Stock Option Vesting Conditions, CEO Turnover, and Myopic Investment

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Abstract

This paper analyzes the optimal design of stock option vesting conditions when the CEO faces a risk of being replaced at an interim date. First, I show that long vesting terms do not necessarily discourage but in fact can encourage short-termism. Second, the model demonstrates that the optimal vesting schedule involves balancing incentives for managerial effort with incentives for long-term investment. Due to this trade-off, overinvestment in myopic projects can arise from optimal contracting and is not necessarily an artifact of faulty pay arrangements. The study generates new empirical predictions regarding the determinants and impacts of stock option vesting terms in contract design.

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1 Introduction

The recent financial crisis has renewed interest in the relation between executive pay arrangements and managerial myopia in corporations. While there is agreement that linking executive pay to long-term firm performance mitigates managerial short-termism (e.g., Bebchuk and Fried 2010; Bhagat and Romano 2010), it is less clear how and to which extent such a link should be established.

This question has lead to a growing literature on the optimal mix of short-term and long-term pay for corporate executives, which includes the works by Bolton et al. 2006, Peng and Roell 2009, Edmans et al. 2010, and Gopalan et al. 2010. In this literature, granting executives equity based compensation with long vesting periods is generally viewed as an effective means to link CEO pay to long-term firm performance and to alleviate short-termist behavior. This is not to say that optimal contracts consist solely of long-term equity compensation. Early vesting of equity awards can be part of an optimal contract because, for example, managers are risk-averse or have liquidity concerns, or incumbent shareholders are short-term oriented.[1]

In this paper, I depart from the existing literature by considering a setting in which the CEO is subject to being replaced at an intermediate date and examine the effects of CEO turnover on optimal contracting. The possibility of CEO turnover has implications not only for the relation between stock option vesting terms and myopic CEO behavior but also for the equilibrium level of myopia that arises in optimal contracting.

[1] See Walker (2010) for a recent overview of the myopia literature. See also Brisley (2006) and Laux (2010). While these studies do not focus on short-termism, they show that allowing early vesting of stock options can be beneficial in that it improves executives' project selection and termination decisions.

Specifically, I consider a setting in which a board hires a new CEO whose tasks are to acquire firm specific human capital and to decide how to allocate a fixed amount of resources between a short-term and a long-term project. Following Holmstrom (1982, 1999), I assume that the CEO's ability is unknown to all parties. However, the board is able to draw inferences about the CEO's talent from the firm's short-term performance. Based on this information, the board decides whether or not to replace the incumbent.

I first analyze a first-best setting in which the CEO's actions are observable and contractible. Although the long-term project is assumed to be strictly more profitable than the short-term project, it is generally not first-best optimal to invest exclusively in the long-term project. Short-term projects generate early results and thus provide timely feedback about CEO talent. This feedback enables the board to update beliefs about talent and to make appropriate CEO replacement decisions. As an example consider the promotion process in academia. When a new assistant professor is hired, the talent of the new hire is rather uncertain. Even when the goal of the department is to generate long-term ground-breaking research, it can still be optimal to also encourage less important shorter-term research projects in the beginning of the new colleague's career. Early failures/successes provide early feedback about talent, which allows for timely replacement decisions.

Consider now the case where the CEO's actions are not observable. The board's task is to induce the CEO to work on acquiring firm specific expertise and to make an appropriate investment allocation. In the present setting, the optimal incentive contract consist solely of stock options.[2] The effectiveness of the option contract

[2] In the Appendix, I solve for the optimal unrestricted contract and show that it can be replicated by a stock option pay plan.

depends on the details of the vesting terms and exercising restrictions. The vesting period determines when the CEO has earned the stock options. Thus, after vesting, the CEO can keep the options even when he leaves the firm. Exercising restrictions further limit the CEO's ability to exercise options and sell the underlying shares after they have vested. Given that extended vesting terms already restrict the exercising of options, the literature typically does not distinguish between vesting terms and exercising restrictions.[3] However, this distinction is important if the CEO is subject to replacement at an intermediate date. While in the present setting it is always optimal to place restrictions on the CEO's ability to exercise options that vest at an early date, the optimal design of the vesting conditions, which is the focus of this paper, is more subtle.[4]

Granting stock options with long vesting periods implies that the CEO forfeits his option compensation when fired at an interim date due to poor performance. Consequently, a long vesting horizon biases the CEO in favor of remaining with the firm. This is beneficial from an effort incentive perspective because the threat of losing his position and forfeiting unvested options provides the CEO with strong incentives to do a good job. But at the same time, the threat of option forfeiture distorts the CEO's investment decision toward short-term projects. The CEO knows that the board will rely on short-term results to update beliefs about managerial talent when making the replacement decision. To reduce the probability of being fired and forfeiting unvested options, the CEO has to impress the board and boost

[3] See, e.g., Peng and Roell (2009), Edmans et al. (2010), Gopalan et al. (2010).

