of discontinuities.[9]

Before entering the core of the analysis, we define the following structures of contracts.

Definition 1.

i) A k-step bonus contract $B(X_1, \ldots, X_k, t_1, \ldots, t_k)$ is defined by k different value thresholds $(v_1, v_2, \ldots, v_k)$ (with $\underline{v} < v_1 < \cdots < v_k < \bar{v}$) and $k+1$ different functions $t_1(\cdot), t_2(\cdot), \ldots, t_{k+1}(\cdot)$ such that, for all $i \in \{1, \ldots, k+1\}$, if a project value v is realized, then the agent receives

$$\begin{cases} t_1(v) = a_1, & \text{if} \quad v_0 \leq v < v_1, \\ t_{i+1}(v) = t_i(v_i) + a_{i+1} + b_{i+1}v, & \text{if} \quad v_i \leq v < v_{i+1}, \\ t_{k+1}(v) = t_k(v_k) + a_{k+1}, & \text{if} \quad v \geq v_k, \end{cases}$$

with $a_i \geq 0$ and $b_i \geq 0$.

ii) An option contract $O(\hat{v}, \beta)$ is defined by an exercise price $\hat{v} \geq \underline{v}$ and a payoff $\beta(v - \hat{v})$ if the project value $v \geq \hat{v}$ is realized, and 0 otherwise.

iii) A contract of stocks $S(\alpha)$ is defined by an attribution of a stake α of the project for the agent generating a payoff αv if the project value v is realized.

The main differences between the three types of contract can be described as follows: Whenever it is based on stocks, the compensation increases linearly with the performance. Under an option contract, there exists a threshold (the exercise price) below which the agent receives no monetary reward and above which the compensation increases linearly with the firm's value. Finally, bonus contracts are characterized by several thresholds. Below the lowest threshold and above the highest, compensation is flat.[10] In the interval between the lowest and the highest thresholds (usually called the incentive zone), the compensation increases (weakly) in performance. Hence, the main difference between an equity grant (either stock or stock options) and a bonus contract is that the latter is characterized by a threshold beyond which the compensation is flat, which is never the case under equity grants.

The Objective of the Shareholders. Shareholders aim at maximizing the value of the firm (i.e., the value of the project net of compensation expenses) under the constraint that the CEO chooses a high effort level.[11]

It has often been advocated that, in the case of top executives, the main concern is not to provide incentives for effort but rather for making proper decisions. Our model can then describe a situation in which the CEO is someone who has

[9] This ensures that the compensation function is Riemann integrable.

[10] All thresholds coincide in the case of a one-step bonus contract.

[11] Following Edmans and Gabaix (2010), we assume that the project value size is several orders of magnitude larger than the cost of effort of the CEO, so that the benefits of effort outweigh the cost of providing incentives to exert effort. In such a situation, a high effort exertion is optimal from the shareholders' point of view.

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some expertise regarding the proper decision to be taken. In such a setting, taking decision e_h is the decision in the interest of the firm, but the CEO derives some private benefits c from taking decision e_l. The problem faced by the shareholders is then identical to the one we describe below.[12]

Finally, as in Hermalin ((2005), Sec. V), we assume that there are many CEO candidates and few firms, so that firms have all the bargaining power in negotiating compensation contracts.

Timing. First, shareholders observe the type of the internal candidate. Second, shareholders decide whether to make an offer to the internal or to an external candidate. Third, a take-it-or-leave-it offer is made to the chosen candidate. Fourth, the selected candidate chooses his effort level. Fifth, the project value is realized and observed, and finally transfers take place.

Given its very nature, the problem is solved by backward induction. That is, first, the optimal contract for each type of CEO candidate (internal or external) is derived. Then, given the expected project value and compensation transfers associated with each type of candidate, shareholders select a candidate.

Though we consider a one-period model (i.e., one realization of the project value), we conjecture that our analysis still holds if we consider a multi-period model and a multi-period contract offered at the time the CEO is appointed and valid for the entire tenure duration. However, considering the negotiation of a new contract after the first one expires would also require taking into account the career concerns of the CEO. This is beyond the scope of this paper.

IV. Contract Offered to an Internal Candidate

If a contract is offered to an internal candidate, shareholders have perfect knowledge of the quality of the candidate. Therefore, the problem of the shareholders is to provide the agent with incentives to exert effort (i.e., choose $e = e_h$). In such a case, the shareholders' maximization program can be defined as

$$\max_{t_{ij}} \int_{\underline{v}}^{\bar{v}} (v - t_{ij}(v)) p_{ij}(v) dv,$$

subject to

i) IC constraints,

$$\int_{\underline{v}}^{\bar{v}} (p_{ij}(v) - q(v))\, t_{ij}(v) dv \quad \geq \quad c, \qquad \forall i, j = H, L; \tag{2}$$

ii) limited liability constraint,

$$t_{ij}(v) \quad \geq \quad 0, \qquad \forall v; \tag{3}$$

[12] A related issue is studied by Prendergast (2000), (2002). However, as the input (i.e., the decision of the agent) is not observable in our model, our issue is not about choosing between input- or output-based compensation. Rather, we focus on the choice between different forms of output-based compensation schemes.

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iii) nondecreasing-contract constraint,

$$t_{ij}(v') \geq t_{ij}(v), \qquad \forall v \text{ and } v' \geq v; \tag{4}$$

iv) participation constraint,

$$\int_{\underline{v}}^{\bar{v}} t_{ij}(v) p_{ij}(v) dv - c \geq 0, \quad \forall i,j = H,L. \tag{5}$$

We derive the following result.

Proposition 1.

i) Suppose that $CLR_{ij}(\cdot)$ reaches its global maximum at a single state $v^* < \bar{v}$; then the unique optimal contract is the one-step bonus contract $B(v^*, T_{ij}(v^*))$ with

$$T_{ij}(v) = \frac{c}{Q(v) - P_{ij}(v)}. \tag{6}$$

ii) Suppose that $CLR_{ij}(\cdot)$ reaches its global maximum at k (with $k \geq 1$) different states $\{v_1^*, \ldots, v_k^*\}$. If $v_k^* < \bar{v}$, then all optimal contracts are i-step bonus contracts with $i \in \{1, \ldots, k\}$.

Proposition 1 states that if the principal only faces a moral-hazard problem and the *CLR* function has only interior global maxima, then all optimal contracts take the simple form of bonus contracts.

These results contrast with those derived by Holmström and Milgrom (1987) and Edmans and Gabaix (2010), who find that compensation should be strictly monotonic in output. Reasons for the difference in results are as follows: First, Holmström and Milgrom assume that uncertainty is normally distributed and effort only shifts the mean of the distribution. Under such assumptions, the *CLR* function is monotonic and increasing. Therefore, the condition of Proposition 1 for an optimal bonus contract (i.e., an interior global maximum for the *CLR* function) is not satisfied. Second, Edmans and Gabaix (2010) assume that effort has a multiplicative effect on the firm value, while this is not the case in our model. The implication of this multiplicative-effect assumption is that the larger the value of the firm, the better the inference about effort. As a consequence, the *CLR* function is monotonic increasing, hence the condition of Proposition 1 for an optimal bonus contract is not satisfied.

The intuition is first, by constraining the wage scheme to be nondecreasing, the strategic decision of the principal to choose for what project value and what amount to *increase* the agent's pay. Second, given that the agent is risk neutral, the marginal utility derived from a marginal increase in expected compensation is independent of the expected compensation level. It implies that, for a given increase in expected pay, the agent is indifferent between all firm values at which the salary increase takes place. Third, the standard intuition (based on likelihood ratios) concerning the relationship between compensation and inference about effort exertion is adapted to the case of nondecreasing contracts. We then get

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the result that the agent receives an increase in salary when the *CLR* function is maximized.

It follows that if CLR_{ij} reaches its unique global maximum for some project value $v < \bar{v}$, then the unique optimal contract is a one-step bonus with threshold v_{ij}^*. Conversely, if CLR_{ij} reaches its global maximum in $k > 1$ states then, applying the same reasoning as in the case of a unique interior maximum, we obtain that any contract that generates a salary increase in a state in which CLR_{ij} reaches a global maximum is optimal. This implies that if CLR_{ij} has only interior maxima, all optimal contracts are i-step bonus contracts with $i \in \{1, \ldots, k\}$.

Before proceeding, several remarks should be made. First, the results of Proposition 1 are consistent with the general shape of bonus contracts described in Murphy (1999), who explains that most bonus contracts are characterized by a first threshold (the lowest) below which no bonus is paid and a last threshold (the highest) beyond which the bonus is flat. In the zone between these two thresholds (the incentive zone), the bonus is increasing in performance.

Second, the first part of Proposition 1 is related to the results of Oyer ((2000), Prop. 1) who establishes that, in the presence of limited liability, if i) hazard rate functions are not monotonically increasing in outputs and ii) the distribution of outputs with a high effort dominates the distribution of outputs with a low effort in the sense of hazard-rate dominance, then bonus contracts are optimal. Our condition that CLR_{ij} reaches its global maximum at some $v_{ij}^* < \bar{v}$ is weaker than hazard-rate dominance, since it is possible to have CLR_{ij} reaching its global maximum at some $v_{ij}^* < \bar{v}$ without hazard-rate dominance. Moreover, the result that the compensation is capped at some $v^* < \bar{v}$ if the *CLR* has an interior global maximum still holds in the case of the risk-averse agent. The intuition is identical to that developed by Oyer ((2000), Prop. 4.ii). However, the difference with the risk-neutrality case is that with a risk-averse agent, there exists an interval $[v^l, v^*]$ over which the compensation increases smoothly in performances.

Finally, our results extend to the case of a continuous effort if, as in Edmans, Gabaix, Sadzik, and Sannikov (2012), we assume that there is a finite optimal effort level that the principal wishes to implement.[13]

Example

Finally, we wish to provide an example of a family of probability distributions such that the conditions of Proposition 1, are satisfied (i.e., the CLR function has an interior global maximum).

[13]Formally, denote $P(v|e)$, $p(v|e)$, and $c(e)$ the probability distribution, the density function, and the effort cost, respectively, associated to an effort level e. Let $P'_e(v|e) = \partial P(v|e)/\partial e$. Then, the CLR function is given by $CLR_e(v) = P'_e(v|e)/(1 - P(v|e))$.

Let $p'_e(v|e) = \partial p(v|e)/\partial e$. In such a case, the IC constraint is given by

$$\int_{\underline{v}}^{\bar{v}} p'_e(v|e)t(v)dv - c'(e) \quad = \quad 0.$$

Assuming that the first-order approach is valid, then if $CLR_e(v)$ is twice continuously differentiable with respect to v and e and has an interior global maximum $v^*(e)$ that belongs to a compact set, and our results about the optimality of the bonus contract go through.

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Let $\underline{v} = 0$, $\bar{v} = +\infty$, and consider the family of log-logistic distribution functions

$$(7) \qquad \begin{cases} P(\alpha, v) = 0, & \text{if} \quad v \in [0, \alpha), \\ P(\alpha, v) = 1 - \dfrac{1}{1 + (v - \alpha)^2}, & \text{if} \quad v \in [\alpha, +\infty], \end{cases}$$

where α is a parameter taken from $[0, 1)$. This family of probability distributions is such that if $\alpha_1 > \alpha_2$, then $P(\alpha_1, \cdot)$ dominates $P(\alpha_2, \cdot)$ in the FOSD sense.

In what follows, we then assume that $Q(v) = P(0, v)$, $P_{ij}(v) = P(\alpha_{ij}, v)$, $(i, j = H, L)$, with $\alpha_{HH} > \alpha_{HL} > \alpha_{LL} > 0$ and $\alpha_{HH} > \alpha_{LH} > \alpha_{LL} > 0$. It implies that CLR_{ij} has a unique global maximum that is reached at $v_{ij}^* = \frac{1}{2}[\alpha_{ij} + (4 + \alpha_{ij}^2)^{1/2}]$. As a consequence, the conditions of Proposition 1 are satisfied. Therefore, the unique optimal contract for an internal candidate of type (i, j) is $B\big(v_{ij}^*, c/[P(0, v_{ij}^*) - P(\alpha_{ij}, v_{ij}^*)]\big)$.

V. Optimal Contract for an External Candidate

We now turn to the case of an external candidate whose level of firm-specific skills is unknown to the shareholders. The problem for the shareholders is now

$$\max_{(t_{HL}, t_{HH})} \theta \int_{\underline{v}}^{\bar{v}} (v - t_{HH}(v)) p_{HH}(v) dv + (1 - \theta) \int_{\underline{v}}^{\bar{v}} (v - t_{HL}(v)) p_{HL}(v) dv,$$

subject to

i) IC constraints,

$$(8) \qquad \int_{\underline{v}}^{\bar{v}} (p_{Hi}(v) - q(v))\, t_{Hi}(v) dv \quad \geq \quad c, \qquad \forall i = H, L;$$

ii) adverse-selection constraints,

$$(9) \qquad \int_{\underline{v}}^{\bar{v}} (t_{Hi}(v) - t_{Hj}(v))\, p_{Hi}(v) dv \quad \geq \quad 0, \qquad \forall i, j = H, L \text{ and } i \neq j,$$

$$(10) \qquad \int_{\underline{v}}^{\bar{v}} (t_{Hi}(v) p_{Hi}(v) - t_{Hj}(v) q(v))\, dv \quad \geq \quad c, \qquad \forall i, j = H, L \text{ and } i \neq j;$$

iii) limited liability constraints,

$$(11) \qquad t_{Hi}(\cdot) \quad \geq \quad 0, \qquad \forall i = H, L;$$

iv) participation constraints,

$$(12) \qquad \int_{\underline{v}}^{\bar{v}} t_{Hi}(v) p_{Hi}(v) dv - c \quad \geq \quad 0, \qquad \forall i = H, L;$$

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v) nondecreasing-contract constraints,

$$t_{Hi}(v') \geq t_{Hi}(v), \qquad \forall v' \geq v, \quad \forall i = H, L. \tag{13}$$

We start by providing the following additional notations. First, let

$$F(v,\theta) \equiv T_{HL}(v)\left[(1-\theta)(1-P_{HL}(v)) + \theta(1-P_{HH}(v))\right].$$

$F(v,\theta)$ represents the cost of offering the one-step bonus contract $B(v, T_{HL}(v))$ to both types of external candidates. Second, denote $HR_{ij}(\cdot)$ the hazard rate function associated to the probability distribution $P_{ij}(\cdot)$ (i.e., $HR_{ij}(v) = p_{ij}(v)/[1-P_{ij}(v)]$). We derive the following results:

Proposition 2. Assume that $F(v,\theta)$ reaches its global minimum at a single state $v_\theta^{**} \in (\underline{v}, \bar{v})$.

i) The equilibrium contract for a candidate of type (H,L) is unique and corresponds to the bonus contract $B(v_\theta^{**}, T_{HL}(v_\theta^{**}))$.

ii) Assume that

- CLR_{HH} reaches its global maximum at a single state $v_{HH}^* \in (\underline{v}, \bar{v})$;
- there exists a unique state $v^o \in (\underline{v}, \bar{v})$ such that, for any $v < v^o$, $HR_{HH}(v) < HR_{HL}(v)$, and for any $v > v^o$, $HR_{HH}(v) > HR_{HL}(v)$.

Then, if $v_\theta^{**} < \min(v_{HH}^*, v^o)$ or $v_\theta^{**} > \max(v_{HH}^*, v^o)$, there exists an equilibrium contract for an agent of type (H,H) made up of a bonus contract and equity (stock or stock options).

The first part of Proposition 2 states that the compensation contract for an agent of type (H,L) is unique and takes the form of a bonus contract.

The second part of the proposition then establishes that equity is part of an equilibrium contract for an agent of type (H,H). A sufficient condition for this result to be obtained is that there should exist a state V such that the relative probability of outperforming V rather than v_θ^{**} is smaller for an agent of type (H,L), either exerting effort or not, than for an agent of type (H,H) exerting effort.[14] If such a state V exists, then there exists a one-step bonus contract $B(V,T)$ such that an agent of type (H,L) strictly prefers $B(v_\theta^{**}, T_{H,L}(v_\theta^{**}))$ to $B(V,T)$, while an agent of type (H,H) is indifferent between the two contracts. As a consequence, there is room to design an optimal contract for the agent of type (H,H) that mixes a bonus contract $B(V,T')$ with $T' < T$ and equity.

The reason for the difference in results between the pure moral-hazard case and the moral-hazard-and-adverse-selection case is the following: In the former

[14]Formally, it must be that i) if the agent of type (H,L) does not exert effort $(1-Q(v_\theta^{**}))/(1-Q(V)) > (1-P_{HH}(v_\theta^{**}))(1-P_{HH}(V)$ and ii) if the agent of type (H,L) exerts effort $(1-P_{HL}(v_\theta^{**}))(1-P_{HL}(V)) > (1-P_{HH}(v_\theta^{**}))(1-P_{HH}(V))$. The condition that CLR_{HH} is maximized at $v_{HH}^* \in (\underline{v}, \bar{v})$ ensures that there exists an interval such that condition i) is verified, while the assumption that there exists a unique state $v^o \in (\underline{v}, \bar{v})$ such that for any $v < v^o$, $HR_{HH}(v) < HR_{HL}(v)$ and for any $v > v^o$ $HR_{HH}(v) > HR_{HL}(v)$ ensures that there exists an interval such that condition ii) is satisfied. Finally, if $v_\theta^{**} < \min(v_{HH}^*, v^o)$ or $v_\theta^{**} > \max(v_{HH}^*, v^o)$, then the intersection of these two intervals is nonempty.

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case, the principal only aims at providing incentives to exert effort, since they know the type of the agent. In the latter case, a contract that provides incentives to exert effort to an agent of type (H, L) also provides incentives to exert effort to an agent of type (H, H), due to the assumption that P_{HH} dominates P_{HL} in the FOSD sense. As a consequence, the principal looks for the cheapest contract that provides incentives to exert effort to both types of agents. As in the pure moral-hazard case, this is achieved with a bonus contract $(B(v_\theta^{**}, T_{H,L}(v_\theta^{**})))$ in the present case.