[4] Note that there are alternatives to restricted option exercising. If the board sets a sufficiently high exercise price or requires the CEO to publicly disclose his intention to cash out options in advance, then the optimal contract can be implemented without imposing limits on option exercising.

its perception about his ability. This can be done by allocating excessive resources to short-term projects. Thus, in the presence of potential CEO turnover, long vesting terms do not link CEO pay to long-term but short-term firm performance, encouraging short-termism.

The board can address excessive managerial myopia by allowing a fraction of the stock options to vest early. Early vesting in combination with restricted exercising has two positive effects on the CEO's investment decision: First, the CEO will put less weight on short-term results because he retains the options that have already vested even when he is fired due to poor performance; second, given that the (ousted) CEO is unable to immediately exercise his vested options, he has an additional incentive to focus on long-term results ex ante. Note that the combination of early vesting and restricted exercising is strictly preferred over cash severance payments, because severance pay can only replicate the first effect, but not the second.

In principle, by fine tuning the vesting terms, the board can fully eliminate managerial myopia and induce the first-best allocation of resources. However, this is in general not optimal because early vesting lowers the penalty associated with being fired and hence adversely affects the CEO's effort choice. Consequently, when designing the optimal vesting terms, the board balances the desire to effectively induce managerial effort with the desire to induce appropriate investment decisions. This trade-off leads to optimal contracts that (i) allow a positive fraction of the CEO's stock options to vest early and (ii) induce the CEO to allocate excessive resources to the short-term project relative to first-best. One immediate implication of this result is that managerial myopia is not necessarily an artifact of faulty pay arrangements or impatient shareholders but can arise endogenously from optimal contracting when shareholders face a multitask agency problem in the spirit of Holmstrom and Milgrom (1991). Regulatory intervention that attempts to curtail myopic behavior in organizations, for example by imposing restrictions on minimum vesting periods, can be counterproductive and further foster short-termism.

The model generates predictions that relate the firm's investment opportunities to the optimal design of executive equity compensation and the likelihood and quality of CEO turnover. Specifically, the model predicts that in firms and industries with more valuable long-term investment opportunities (such as pharmaceutical or energy companies), (i) the board allows a larger fraction of the CEO's option to vest early, (ii) the size of the CEO's option grant is larger, (iii) the likelihood of forced CEO turnover is higher, and (iv) the average quality of the CEO in charge in the long run is lower than in firms with less valuable long-term investment opportunities.

The model suggests that the link between stock option vesting terms and executives' investment horizon depends crucially on whether or not the CEO is subject to being replaced at an interim date. In firms in which CEO turnover is not an issue because, for example, the CEO is well entrenched and already has established that he is the right person to run the firm, the standard argument applies and long vesting periods effectively link executive pay to long-term firm performance.[5] However, in firms in which the CEO is not entrenched because he is a relatively new (outside) hire with uncertain talent and fit (as assumed in the model), long vesting periods can backfire and encourage myopic behavior. These findings suggest that empirical studies that investigate the determinants of vesting schedules and investment strategies should distinguish between these two types of firms. Assuming that boards design optimal compensation contracts, the model predicts that both the fraction of stock options that vest early and the level of short-term investment is larger in firms in

[5]Of course, the same can be achieved by restricting the early exercising of already vested options.

which the incumbent is a new hire with uncertain talent or fit than in firms in which the incumbent is well established and entrenched.