However, due again to P_{HH} dominating P_{HL} in the FOSD sense, and the conditions of Part ii of Proposition 2, this contract is not unique for an agent of type (H, H). There also exist contracts mixing a bonus scheme and equity that provide the same expected revenue to the agent of type (H, H), while never being chosen by an agent of type (H, L). There exists a separating equilibrium in which an agent of type (H, H) is compensated with a contract consisting of a bonus plan and equity.

The simultaneous use of equity and bonus plans in compensation contracts is consistent with empirical evidence. First, according to Murphy (1999), the typical executive compensation package contains three components: a base salary, an annual cash bonus, and equity. This compensation structure is observed worldwide. Second, according to Towers Perrin's *Worldwide Total Remuneration Report 2005–2006*, in many countries CEOs receive both cash bonuses and equity, and cash bonuses represent a large share of their total remuneration.

Note also that by comparing the results of Propositions 1 and 2, we obtain that equity is only offered to an external candidate. This is consistent with the results of Gillan et al. ((2009), Tab. 3.B), who study CEO employment agreements and find that, with respect to the median CEO and with an implicit employment agreement, the median CEO with an explicit employment agreement i) has a higher fraction of his total remuneration that is stock based and ii) is more likely to have been appointed from outside the firm.

Stocks versus Options

For any set of parameters satisfying the conditions of Proposition 2, both stock and options can be components of the compensation contract of an agent of type (H, H). Therefore, Proposition 2 does not say anything about the conditions under which one type of equity is part of an equilibrium compensation contract while another type of equity is not. Moreover, under the conditions of Proposition 2, equity can only be a minor component of the compensation contract of the agent of type (H, H), in terms of expected compensation.

It is also of interest to study the conditions under which one specific type of equity is the main component of the compensation contract offered to an agent of type (H, H). For that purpose, we restrict our attention to compensation contracts consisting solely of stocks or solely of options (for an agent of type (H, H)). We derive the following results:

Proposition 3. Assume that $F(v, \theta)$ reaches its global minimum at a single state $v_\theta^{**} \in (\underline{v}, \bar{v})$. Then,

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i) there exists an equilibrium in which an agent of type (H,H) is compensated uniquely with stocks if and only if

$$\frac{1-P_{HL}(v_\theta^{**})}{\mathrm{E}_{HL}(v)} \geq \frac{1-P_{HH}(v_\theta^{**})}{\mathrm{E}_{HH}(v)}; \tag{14}$$

ii) there exists an equilibrium in which an agent of type (H,H) is compensated uniquely with options with exercise price $\hat{v} \in (\underline{v},\bar{v})$ if and only if

$$\frac{1-P_{HL}(v_\theta^{**})}{\mathrm{E}_{HL}[\max(0,v-\hat{v})]} \geq \frac{1-P_{HH}(v_\theta^{**})}{\mathrm{E}_{HH}[\max(0,v-\hat{v})]}. \tag{15}$$

The rationale for the results of Proposition 3 is as follows: The expected compensation of an agent of type (H,L) choosing the equilibrium contract $B(v_\theta^{**},T)$ is $T[1-P_{HL}(v_\theta^{**})]$. Now, if this agent deviates from this contract and chooses the equilibrium stock contract $S(\alpha)$ designed for an agent of type (H,H), then the expected compensation is $\alpha\mathrm{E}_{HL}(v)$. The ratio of expected compensations between the two contracts is then $[1-P_{HL}(v_\theta^{**})]T/\alpha\mathrm{E}_{HL}(v)$. Now, for an agent of type (H,H), the ratio of expected compensations for the same two contracts is $[1-P_{HH}(v_\theta^{**})]T/\alpha\mathrm{E}_{HH}(v)$. Proposition 3 states that for a separating equilibrium in which i) an agent of type (H,L) receives a pure bonus contract $B(v_\theta^{**},T_{HL}(v_\theta^{**}))$ and ii) an agent of type (H,H) is compensated solely with stock, a necessary and sufficient condition is the existence of a stock contract such that the expected compensation provided by the bonus contract relative to the stock contract is larger for the agent of type (H,L) than for an agent of type (H,H). The reasoning for the equilibrium with a pure option contract for an agent of type (H,H) is identical.

Given that inequalities (14) and (15) are equivalent if we set $\hat{v}=0$,[15] options offer one more degree of freedom with respect to stock in the design of optimal contracts. It implies that even if inequality (14) does not hold, we can have inequality (15) satisfied (in some cases) by appropriately choosing the exercise price for the options. Conversely, if for any $\hat{v} \geq \underline{v}$, inequality (15) does not hold, then inequality (14) also does not hold.[16]

This shows that option contracts, because they offer one more degree of freedom with respect to stocks in the design of the performance-compensation relationship, are more likely to be optimal contracts than pure stock contracts.

[15]This does not mean that stock is a specific case of option, since we assume that $\underline{v} \geq 0$, and by definition the exercise price of an option is larger than or equal to $\underline{v}$. So, for any $\underline{v} > 0$, stocks cannot be replicated with call options.

[16]If $\hat{v}=\underline{v}$, then inequality (15) is equivalent to

$$\frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})} \geq \frac{\mathrm{E}_{HL}(v)-\underline{v}}{\mathrm{E}_{HH}(v)-\underline{v}},$$

and $\mathrm{E}_{HL}(v)/\mathrm{E}_{HH}(v) > (\mathrm{E}_{HL}(v)-\underline{v})/(\mathrm{E}_{HH}(v)-\underline{v})$. So, if the above inequality does not hold, then inequality (14) also does not hold.

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VI. Optimal CEO Choice

Having derived the optimal (menu of) contracts proposed to an internal and an external CEO candidate, we can now turn to the optimal CEO choice.

Additionally, we want to study how the choice and the compensation of a CEO are affected by a shift from the predominance of firm-specific skills to the predominance of general skills required for the CEO job. In this respect, we follow Murphy and Zabojnik (2004), (2007).

In order to capture the increasing importance of general skills relative to firm-specific skills, we distinguish two regimes. In the first, firm-specific skills are the predominant skills, hence we assume that P_{LH} dominates P_{HL} in the FOSD sense (*FS*-regime hereafter). Conversely, in the second regime, general skills are the predominant skills, and P_{HL} dominates P_{LH} in the FOSD sense (*G*-regime hereafter). Formally, we make the following assumption:

Assumption 3. Consider any two probability distributions P_1 and P_2 such that

$$P_{HH} \quad >_{FOSD} \quad P_1 \quad >_{FOSD} \quad P_2 \quad >_{FOSD} \quad P_{LL},$$

where $P_1 >_{FOSD} P_2$ means that P_1 dominates P_2 the FOSD sense.

Under the *FS*-regime, $P_{LH} = P_1$ and $P_{HL} = P_2$, while under the *G*-regime, $P_{HL} = P_1$ and $P_{LH} = P_2$.

In our model, a CEO impacts the value of the firm in two ways: first, through the expected value of the project, and second, through the expected compensation cost, since all compensation costs are expensed.

We then derive the following results regarding the optimal CEO choice.

Lemma 1.

i) Assume that the internal candidate is of type (H, H). Then, he is always the hired candidate.

ii) Assume that the internal candidate is of type (L, H). Then, the hiring of external candidates increases when switching from the *FS*-regime to the *G*-regime. (Formally, for any set of parameters such that an external candidate is hired under the *FS*-regime, an external candidate is hired under the *G*-regime. There exist sets of parameters such that the internal candidate is hired under the *FS*-regime while an external candidate is hired under the *G*-regime.)

The rationale for these results is as follows: If the internal candidate is of type (H, H) then, for any θ, an external candidate generates a lower expected project value and a higher expected compensation. As a consequence, the internal candidate is always preferred to an external one. If the internal candidate is of type (L, H), then the benefits of hiring an external candidate depends on whether $\mathrm{E}_{HL}(V) > \mathrm{E}_{LH}(V)$ or $\mathrm{E}_{HL}(V) < \mathrm{E}_{LH}(V)$. The first inequality holds under the *G*-regime, while the second holds under the *FS*-regime. Moreover, Assumption 3 implies that when shifting from the *FS*-regime to the *G*-regime, the expected compensation of an internal candidate of type (L, H) increases, while that of an external candidate decreases due to the fact that $P_1(\cdot)$ dominates $P_2(\cdot)$ in the

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FOSD sense.[17] As a consequence, hiring an external candidate is more profitable under the *G*-regime than under the *FS*-regime.

Finally, regarding the evolution of compensation expenses as a shift from the *FS*-regime to the *G*-regime occurs, we derive the following result:

Proposition 4. Assume that the internal candidate is hired in the *FS*-regime. Then,

i) CEO compensation increases in case of a shift from the *FS*-regime to the *G*-regime;

ii) under the G-regime, the compensation of externally hired CEOs is larger than the compensation of internally promoted CEOs.