Myopic behavior in organizations has been discussed extensively in other settings. For example, Narayanan (1985), Stein (1989), Bebchuk and Stole (1993), and Fisher and Verrecchia (2000) show that managers' desire to enhance short-term stock prices or personal reputation can lead to equilibria where executives engage in short-termist actions at the detriment of long-term firm value. Von Thadden (1995) studies contracting between an outside investor and an entrepreneur and shows that the threat of early project termination by the investor can distort the entrepreneur's project choice. Feltham and Xie (1992), Dutta and Gigler (2002), and Goldman and Slezak (2006) study contracting and short-termism (which takes the form of accounting manipulation) in settings in which CEO pay can only be linked to short-term performance measures such as interim stock prices or interim earnings reports. In contrast to these studies, the current paper focuses on optimal long-term equity pay arrangements and analyzes the effects of stock option vesting terms on executives' investment and effort choices. The model generates new empirical predictions regarding the determinants of CEO equity pay arrangements, CEO turnover, and short-termism in organizations.

Section 2 outlines the model and Section 3 analyzes the first-best case. Section 4 presents the main results and Section 5 discusses the empirical implications of the model. Section 6 concludes. All proofs are in the appendix.

2 Model

Consider a setting with three risk-neutral parties: shareholders, the board of directors, and the CEO. The board of directors represents the interests of shareholders and is responsible for designing the incentive contract for the CEO and replacing the CEO if necessary.

Timing: There are three dates t_0, t_1, and t_2. In the beginning of the game (date t_0), the board hires a new CEO and offers him an incentive pay plan. After signing the contract, the CEO works on acquiring firm specific expertise and decides how to allocate a fixed amount of resources among a short-term and a long-term project. The CEO's effort and investment choices influence the firm's cash flows at dates t_1 and t_2, where t_1 represents the short-run and t_2 the long-run horizon of the firm. At date t_1, short-term cash flows x_1 are realized and the board decides whether or not to replace the incumbent with a new CEO. In case the incumbent is retained, long-term cash flows are realized and the game ends. In case the incumbent is replaced, the board hires a new CEO and offers him a pay plan. After accepting the contract, the new CEO works on acquiring firm specific expertise. At date t_2, long-term cash flows, x_2, are realized and the game ends.

Effort choice: After the CEO is hired and signed the contract (the details of the contract are discussed below), he can take an unobservable action, $e = \{e_L,\ e_H\}$, to enhance his expected ability to perform in the firm. This action can be viewed as an investment in firm specific human capital or expertise. If the CEO chooses the high action, $e = e_H$, he will be a good fit, $F = G$, with probability $p > 0$ and a bad fit, $F = B$, with probability $(1 - p)$. If the CEO shirks and chooses the low action, $e = e_L$, he will be a bad fit, $F = B$, for sure. While it is common knowledge that high effort increases the CEO's expected ability, neither the CEO nor the board can observe the realization of F. The private cost associated with effort e is given by $v(e)$. For simplicity and without loss of generality, I assume that $v(e_H) = k$ and $v(e_L) = 0$.

If the incumbent CEO is replaced after short-term cash flows are realized (as discussed in detail below) the board hires a replacement. Similar to the initial CEO, the new CEO can choose an unobservable action, $e_N = \{e_L, e_H\}$, to increase his expected ability to perform in the firm. As before, the new CEO can be either good, $T_N = G$, or bad, $T_N = B$, with $Pr[T_N = G|e_N = e_H] = p$ and $Pr[T_N = G|e_N = e_L] = 0$. The personal cost of effort is given by $v_N(e_N)$, with $v_N(e_H) = k_N$ and $v_N(e_L) = 0$. Assume that the effort cost is sufficiently small such that shareholders always wish to induce the incumbent CEO and, in case of CEO turnover, the new CEO to invest in firm specific human capital. Given that the replacement CEO cannot succeed if he does not invest in firm specific expertise, the new CEO is not able to capture any rents and the shareholders' expected cost of inducing $e_N = e_H$ is simply k_N. Thus, k_N can be interpreted as a direct cost of replacing the incumbent because this cost only occurs in case of CEO turnover.

Investment and cash flows: The CEO has one dollar of capital available and can invest in a long-term and a short-term project. Assume that the cost of capital is zero. Let $I \leq 1$ denote the capital allocated to the long-term project. Consequently, $1 - I$ is the amount invested in the short-term project. Assume that the CEO's investment decision is non-observable and non-contractible.