If an internal candidate is hired under the *FS*-regime and a shift of regime occurs, then three cases must be considered. First, the internal candidate is of type (H,H). In such a case, he is hired under both regimes, and his compensation is unaffected by a change of regime. Second, the internal candidate is of type (L,H) and is still the hired candidate under the *G*-regime. In such a case, external candidates are never hired, and the compensation of the selected CEO increases when the regime shift occurs, since P_{LH} dominates P_{HL} in the FOSD sense under the *FS*-regime. The reverse is true under the *G*-regime. Third, the internal candidate is of type (L,H), and the external candidate is selected under the *G*-regime. In such a case, the expected CEO compensation increases through a regime shift. The reason is the following: Given that $P_{LH} = P_1$ under the *FS*-regime and $P_{HL} = P_1$ under the *G*-regime, these two probability distributions generate the same compensation contract, absent adverse-selection consideration.[18] However, the adverse-selection constraints faced by the principal when hiring an outsider imply that the expected compensation paid to a type (H,L) agent under the *G*-regime is larger than that paid to an agent of type (L,H) under the *FS*-regime. Moreover, in an equilibrium with adverse selection, it must be the case that the expected compensation of an agent of type (H,H) is larger than the expected compensation of an agent of type (L,H). As a consequence, the expected compensation paid to an external candidate (who is either of type (H,L) or of type (H,H)) under the *G*-regime is larger than that paid to an agent of type (L,H) under the *FS*-regime. Hence, considering the three cases, we obtain the result that CEO compensation increases if a regime shift occurs (part i) of the proposition).

Furthermore, since P_{HH} dominates P_{HL} in the FOSD sense, it follows that the compensation of an internally selected CEO of type (H,H) is lower than that of an externally selected candidate, under the *G*-regime. Consequently, if the external candidate is selected under the *G*-regime (this happens when the insider is of type (L,H)), his compensation is larger than that of an internal candidate of type (H,H) selected under the *G*-regime (part ii) of the proposition).

[17] The expected compensation of an internal candidate of type (L,H) is $c/CLR_1(v_1^*)$ under the *FS*-regime and $c/CLR_2(v_2^*)$ under the *G*-regime. Since, P_1 dominates P_2 in the FOSD sense, it implies that for any v, $CLR_1(v) > CLR_2(v)$. As a consequence, $CLR_1(v_1^*) > CLR_2(v_2^*)$, hence providing the desired result.

[18] This contract would be $B(v_1^*, c/Q(v_1^*) - P_1(v_1^*))$.

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These results are consistent with several pieces of empirical evidence. First, our results showing that CEO compensation increases if a regime switch occurs are consistent with evidence about the simultaneous transformation of the job of CEO and increase in CEO pay over the last decades (see Frydman (2007), Gabaix and Landier (2008)). Second, the result showing that outsiders receive a higher compensation than insiders is consistent with empirical evidence provided by Murphy and Zabojnik (2007), who document that the premium for external hires is about 15.3%.

Finally, we would like to address the issue of a regime-dependent reservation utility. Our model implicitly assumes that when a regime switch occurs, CEO candidates' outside options are not affected, since their reservation utility is not modified. However, if such a regime switch takes place, an internal candidate for a given firm may become an external candidate for another firm. As a consequence, the set of outside opportunities of a CEO candidate expands as firms consider larger sets of candidates for the CEO position. This should result in a higher value of outside opportunities, hence in a higher reservation utility for the candidates.

Taking such changes in reservation utilities into account in our model, then in the *G*-regime, the participation constraints (5) and (12) have to be replaced by

$$\int_{\underline{v}}^{\bar{v}} t_{ij}(v)p_{ij}(v)dv - c \quad \geq \quad \bar{u} \quad > \quad 0, \qquad \forall i,j = H,L \qquad \text{and} \tag{16}$$

$$\int_{\underline{v}}^{\bar{v}} t_{Hi}(v)p_{Hi}(v)dv - c \quad \geq \quad \bar{u} \quad > \quad 0, \qquad \forall i = H,L, \tag{17}$$

respectively.

The direct implication of such increases in reservation utility levels when a regime switch occurs is that the compensation of CEOs (selected either externally and internally) increases when such a regime switch happens. This result then reinforces those derived in Proposition 4 with regards to the increase in CEO pay following a switch from the *FS*-regime to the *G*-regime.

VII. Concluding Remarks

Over the last three decades, an unprecedented rise in CEO pay and increase in the use of equity in compensation packages has been observed, at least in the United States. However, another important change regarding CEOs took place over the same period: their prior working experience. Increasingly, boards of directors would choose a CEO from outside the firm rather than promoting an insider.

In this article, we show that the simultaneous increases in i) CEO pay level, ii) the use of equity in CEO compensation packages, and iii) the hiring of CEOs externally may be the consequences of the same phenomenon: an evolution of the economic environment influencing the type of skills for the job of CEO, with general rather than firm-specific skills becoming the predominantly required type of skills.

The rationale for our results is that as general skills have become the dominant type of skills required for a CEO's job, firms increasingly consider outsiders

as CEO candidates. Firms, however, have less information about these candidates than about internal candidates. We show that equity and cash bonuses may be simultaneously used in compensation packages to i) provide incentives and ii) solve these problems of information asymmetry.

Furthermore, this lower level of information about outsiders implies that they are more expensive for firms. Hence, the increase in the hiring of CEOs externally will be accompanied by an increases in CEO pay and in the use of equity in compensation packages. These results are consistent with empirical evidence showing that outsiders receive higher compensation than insiders and get a higher fraction of the total remuneration that is equity based.

One issue we do not address is how tenure duration interacts with compensation structure and the choice between insiders and outsiders for a CEO position. This is the objective of our future work.

Appendix. Proofs

1. Proof of Proposition 1

We proceed as in Palomino and Prat (2003), through a discretization of the original continuous problem.

Suppose that the principal is restricted to using contracts that have no more than n steps, where n is a positive integer. Having a finite number of discontinuities, $t_{ij}(\cdot)$ is Riemann integrable. Hence, as n tends to infinity, any contract $t_{ij}(\cdot)$ is approximated by a n-step contracts.

Formally, we consider, first, a decreasing sequence of real numbers d_n ($n = 1, \ldots, +\infty$) with $d_{n+1} < d_n$, and $\lim_{n\to+\infty} d_n = 0$. Second, we consider a discretization such that, for any n, and for any $m = 1, \ldots, n$, $v_m < v_{m+1}$ and $(v_{m+1} - v_m) < d_n$. An n-step contract is defined by thresholds v_m ($m = 1, \ldots, n$) and $n + 1$ compensation levels t_{ij}^m ($m = 1, \ldots, n+1$), with t_{ij}^m nondecreasing in m.

If n is held fixed and the principal is restricted to using n-step contracts, then the principal's problem becomes

$$\max_{t_{ij}^m} \mathrm{E}_{ij}[v|e=1] - \sum_{m=1}^{n+1} t_{ij}^m (P_{ij}(v_m) - P_{ij}(v_{m-1})),$$

subject to

$$\sum_{m=1}^{n+1} t_{ij}^m (P_{ij}(v_m) - P_{ij}(v_{m-1})) - \sum_{m=1}^{n+1} t_{ij}^m (Q(v_m) - Q_{ij}(v_{m-1})) \quad \geq \quad c,$$

$$t_{ij}^1 \geq 0 \text{ and } t_{ij}^{m+1} \geq t_{ij}^m \ (m = 1, \ldots, n).$$

Given the limited liability constraints, it is a routine matter to show that agents' participation constraints are always slack.

For the rest of the analysis, it will be convenient to make a change of variable and consider the following equivalent optimization program: For all $m = 1, \ldots, n$, we denote τ_{ij}^m the differential in transfers between two successive states (i.e., $\tau_{ij}^m \equiv t_{ij}^{m+1} - t_{ij}^m$). We can then rewrite the optimization problem of the principal as

$$\max_{(t_{ij}^1, \tau_{ij}^m)} \ \mathrm{E}_{ij}[V|e_h] - t_{ij}^1 - \sum_{m=1}^{n} \tau_{ij}^m (1 - P_{ij}(v_m)),$$

subject to

$$\text{(A-1)} \qquad t_{ij}^1 + \sum_{m=1}^{n} \tau_{ij}^m (1 - P_{ij}(v_m)) - c \quad \geq \quad t_{ij}^1 + \sum_{m=1}^{n} \tau_{ij}^m (1 - Q(v_m)),$$

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$$\text{(A-2)} \qquad \tau_{ij}^{m} \geq 0, \quad \forall m \geq 1 \quad \text{and} \quad i,j = H,L,$$

$$\text{(A-3)} \qquad t_{ij}^{1} \geq 0, \quad \forall i,j = H,L.$$

Obviously it is optimal to set $t_{ij}^{1} = 0$, since the principal's objective is decreasing in t_{ij}^{1} and this transfer provides no incentives to exert effort.