The firm generates cash flows in two subsequent periods, i.e., at t_1 and t_2. The cash flow in period t_i ($i = 1, 2$), denoted $x_i \in \{X_i, 0\}$, is either high, $x_i = X_i > 0$, or low, $x_i = 0$. The probability of success in period t_i depends on the capital allocation and the fit of the CEO in charge in that period. If the CEO in charge is a bad fit, then cash flows in this period are low for sure. If the CEO in charge is a good fit, the probability of success is a function of the initial investment decision. Allocating more capital to the short-term (long-term) project increases the expected return in the first-period (second-period). Specifically, the probability of success at date t_1 is $(a_1 + s_1(1 - I))$

and the probability of success at date t_2 is $(a_2 + s_2 I)$, where $a_1, a_2, s_1, s_2 \in (0, 0.5)$ are exogenous parameters. Thus, given the CEO in charge is a good fit, the expected return of investment over both periods is $(a_1 + s_1(1 - I)) X_1 + (a_2 + s_2 I) X_2$. The parameter $a_1(a_2)$ represents the probability of success at t_1 (t_2) that is independent of the investment decision and due to the firm's typical operations. Consequently, first-period cash flows are informative about the CEO's talent even when the CEO exclusively invests in the long-term project $(I = 1)$.

I assume that short-term cash flows, x_1, are paid out immediately to shareholders as dividends. Using the alternative assumption that the firm retains the cash flows x_1 until the final period (date t_2) would have no effect on the cost of the incentive scheme or the equilibrium decisions but would render the optimal stock option plan slightly more complex.[6]

To focus on dysfunctional myopic behavior, I assume that the long-term project is strictly more productive than the short-term project. Specifically, I assume that $s_2 X_2 - s_1 X_1 > s_1 k_N$; otherwise, the incentive friction with respect to the investment decision becomes trivial and the optimal contract achieves the first-best outcome (see the appendix for details).

CEO replacement: When the board observes the realization of the first-period outcome, x_1, it decides whether or not to replace the incumbent with a new CEO. The board is unable to precommit to a specific replacement policy up front and hence replaces the CEO whenever this is ex post optimal. Conditional on observing short-term success, $x_1 = X_1$, the board knows that the incumbent is a good fit and retains him. Conditional on observing short-term failure, $x_1 = 0$, the board revises

[6] Specifically, if there are no intermediate dividend payments and X_1 is relatively large compared to X_2, the optimal contract may require the resetting of stock options to provide optimal incentives.

the probability that the incumbent is a good fit downwards to $Pr[F = G|x_1 = 0] = \frac{p(1-s_1(1-I)-a_1)}{(p(1-s_1(1-I)-a_1)+(1-p))} < p$. Throughout the paper, I focus on parameter constellations for which it is Pareto efficient to replace the incumbent in case of short-term failure. Otherwise, if it is efficient to always retain the incumbent, the model becomes trivial. This assumption requires that conditional on short-term failure, $x_1 = 0$, the expected cash flows under a new CEO minus the additional effort cost k_N exceed the expected cash flows under the incumbent CEO. Note that the probability of long-term success depends on the initial capital allocation even when a new CEO takes over. Formally, CEO replacement is optimal if and only if[7]

$$p\,(a_2 + s_2 I)\,X_2 - k_N > Pr[F = G|x_1 = 0]\,(a_2 + s_2 I)\,X_2. \tag{1}$$

Note that condition (1) contains the equilibrium investment level I, which is itself a function of the model's parameters and determined later in this paper. However, it is straightforward to show that $\frac{p(1-p)a_1}{(1-pa_1)}a_2 X_2 > k_N$ is a sufficient condition for (1). Thus, replacing the incumbent in case of poor interim performance is efficient if the direct cost of CEO turnover, k_N, is relatively small and a_1, a_2, and X_2 are relatively large. While the first part of this result is obvious the second part can be explained as follows: for a larger parameter a_1, early failure becomes a more accurate indicator that the incumbent is a low talent and larger values of a_2 and X_2 render it more important

[7] When making the replacement decision, the board will also take into consideration the difference in pay for the incumbent CEO when he is dismissed and when he is retained. However, this will not have an effect on CEO turnover: conditional on observing bad news, if the incumbent's expected compensation is higher when he stays in the firm than when he leaves, then it is even more beneficial for shareholders to replace the incumbent and if the opposite is true, then the incumbent would voluntarily leave the firm to make room for a new CEO.

to have a talented CEO in charge of the second period. Both effects increase the value of replacing the incumbent in case of poor performance.