The Lagrangian is then

$$\mathcal{L} = \mathrm{E}_{ij}[V|e_h] - \sum_{m=1}^{n} \tau_{ij}^{m}(1 - P_{ij}(v_m)) + \lambda \sum_{m=1}^{n} \tau_{ij}^{m}(Q(v_m) - P_{ij}(v_m)) + \sum_{m=1}^{n} \mu_m \tau_{ij}^{m}.$$

The first-order conditions (FOCs) of the maximization problem are then given by

$$\text{(A-4)} \qquad \frac{\partial \mathcal{L}}{\partial \tau_{ij}^{m}} = -[1 - P_{ij}(v_m)] + \lambda[Q(v_m) - P_{ij}(v_m)] + \mu_m = 0, \quad \forall m \geq 1.$$

These FOCs can be rewritten as

$$\text{(A-5)} \qquad -\frac{1}{CLR_{ij}(v_m)} + \lambda + \frac{\mu_m}{Q(v_m) - P_{ij}(v_m)} = 0.$$

Let

$$\mathcal{M}_{ij}^{n} = \{m \in \{1,\ldots,n\} | \quad CLR_{ij}(v_m) \geq CLR_{ij}(v_{m'}) \quad \forall m' \in \{1,\ldots,n\}\},$$

and denote K_{ij}^{n} the number of elements of $\mathcal{M}_{ij}^{n}$.

First, assume that $K_{ij}^{n} = 1$, and denote $\hat{m}_{ij}^{n}$, the unique element of $\mathcal{M}_{ij}^{n}$. Then, the unique solution of the system of FOCs is $\lambda = 1/CLR_{ij}(v_{\hat{m}_{ij}^{n}})$, $\mu_{\hat{m}_{ij}^{n}} = 0$, and for all $m \neq \hat{m}_{ij}^{n}$, $\mu_m > 0$. Indeed, obviously λ cannot be strictly larger than $1/CLR_{ij}(v_{\hat{m}_{ij}^{n}})$. Now, suppose that $\lambda < 1/CLR_{ij}(v_{\hat{m}_{ij}^{n}})$. Then, $-1/CLR_{ij}(v_m) + \lambda$ is negative and largest at $m = \hat{m}_{ij}^{n}$. This entails that all μ_m must be positive. If this were the case, then the IC constraint would not be satisfied. This implies that the unique solution is as follows: For all $m \neq \hat{m}_{ij}^{n}$, $\tau_{ij}^{m} = 0$ and the IC constraint is binding. In turn, it implies that

$$\tau_{ij}^{\hat{m}_{ij}^{n}} = \frac{c}{Q\left(v_{\hat{m}_{ij}^{n}}\right) - P_{ij}\left(v_{\hat{m}_{ij}^{n}}\right)}.$$

The expected compensation cost for the principal is then $c/CLR_{ij}(v_{\hat{m}_{ij}^{n}})$.

Second, assume that $K_{ij}^{n} > 1$. The system of FOCs remains as in the case $K_{ij}^{n} = 1$. However, the solution of this system is not unique anymore. For any $\hat{m}_{ij}^{n} \in \mathcal{M}_{ij}^{n}$, it is always optimal to set $\lambda = 1/CLR_{ij}(v_{\hat{m}_{ij}^{n}})$, $\mu_{\hat{m}_{ij}^{n}} = 0$, and for all $m \neq \hat{m}_{ij}^{n}$, $\mu_m > 0$. Hence, for any $\hat{m}_{ij}^{n} \in \mathcal{M}_{ij}^{n}$, the n-step contract with $\tau_{ij}^{\hat{m}_{ij}^{n}} = c/[Q(v_{\hat{m}_{ij}^{n}}) - P_{ij}(v_{\hat{m}_{ij}^{n}})]$ and for all $m \neq \hat{m}_{ij}^{n}$, $\tau_{ij}^{m} = 0$ is optimal.

However, since the expected implementation cost is identical (and minimized) for all $\hat{m}_{ij}^{n} \in \mathcal{M}_{ij}^{n}$, it directly follows that any linear combination of these K_{ij}^{n} contracts is also optimal.

Now, assume that $CLR_{ij}(\cdot)$ reaches its global maximum at a unique point v^*. Since P_{ij} and Q are continuous, then, as n tends to infinity, for any element $\hat{m}_{ij}^{n} \in \mathcal{M}_{ij}^{n}$, $|v^* - v_{\hat{m}_{ij}^{n}}|$ tends to 0. Hence, $B(v^*, T_{ij}(v^*))$ is the unique optimal contract of the original continuous problem.

Now, assume that $CLR_{ij}(\cdot)$ reaches its global maximum at K points $v_1^*, \ldots, v_K^*$. Then, for any v_k^* $(k = 1,\ldots,K)$ and for any $\varepsilon > 0$, there exists $\bar{n}$ such that if $n > \bar{n}$ $d_n < \varepsilon$, implying that there exists $\hat{m}_{ij}^{n} \in \mathcal{M}_{ij}^{n}$ such that $|v_k^* - v_{\hat{m}_{ij}^{n}}| < \varepsilon$. Therefore, any contract $B(v_k^*, T_{ij}(v_k^*))$ is a solution of the original continuous problem. As a consequence, any linear combination of these solutions is a solution of the original continuous problem. □

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2. Proof of Proposition 2

As for Proposition 1, the proof proceeds through a discretization of the original continuous problem, and the same discretization is used. An n-step contract is defined by thresholds v_m ($m = 1, \ldots, n$) and $n+1$ compensation levels t^m ($m = 1, \ldots, n+1$), with t^m nondecreasing in m.

For all $m = 1, \ldots, n$, we denote τ_{Hi}^m the differential in transfers between two successive states (i.e., $\tau_{Hi}^m \equiv t_{Hi}^{m+1} - t_{Hi}^m$).

If n is held fixed and the principal is restricted to using n-step contracts, then the principal's problem becomes

$$\max_{(t_{Hi}^1, \tau_{Hi}^m)} \quad \theta \left[\mathrm{E}_{HH}(V|e_h) - t_{HH}^1 - \textstyle\sum_{m=1}^n \tau_{HH}^m (1 - P_{HH}(v_m)) \right] + (1-\theta) \left[\mathrm{E}_{HL}(V|e_h) - t_{HL}^1 - \textstyle\sum_{n=1}^n \tau_{HL}^m (1 - P_{HL}(v_m)) \right],$$

subject to

$$\text{(A-6)} \qquad t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - P_{HH}(v_m)) - c \geq t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - Q(v_m)),$$

$$\text{(A-7)} \qquad t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - P_{HH}(v_m)) - c \geq t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - P_{HH}(v_m)) - c,$$

$$\text{(A-8)} \qquad t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - P_{HH}(v_m)) - c \geq t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - Q(v_m)),$$

$$\text{(A-9)} \qquad t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - P_{HL}(v_m)) - c \geq t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - Q(v_m)),$$

$$\text{(A-10)} \qquad t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - P_{HL}(v_m)) - c \geq t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - P_{HL}(v_m)) - c,$$

$$\text{(A-11)} \qquad t_{HL}^1 + \sum_{m=1}^n \tau_{HL}^m (1 - P_{HL}(v_m)) - c \geq t_{HH}^1 + \sum_{m=1}^n \tau_{HH}^m (1 - Q(v_m)),$$

$$t_{ij}^1 \geq 0 \quad \text{and} \quad t_{ij}^{m+1} \geq t_{ij}^m (m = 1, \ldots, n).$$

The Lagrangian is then

$$\begin{aligned}
\mathcal{L} \;=\; & \theta \left[\mathrm{E}_{HH}(V|e_h) - t_{HH}^1 - \sum_{m=1}^n \tau_{HH}^m (1 - P_{HH}(v_m)) \right] \\
& + (1-\theta) \left[\mathrm{E}_{HL}(V|e_h) - t_{HL}^1 - \sum_{n=1}^n \tau_{HL}^m (1 - P_{HL}(v_m)) \right] \\
& + \lambda_1 \left[\sum_{m=1}^n \tau_{HH}^m (Q(v_m) - P_{HH}(v_m)) \right] \\
& + \lambda_2 \left[t_{HH}^1 - t_{HL}^1 + \sum_{m=1}^n (\tau_{HH}^m - \tau_{HL}^m)(1 - P_{HH}(v_m)) \right] \\
& + \lambda_3 \left[t_{HH}^1 - t_{HL}^1 + \sum_{m=1}^n (\tau_{HH}^m (1 - P_{HH}(v_m)) - \tau_{HL}^m (1 - Q(v_m)) \right]
\end{aligned}$$

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$$+\lambda_4\left[\sum_{m=1}^{n}\tau_{HL}^{m}(Q(v_m)-P_{HL}(v_m))\right]$$

$$+\lambda_5\left[t_{HL}^{1}-t_{HH}^{1}+\sum_{m=1}^{n}(\tau_{HL}^{m}-\tau_{HH}^{m})(1-P_{HL}(v_m))\right]$$

$$+\lambda_6\left[t_{HH}^{1}-t_{HL}^{1}+\sum_{m=1}^{n}(\tau_{HL}^{m}(1-P_{HL}(v_m))-\tau_{HH}^{m}(1-Q(v_m))\right].$$