Contracting: The company is publicly traded and the value of the assets-in-place is exogenously given by $A > 0$. There is one issued share of stock, which is held by initial shareholders. The CEO is protected by limited liability such that payments to the CEO must be nonnegative. The reservation utility of the CEO is normalized to zero.

I consider contracts where the only available incentive instrument is stock options.[8] Restricting attention to stock option plans is without loss of generality because there is no other more general contract that can yield a higher payoff to shareholders. To prove this claim, I solve for the optimal unrestricted contract in the appendix and show that it can be replicated by a stock option pay plan.

In the current setting, it is natural to consider stock option plans instead of, say, state contingent bonus payments for one reason: As will be discussed in the main part of the paper, the optimal contract restricts the CEO's freedom to exercise his (vested) options regardless of whether or not he loses his position. A state contingent bonus plan can replicate these incentives only if the board promises to reward the CEO for results that are realized long after he has been fired.

The CEO's compensation contract is publicly observable and has the form $c = (\beta, E, \alpha, \beta_V, \beta_E)$. The contract specifies the number of options granted to the CEO in t_0, denoted β, the exercise price, denoted E, and the fixed salary, denoted α. Note that the fixed salary is always zero in the optimal solution and hence is omitted in what follows. The contract also determines the terms and conditions under which the

[8] This includes stock compensation because stock is equivalent to an option with an exercise price of zero.

options vest and may be exercised. Specifically, β_V denotes the number of options that vest early, i.e., at date t_1. The remaining options, $\beta - \beta_V$, vest at t_2. In addition, β_E denotes the number of already vested options that can be exercised at t_1. The remaining options $(\beta - \beta_E)$ can be exercised at t_2.

Upon vesting, the CEO owns the stock options. Thus, if fired at date t_1, the CEO retains the options that have already vested (β_V) and forfeits the remaining options $(\beta - \beta_V)$. An alternative to early vesting $(\beta_V > 0)$ is accelerated vesting upon termination. Under accelerated vesting provisions, a fraction of the CEO's options vest immediately when he is dismissed. In the setting discussed here, accelerated vesting and early vesting have identical effects.[9]

3 First-Best Solution

In this section, I consider the optimal investment decision in a first-best world where the CEO's choices of e and I are observable and contractible. In this case, the board can implement any levels of e and I through a forcing contract. To ensure participation, the board needs to compensate the incumbent CEO (and, in case of CEO turnover, the replacement CEO) for his effort cost.

The board's expected utility can be written as

$$U_{Board} = \left(s_1(1-I) + a_1\right) pX_1 + \left(s_2 I + a_2\right) pX_2 - k \tag{2}$$
$$+ \left(s_2 I + a_2\right) X_2 \left(s_1(1-I) + a_1\right) p(1-p) - \left(1 - p\left(s_1(1-I) + a_1\right)\right) k_N.$$

The first line in (2) captures the shareholders' expected payoff (including the initial

[9] In his study of 179 turnover cases, Yermack (2006) finds that departing executives generally forfeit stock options and shares that have not yet vested unless the executives have attained a minimum retirement age.

effort cost) if the board does not have the option to replace the incumbent CEO at date t_1. The second line in (2) captures the ex ante value of the option to replace the CEO. The ex ante value of the replacement option can be rewritten to

$$\Pr\left[x_1=0\right]\left(\frac{p\left(1-p\right)\left(a_1+s_1(1-I)\right)}{\left(p\left(1-s_1(1-I)-a_1\right)+(1-p)\right)}\left(a_2+s_2I\right)X_2-k_N\right), \tag{3}$$

where $\Pr\left[x_1=0\right]=\left(p\left(1-s_1(1-I)-a_1\right)+(1-p)\right)$ is the probability that the CEO will be removed at date t_1 and the term in brackets in (3) is the ex post value of CEO turnover in the event of poor short-term performance. Note that the term in brackets in (3) is positive due to assumption (1).