The FOCs of the maximization program are

$$\text{(A-12)}\quad \frac{\partial L}{\partial \tau_{HH}^{m}} = (-\theta+\lambda_2+\lambda_3)(1-P_{HH}(v_m))+\lambda_1(Q(v_m)-P_{HH}(v_m)) - \lambda_5(1-P_{HL}(v_m))-\lambda_6(1-Q(v_m))+\mu_{HH}^{m} = 0,$$

$$\text{(A-13)}\quad \frac{\partial L}{\partial \tau_{HL}^{m}} = (-(1-\theta)+\lambda_5+\lambda_6)(1-P_{HL}(v_m))-\lambda_2(1-P_{HH}(v_m)) - \lambda_3(1-Q(v_m))+\lambda_4(Q(v_m)-P_{HL}(v_m))+\mu_{HL}^{m} = 0,$$

$$\text{(A-14)}\quad \frac{\partial L}{\partial t_{HH}^{1}} = -\theta+\lambda_2+\lambda_3-\lambda_5-\lambda_6+\mu_{HH}^{0} = 0,$$

$$\text{(A-15)}\quad \frac{\partial L}{\partial t_{HL}^{1}} = -(1-\theta)-\lambda_2-\lambda_3+\lambda_5+\lambda_6+\mu_{HL}^{0} = 0.$$

Given that condition (A-12) must hold for all m, it implies that we cannot have $\lambda_1=\lambda_2=\lambda_3=0$. Similarly, it follows from equation (A-13) that we cannot have $\lambda_4=\lambda_5=\lambda_6=0$. From conditions (A-14) and (A-15), we get that $\mu_{HH}^{0}+\mu_{HL}^{0}=1$. Therefore, we cannot have both $t_{HH}^{1}>0$ and $t_{HL}^{1}>0$.

We know from FOSD (Assumption 1) and the fact that the reward scheme is nondecreasing that

$$\text{(A-16)}\quad t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}[1-P_{HH}(v_m)]-c > t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}[1-P_{HL}(v_m)]-c.$$

Now suppose that $t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}[1-P_{HH}(v_m)]-c \le t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}[1-Q(v_m)]$. Inequality (A-16) implies that the IC constraint of the agent of type (H,L), given by condition (A-9) cannot be satisfied. So, if the agent of type (H,H) ever chooses the contract designed for an agent of type (H,L), he should strictly exert effort. It implies also that the right-hand side (RHS) of condition (A-7) must be larger than the RHS of condition (A-8). It follows then that $\lambda_3=0$.

Consider again inequality (A-16). Using condition (A-11), it implies that

$$\text{(A-17)}\quad t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}(1-P_{HH}(v_m))-c > t_{HH}^{1}+\sum_{m=1}^{n}\tau_{HH}^{m}(1-Q(v_m)).$$

From condition (A-7), we know that

$$t_{HH}^{1}+\sum_{m=1}^{n}\tau_{HH}^{m}(1-P_{HH}(v_m))-c \ge t_{HL}^{1}+\sum_{m=1}^{n}\tau_{HL}^{m}(1-P_{HH}(v_m))-c.$$

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We then get

$$t^1_{HH} + \sum_{m=1}^{n} \tau^m_{HH}(1 - P_{HH}(v_m)) - c \quad > \quad t^1_{HH} + \sum_{m=1}^{n} \tau^m_{HH}(1 - Q(v_m)).$$

Namely, the IC constraint of the agent of type (H, H) must be nonbinding. We then deduce that $\lambda_1 = 0$. Since, as stated above, λ_1, λ_2, and λ_3 cannot be simultaneously equal to 0, we conclude that $\lambda_2 > 0$.

Proof of Part i) We show now that the equilibrium with the above described characteristics is the unique equilibrium contract for an agent of type (H, L) in the maximization problem of the principal. Given that $\lambda_2 > 0$, the high type is indifferent, conditionally on exerting effort, between choosing the contract designed for him or the one designed for the low type. This entails that the expected cost for the principal of offering the contract initially designed for an agent of type (H, L) to both agents must only be equal to the cost of offering two separate contracts.

It directly implies that the contract offered to an agent of type (H, L) corresponds exactly to the optimal pooling contract. Proceeding by contradiction, let us suppose that there exists another equilibrium contract for an agent of type (H, L). That is, there would exist a separating equilibrium in which the implementation cost of the principal would be lower than that associated to the optimal pooling contract. But, since $\lambda_2 > 0$, the expected cost for the principal of such a contract is equivalent to a pooling contract where both agent would choose the contract designed for an agent of type (H, L). But this cannot be, since, as we show below, the pooling contract is unique.

Let us indeed derive the optimal pooling equilibrium. It is the solution of the maximization program

$$\max_{t^1, \tau^m} \theta \left[\mathrm{E}_{HH}(V|e_h) - t^1 - \sum_{m=1}^{n} \tau^m (1 - P_{HH}(v_m)) \right]$$

$$+ (1 - \theta) \left[\mathrm{E}_{HL}(v|e_h) - t^1 - \sum_{m=1}^{n} \tau^m (1 - P_{HL}(v_m)) \right],$$

subject to equations (A-6)–(A-9), the limited liability, and the nondecreasing contract constraints.

As in the case of Proposition 1, setting $t^1 = 0$ is optimal, since the objective function of the principal is decreasing in t^1, and t^1 provides no incentives to exert effort.

The Lagrangian is then

$$\begin{aligned}
\mathcal{L} \quad = \quad & \theta \left[\mathrm{E}_{HH}(V|e_h) - \sum_{m=1}^{n} \tau^m (1 - P_{HH}(v_m)) \right] \\
& + (1 - \theta) \left[\mathrm{E}_{HL}(V|e_h) - \sum_{m=1}^{n} \tau^m (1 - P_{HL}(v_m)) \right] \\
& + \eta_1 \left[\sum_{m=1}^{n} \tau^m (Q(v_m) - P_{HH}(v_m)) \right] \\
& + \eta_2 \left[\sum_{m=1}^{n} \tau^m (Q(v_m) - P_{HL}(v_m)) \right] + \sum_{m=1}^{n} \mu_m \tau^m.
\end{aligned}$$

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The FOCs of this maximization program are

$$\text{(A-18)} \quad \frac{\partial L}{\partial \tau^m} = -\theta(1-P_{HH}(v_m)) - (1-\theta)(1-P_{HL}(v_m)) + \eta_1(Q(v_m)-P_{HH}(v_m)) + \eta_2(Q(v_m)-P_{HL}(v_m)) + \mu^m = 0.$$

FOSD implies that

$$\sum_{m=1}^{n} \tau^m (Q(v_m)-P_{HH}(v_m)) > \sum_{m=1}^{n} \tau^m (Q(v_m)-P_{HL}(v_m)),$$

so equation (A-6) cannot be binding. Therefore $\eta_1 = 0$. Equation (A-18) can then be rewritten as

$$-\frac{1}{CLR_{HL}(v_m)}\left[1-\theta+\theta\frac{1-P_{HH}(v_m)}{1-P_{HL}(v_m)}\right] + \eta_2 + \frac{\mu^m}{Q(v_m)-P_{HL}(v_m)} = 0,$$

which is equivalent to

$$-F(v_m,\theta) + \eta_2 + \frac{\mu^m}{Q(v_m)-P_{HL}(v_m)} = 0.$$

The rest of the proof is similar to that of Proposition 1. That is, let

$$\mathcal{M}'_n(\theta) = \{m| \quad F(v_m,\theta) \geq F(v_{m'},\theta) \quad \forall m' \in \{1,\ldots,n\}\},$$

and denote $K'_n(\theta)$ the number of elements of $\mathcal{M}'_n(\theta)$.

First, assume that $K'_n(\theta) = 1$, and denote m_n^θ, the unique element of $\mathcal{M}'_n(\theta)$. Using the same reasoning as in the proof of Proposition 1, we obtain that the unique solution of the system of FOCs is $\eta_2 = 1/F(v_{m_n^\theta},\theta)$, $\mu_{m_n^\theta} = 0$, and for all $m \neq m_n^\theta$, $\mu_m > 0$, implying that for all $m \neq m_n^\theta$, $\tau^m = 0$ and $\tau_{m_n^\theta} = c/[Q(v_{m_n^\theta}) - P_{HL}(v_{m_n^\theta})]$.

Second, assume that $K'_n > 1$. Proceeding as in the proof of Proposition 1, we obtain that for any $m_n^\theta \in \mathcal{M}'_n(\theta)$, there is a solution such that $m \neq m_n^\theta$, $\tau^m = 0$ and $\tau_{m_n^\theta} = c/[Q(v_{m_n^\theta}) - P_{HL}(v_{m_n^\theta})]$.

By assumption, $F(\cdot,\theta)$ reaches its global maximum at a unique point v_θ^{**}. Since P_{HH}, P_{HL}, and Q are continuous, so is $F(\cdot,\theta)$. Hence, as n tends to infinity, for any element $m_n^\theta \in \mathcal{M}'_n(\theta)$, $|v_\theta^{**} - v_{m_n^\theta}|$ tends to 0. Hence, $B(v_\theta^{**}, T_{HL}(v_\theta^{**}))$ is the unique pooling contract of the original continuous problem. Consequently, the equilibrium contract for an agent of type (H,L) is also unique and is given by $B(v_\theta^{**}, T_{HL}(v_\theta^{**}))$.