Taking the first-order condition of (2) with respect to I yields the first-best investment decision

$$I^{FB}=\frac{1}{2}-\frac{1}{2}\frac{s_1a_2-s_2a_1}{s_1s_2}+\frac{1}{2}\frac{s_2X_2-s_1X_1-s_1k_N}{s_1s_2X_2\left(1-p\right)}, \tag{4}$$

which can be rewritten to

$$I^{FB}=\left[\frac{1}{2}-\frac{1}{2}\frac{s_1a_2-s_2a_1}{s_1s_2}-\frac{1}{2}\frac{s_1k_N}{s_1s_2X_2\left(1-p\right)}\right]+\frac{1}{2}\frac{s_2X_2-s_1X_1}{s_1s_2X_2\left(1-p\right)}. \tag{5}$$

Note that the second-order condition for a maximum is satisfied and given by

$$-2X_2ps_1s_2\left(1-p\right)<0.$$

The term in square brackets in (5) represents the level of I that maximizes the ex ante value of the option to replace the CEO. In the absence of this term, that is, if CEO turnover is not possible or not optimal, then the first-best investment level is a corner solution and determined by $I=1$ since the long-term project is strictly more profitable than the short-term project.

Based on the firm's short-term performance, the board draws inferences about the incumbent CEO's talent and decides whether or not to replace him with a new CEO.

While good interim performance is a perfect signal that the CEO is a high talent ($F = G$), observing poor performance is less informative: short-term failure is either the result of low talent ($F = B$) or the result of a long-term oriented investment strategy. However, by allocating more capital to the myopic project the board can increase the information content of short-term failure. Intuitively, if the firm spends a lot of resources for short-term projects and still fails in the short run, the board can be confident that the incumbent's talent is low. To see this formally, note that the probability that the CEO is a high talent given poor interim performance, $Pr[F = G|x_1 = 0] = \frac{p(1-s_1(1-I)-a_1)}{(p(1-s_1(1-I)-a_1)+(1-p))}$, declines with the level of short-term investment $(1 - I)$. As a result, larger investments in myopic projects improve the board's turnover decision in that it reduces the likelihood that good-type CEOs are mistakenly replaced.

However, this does not imply that the ex ante value of the replacement option is maximized if the board invests solely in the myopic project. Given that improved CEO turnover decisions increase the expected probability that the CEO in the second period is a high talent, the board wishes to shift production from the first period to the second period by investing more in the long-term project.

Thus, an increase in the short-term investment has two opposing effects on the ex ante value of the replacement option: it increases the information content of short-term cash flows leading to better replacement decisions, but decreases the advantage of having a talented CEO in charge of the second period by shifting production away from the second period.

Proposition 1 *In the first-best solution it holds that $I^{FB} \leq 1$. Assuming an interior solution, the first-best investment in the short-term project increases (I^{FB} declines) if X_2/X_1 declines, s_2/s_1 declines, k_N increases, and a_2/a_1 increases.*

The first-best investment in the long-term project increases with long-term cash flows X_2. The reasoning behind this result is more subtle than is apparent at first glance because an increase in X_2 involves direct and indirect effects. The direct effect is clear; if X_2 increases, the long-term project becomes more productive relative to the short-term project which leads to an increase in I^{FB}. There is also an indirect effect that works in the opposite direction. If X_2 increases, it becomes more important to have a talented CEO in charge of the second period, which makes it optimal to increase the level of short-term investment to improve the turnover decision. However, the first effect always dominates the second, resulting in a positive relation between X_2 and I^{FB}.

When k_N increases, replacing the incumbent CEO becomes more costly to the firm. Thus, for larger values of k_N, the board allocates more capital to the short-term project to reduce the probability that talented executives are accidentally replaced.

An increase in a_2 increases second-period production. Thus, for large values of a_2, it becomes more important that the CEO in charge in the long run is a good fit. As a result, the board allocates more capital to the short-term project to induce a better replacement decision at t_1, implying that I^{FB} declines with a_2.

An increase in a_1 increases first-period production and hence renders short-term cash flows more informative about CEO talent ($Pr[F = G|x_1 = 0]$ declines with a_1). Thus, for larger values of a_1, the board is able to make better replacement decisions, which increases the probability that the CEO in charge of the second period is a good fit. To exploit the fact that the long-run CEO is likely a high-talent, the board shifts capital from the short-term project to the long-term project; hence I^{FB} increases with a_1.