Proof of Part ii) First, we already know that the adverse-selection IC constraint of an agent of type (H,H) (constraint (A-7)) is binding. Consider as candidate for an equilibrium contract for an agent of type (H,H), a contract designed with a bonus plan $B(T,V)$ and a stock-option plan $O(\beta,\hat{v})$. This contract must satisfy the following conditions:

i) The expected compensation is equal to that of the pooling equilibrium, that is,

$$\text{(A-19)} \quad T[1-P_{HH}(V)] + \beta\int_{\hat{v}}^{\bar{v}} (v-\hat{v}) p_{HH}(v)dv = \frac{1-P_{HH}(v_\theta^{**})}{Q(v_\theta^{**})-P_{HL}(v_\theta^{**})}c.$$

ii) The agent of type (H,H) exerts effort, that is,

$$\text{(A-20)} \quad T[Q(V)-P_{HH}(V)] + \beta\int_{\hat{v}}^{\bar{v}} (v-\hat{v})[p_{HH}(v)-q(v)]dv \geq c.$$

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iii) Adverse-selection constraints (A-10) and (A-11) are satisfied, that is,

$$\text{(A-21)} \quad \frac{1-P_{HL}(v_\theta^{**})}{Q(v_\theta^{**})-P_{HL}(v_\theta^{**})}c-c \;\geq\; T[1-P_{HL}(V)]+\beta\int_{\hat{v}}^{\bar{v}}(v-\hat{v})p_{HL}(v)dv-c,$$

$$\text{(A-22)} \quad \frac{1-Q(v_\theta^{**})}{Q(v_\theta^{**})-P_{HL}(v_\theta^{**})}c \;\geq\; T[1-Q(V)]+\beta\int_{\hat{v}}^{\bar{v}}(v-\hat{v})q(v)dv.$$

Using equality (A-19), inequalities (A-21) and (A-22) can be rewritten as

$$\text{(A-23)} \quad T\left[\frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}[1-P_{HH}(V)]-[1-P_{HL}(V)]\right] + \beta\int_{\hat{v}}^{\bar{v}}\left[\frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}p_{HH}(v)-p_{HL}(v)\right](v-\hat{v})dv \;\geq\; 0 \quad \text{and}$$

$$\text{(A-24)} \quad T\left[\frac{1-Q(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}[1-P_{HH}(V)]-[1-Q(V)]\right] + \beta\int_{\hat{v}}^{\bar{v}}\left[\frac{1-Q(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}p_{HH}(v)-q(v)\right](v-\hat{v})dv \;\geq\; 0,$$

respectively. Let

$$A_{HL}(v) \;=\; \frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}[1-P_{HH}(v)]-[1-P_{HL}(v)] \quad \text{and}$$

$$A_Q(v) \;=\; \frac{1-Q(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}[1-P_{HH}(v)]-[1-Q(v)].$$

A sufficient condition for the two adverse-selection constraints to be satisfied simultaneously is that there exists an interval I such that for any bonus threshold $V \in I$, $A_Q(V) > 0$ and $A_{HL}(V) > 0$. In such a case, for any $\hat{v} \in (\underline{v}, \bar{v})$, there exists $\bar{\beta}_1(\hat{v}) > 0$ such that for any $\beta \in (0, \bar{\beta}_1(\hat{v}))$, inequalities (A-23) and (A-24) are satisfied.

We now show that the conditions stated in the proposition are sufficient for the interval I to be nonempty. First, note that $A_Q(v) > 0$ is equivalent to $CLR_{HH}(v) > CLR_{HH}(v_\theta^{**})$. Second, given that CLR_{HH} is positive and reaches its global maximum at $v_{HH}^* \in (\underline{v}, \bar{v})$, it implies that there exists an interval I_Q containing v_{HH}^* such that for any $v \in I_Q$, $A_Q(v) > 0$. Third, note that $HR_{HH}(v) > (<) HR_{HL}(v)$ on some interval is equivalent to having the function $(1-P_{HL}(\cdot))/(1-P_{HH}(\cdot))$ decreasing (increasing) in v in that interval. Given the assumption that there exists a unique state $v^o \in (\underline{v}, \bar{v})$ such that for any $v < v^o$, $HR_{HH}(v) < HR_{HL}(v)$ and for any $v > v^o$, $HR_{HH}(v) > HR_{HL}(v)$, it follows that the function $(1-P_{HL}(\cdot))/(1-P_{HH}(\cdot))$ is decreasing on $[\underline{v}, v^o]$ and increasing on $[v^o, \bar{v})$. As a consequence, there exists an interval I_{HL} such that for any bonus threshold $V \in I_{HL}$, $A_{HL}(V) > 0$. The interval I is then the intersection of I_Q and I_{HL}.

The next task is then to derive conditions under which this intersection is nonempty. First, note that $A_Q(v_\theta^{**}) = A_{HL}(v_\theta^{**}) = 0$. By continuity, it implies that if $v_\theta^{**} < \min(v_{HH}^*, v^o)$, there exists $\varepsilon > 0$ such that for any $v \in (v_\theta^{**}, v_\theta^{**} + \varepsilon)$, $A_Q(v) > 0$ and $A_{HL}(v) > 0$. Hence, $v \in I$, implying that I is nonempty. Similarly, if $v_\theta^{**} > \max(v_{HH}^*, v^o)$, there exists $\varepsilon' > 0$ such that for any $v' \in (v_\theta^{**} - \varepsilon', v_\theta^{**})$, $A_Q(v') > 0$ and $A_{HL}(v') > 0$. Hence, $v' \in I$, implying that I is nonempty.

Finally, we need to check that the IC constraint for the agent of type (H, H) is satisfied with the new contract. Using equation (A-19), then inequality (A-20) can be rewritten as

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$$\text{(A-25)}\qquad \left(\frac{1-P_{HH}(v_\theta^{**})}{Q(v_\theta^{**})-P_{HL}(v_\theta^{**})}\frac{[Q(V)-P_{HH}(V)]}{[1-P_{HH}(V)]}-1\right)c + \beta\int_{\hat{v}}^{\bar{v}}\left(\frac{1-Q(V)}{1-P_{HH}(V)}p_{HH}(v)-q(v)\right)(v-\hat{v})dv \quad \geq \quad 0.$$

In turn, this can be rewritten as

$$\text{(A-26)}\qquad \left(\frac{Q(v_\theta^{**})-P_{HH}(v_\theta^{**})}{Q(v_\theta^{**})-P_{HL}(v_\theta^{**})}\frac{CLR_{HH}(V)}{CLR_{HH}(v_\theta^{**})}-1\right)c + \beta\int_{\hat{v}}^{\bar{v}}\left(\frac{1-Q(V)}{1-P_{HH}(V)}p_{HH}(v)-q(v)\right)(v-\hat{v})dv \quad \geq \quad 0.$$

First, we know that for any $V \in I_Q$, $CLR_{HH}(V) > CLR_{HH}(v_\theta^{**})$. Second, since $P_{HH}(\cdot)$ dominates $P_{HL}(\cdot)$ in the FOSD sense, then for any v, $(Q(v)-P_{HH}(v))/(Q(v)-P_{HL}(v)) \geq 1$. Therefore, by continuity, for any $\hat{v}$, there exists $\bar{\beta}_2(\hat{v}) > 0$ such that if $\beta < \bar{\beta}_2(\hat{v})$, then inequality (A-26) is satisfied and so is the IC constraint.

As a consequence, a compensation contract consisting of a bonus plan $B(T,V)$ and a stock option plan $O(\beta,\hat{v})$ such that $V \in I$, $\beta \in \left(0, \min(\bar{\beta}_1(\hat{v}), \bar{\beta}_2(\hat{v}))\right)$ and equality (A-19) is satisfied in an equilibrium contract for an agent of type (H,H).

Consider now as a candidate equilibrium contract for an agent of type (H,H), a contract designed with a bonus plan $B(T,V)$ and a stock plan $S(\alpha)$. Note that the proof derived for the optimality of option contracts does not use the fact that $\hat{v} > \underline{v}$. Therefore, from a technical viewpoint, the proof still holds if we set $\hat{v} = 0$. Then, taking $\alpha \in \left(0, \min(\bar{\beta}_1(\underline{v}), \bar{\beta}_2(\underline{v}))\right)$. This completes the proof. □

3. Proof of Proposition 3

We build upon the proof of Proposition 2.

Consider, first, the case of a pure stock contract $S(\beta)$ for an agent of type (H,H). Using equality (A-19), then inequalities (A-21) and (A-22) can be rewritten as

$$\text{(A-27)}\qquad \frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}\mathrm{E}_{HH}(v)-\mathrm{E}_{HL}(v) \quad \geq \quad 0 \qquad \text{and}$$

$$\text{(A-28)}\qquad \beta\left[\frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}\mathrm{E}_{HH}(v)-\mathrm{E}_{HL}(v)\right] \quad \geq \quad c.$$

It implies that if c is small enough, then a necessary and sufficient condition for the two adverse-selection constraints to be satisfied is

$$\frac{1-P_{HL}(v_\theta^{**})}{\mathrm{E}_{HL}(v)} \quad \geq \quad \frac{1-P_{HH}(v_\theta^{**})}{\mathrm{E}_{HH}(v)}.$$

Consider now the case of a pure option contract $O(\hat{v},\beta)$. Proceeding as above, we deduce that equality (A-19), then inequalities (A-21) and (A-22), can be rewritten as

$$\text{(A-29)}\qquad \frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}\mathrm{E}_{HH}(\max(0,v-\hat{v}))-\mathrm{E}_{HL}(\max(0,v-\hat{v})) \quad \geq \quad 0 \qquad \text{and}$$

$$\text{(A-30)}\qquad \beta\left[\frac{1-P_{HL}(v_\theta^{**})}{1-P_{HH}(v_\theta^{**})}\mathrm{E}_{HH}[\max(0,v-\hat{v})]-\mathrm{E}_{HL}[\max(0,v-\hat{v})]\right] \quad \geq \quad c.$$

It implies that if c is small enough, then a necessary and sufficient condition for the two adverse-selection constraints to be satisfied is that

$$\frac{1-P_{HL}(v_\theta^{**})}{\mathrm{E}_{HL}[\max(0,v-\hat{v})]} \quad \geq \quad \frac{1-P_{HH}(v_\theta^{**})}{\mathrm{E}_{HH}[\max(0,v-\hat{v})]}. \quad \square$$

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4. Proof of Lemma 1

For any type of internal candidate, the first task is to compare the firm value generated by this internal candidate with the firm value generated by an external candidate. The expected firm value generated by this latter candidate is

$$\mathcal{V}_{EXT} = \theta \mathrm{E}_{HH}(V|e_h) + (1-\theta)\mathrm{E}_{HL}(V|e_h) - F(v_\theta^{**}, \theta), \tag{A-31}$$

while the expected firm value generated by an internal candidate of type (i, j) is

$$\mathcal{V}_{ij} = \mathrm{E}_{ij}(V|e_h) - [1 - P_{ij}(v_{ij}^*)]T_{ij}(v_{ij}^*), \tag{A-32}$$

where $v_{ij}^* \in \operatorname{argmax}_v 1/CLR_{ij}(v)$.

The difference $\mathcal{V}_{ij} - \mathcal{V}_{EXT}$ can then be written as

$$\begin{aligned}\mathcal{V}_{ij} - \mathcal{V}_{EXT} &= \theta[\mathrm{E}_{ij}(V|e_h) - \mathrm{E}_{HH}(V|e_h)] + (1-\theta)[\mathrm{E}_{ij}(V|e_h) - \mathrm{E}_{HL}(V|e_h)] \\ &\quad - \frac{c}{CLR_{ij}(v_{ij}^*)} + \frac{c}{CLR_{HL}(v_\theta^{**})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v_\theta^{**})}{1 - P_{HL}(v_\theta^{**})}\right].\end{aligned} \tag{A-33}$$

First, note that if P_{ij} dominates P_{HL} in the FOSD sense, then for any v $CLR_{ij}(v) \geq CLR_{HL}(v)$.

If the internal candidate is of type (H, H), then $\mathcal{V}_{HH} - \mathcal{V}_{EXT} > 0$. As a consequence, an internal candidate is always hired.

Now, assume that the internal candidate is of type (L, H) and consider, first, the *FS*-regime. The expected compensation of the external candidate is always larger than that of the internal candidate since, by definition

$$\frac{c}{CLR_{LH}(v_{LH}^*)} < \frac{c}{CLR_{LH}(v_\theta^{**})} < \frac{c}{CLR_{HL}(v_\theta^{**})}, \quad \text{and}$$

$$\frac{c}{CLR_{HL}(v_\theta^{**})} \leq \frac{c}{CLR_{HL}(v_\theta^{**})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v_\theta^{**})}{1 - P_{HL}(v_\theta^{**})}\right],$$

since for all v, $(1 - P_{HH}(v))/(1 - P_{HL}(v)) \geq 1$.

Let p_i and CLR_i $(i = 1, 2)$ be the probability distribution and the CLR function associated to the cumulative distribution function P_i, and $\mathrm{E}_i(V) = \int_{\underline{v}}^{\bar{v}} vp_i(v)dv$. Under the *FS*-regime,

$$\begin{aligned}\mathcal{V}_{LH} - \mathcal{V}_{EXT} = \Delta_{\mathrm{FS}}\mathcal{V} &= \theta[\mathrm{E}_1(v) - \mathrm{E}_{HH}(v|e_h)] + (1-\theta)[\mathrm{E}_1(v) - \mathrm{E}_2(v)] \\ &\quad - \frac{c}{CLR_1(v_1^*)} + \frac{c}{CLR_2(v_{\theta,2}^{**})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v_{\theta,2}^{**})}{1 - P_2(v_{\theta,2}^{**})}\right],\end{aligned}$$

while under the *G*-regime,

$$\begin{aligned}\mathcal{V}_{LH} - \mathcal{V}_{EXT} = \Delta_G\mathcal{V} &= \theta[\mathrm{E}_2(V) - \mathrm{E}_{HH}(V|e_h)] + (1-\theta)[\mathrm{E}_2(V) - \mathrm{E}_1(V)] \\ &\quad - \frac{c}{CLR_2(v_2^*)} + \frac{c}{CLR_1(v_{\theta,1}^{**})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v_{\theta,1}^{**})}{1 - P_1(v_{\theta,1}^{**})}\right].\end{aligned}$$

To get the desired result, it is sufficient to show that $\Delta_G\mathcal{V} - \Delta_{\mathrm{FS}}\mathcal{V} < 0$. Let

$$F_i(v, \theta) = \frac{c}{CLR_i(v)}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v)}{1 - P_i(v)}\right], \qquad i = 1, 2,$$

and $v_{\theta,i}^{**}$ the unique state at which $F_i(v, \theta)$ reaches its global minimum.

Then,

$$\Delta_G \mathcal{V} - \Delta_{\text{FS}} \mathcal{V} = -(2-\theta)(\text{E}_1(V) - \text{E}_2(V)) + F_1(v^{**}_{\theta,1}, \theta) - F_2(v^{**}_{\theta,2}, \theta) + \frac{c}{CLR_1(v^*_1)} - \frac{c}{CLR_2(v^*_2)}.$$

Given that P_1 dominates P_2 in the FOSD sense, $F_1(v^{**}_{\theta,1}, \theta) < F_2(v^{**}_{\theta,2}, \theta)$ and $c/(CLR_1(v^*_1)) < c/(CLR_2(v^*_2))$. Hence, we have the desired result. □

5. Proof of Proposition 4

First, assume that the internal candidate hired under the *FS*-regime is of type (H, H). As established by Lemma 1, this candidate is also chosen under the *G*-regime, and his expected compensation is not affected by a change of regime.

Second, assume that the internal candidate is of type (L, H) and is hired under both regimes. His expected compensation is $c/CLR_1(v^*_1)$ under the *FS*-regime, while it is $c/CLR_2(v^*_2)$ under the *G*-regime. Given that P_1 dominates P_2 in the FOSD sense, then for any v, $CLR_1(v) \geq CLR_2(v)$, then the compensation increases when a shift from the *FS*-regime to the *G*-regime occurs.

Third, assume that the internal candidate of type (L, H) is hired in the *FS*-regime but an external candidate is hired under the *G*-regime. The expected CEO compensation under the *FS*-regime is $c/CLR_1(v^*_1)$, while under the *G*-regime it is

$$\frac{c}{CLR_1(v^{**}_{\theta,1})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v^{**}_{\theta,1})}{1 - P_1(v^{**}_{\theta,1})}\right].$$

Given that P_{HH} dominates P_1 in the FOSD sense, then $(1 - P_{HH}(v^{**}_{\theta,1})) > (1 - P_1(v^{**}_{\theta,1}))$. Furthermore, given the definitions of $v^{**}_{\theta,1}$ and v^*_1, $c/CLR_1(v^*_1) < c/CLR_1(v^{**}_{\theta,1})$. Hence, the expected compensation of the hired candidate is larger under the *G*-regime than under the *FS*-regime. This proves part i) of the proposition.

Now, given that P_{HH} dominates P_1 in the FOSD sense, it implies that

$$\frac{c}{CLR_{HH}(v^*_{HH})} < \frac{c}{CLR_1(v^{**}_{\theta,1})}\left[(1-\theta) + \theta\frac{1 - P_{HH}(v^{**}_{\theta,1})}{1 - P_1(v^{**}_{\theta,1})}\right].$$

As a consequence, if external candidates are selected under the *G*-regime, their compensation is larger than that of internally selected candidates under the *G*-regime, since only internal candidates of type (H, H) are promoted as CEO in the *G*-regime in this case (part ii) of the proposition). This completes the proof. □

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