4 Main Results

I now consider the original setting in which the CEO's actions are unobservable. The board's task is to design a compensation contract that induces the CEO to work on acquiring firm specific expertise and to make an appropriate investment decision. Consider the contract outlined in the model section, $c = (\beta, E, \beta_V, \beta_E)$. I first discuss a benchmark case where early vesting of the CEO's stock options is prohibited, i.e., where $\beta_V = 0$. I then analyze the optimal contract.

4.1 Benchmark: Long-Term Vesting

As a benchmark it is useful to study the case where early vesting is not permitted, $\beta_V = 0$. This contract can be viewed as a simple long-term option plan because the options vest and can be exercised only after long-term cash flows, x_2, are realized. The goal of this section is to show that such a contract fails to induce appropriate investment decisions when the CEO faces a risk of being replaced at an intermediate date.

The CEO obtains β options in the beginning of the game. Due to the long vesting horizon, the CEO forfeits his option compensation if he is fired at date t_1. If he is retained, the value of his option compensation at date t_2 is $\beta(A + x_2 - E)$ since intermediate cash flows x_1 have already been cashed out to initial shareholders.

The level of the exercise price, E, must be sufficiently high to ensure that the CEO's stock options have value if and only if the firm succeeds in the long run; that is, it must hold that $E \geq A$ (recall A are the assets in place). For simplicity, I assume in what follows that $E = A$. Thus, in case of first-period and second-period success, the value of the CEO's option compensation is βX_2.

The CEO's ex ante utility if he chooses high effort, $e = e_H$, can now be stated as

$$U_{CEO}^{NV}(\beta) = p\,(s_1(1-I)+a_1)\,(s_2 I + a_2)\,\beta X_2 - k. \tag{6}$$

If the CEO shirks and chooses low effort, $e = e_L$, short-term cash flows will be low with certainty, which leads to his replacement and the forfeiture of his equity compensation. Given that the CEO cannot reap any benefits by shirking he is not able to obtain any rents in equilibrium and the effort incentive constraint is identical to the CEO's participation constraint and given by $U_{CEO}^{NV}(\beta) \geq 0$. To ensure participation (and high effort) the board must ensure that the expected value of the option award equals the cost of effort, $U_{CEO}^{NV}(\beta) = 0$.

Consider now the CEO's optimal investment decision, denoted I^{NV}. Taking the first-order condition of (6) with respect to I leads to

$$I^{NV} = \frac{1}{2} - \frac{1}{2}\frac{s_1 a_2 - s_2 a_1}{s_1 s_2}. \tag{7}$$

Condition (7) shows that the long-term equity contract discussed here is not effective in encouraging the CEO to focus on the firm's long-term goals. Quite the contrary is the case. The incumbent knows that the board will rely on short-term results to update beliefs about CEO talent when making the replacement decision. The CEO also knows that if he is fired at date t_1 he will forfeit all his options because they have not yet vested. Thus, the combination of potential replacement and long vesting terms creates an incentive for the CEO to boost the board's perception about his ability. The CEO can do so by allocating excessive resources to the short-term project, neglecting long-term investment opportunities. Thus, in the presence of potential CEO turnover, long vesting periods do not tie CEO pay to long-term but short-term firm performance, inducing short-termism.

Comparing the CEO's investment choice, I^{NV}, with the first-best investment level, I^{FB}, leads to the next proposition.

Proposition 2 *Stock option grants with long vesting terms* ($\beta_V = 0$) *induce the CEO to overinvest in the short-term project relative to first-best,* $I^{NV} < I^{FB}$.

4.2 Optimal Contracting

I now turn to the optimal stock option contract c. The focus here is on the design of the stock option vesting terms. Note that the date at which the options vest and the date at which they can be cashed out are not necessarily identical. As will become clear later, it is always optimal to require the CEO to hold his (vested) options until date t_2; that is, the optimal contract sets $\beta_E = 0$. However, there are two alternatives to restricted option exercising that I discuss briefly in Section 4.3. Specifically, if the board sets a sufficiently high exercise price and/or requires the CEO to publicly disclose his intention to unload options in advance, then the optimal contract can be implemented without imposing limits on option exercising.

As in the previous section, to ensure that the CEO's options have a positive value if and only if the firm succeeds in the long run, the exercise price must satisfy $E \geq A$. For convenience, I assume again that $E = A$.

In case of first-period success, the CEO is retained and the value of his options at date t_2 is $\beta(A + X_2 - E) = \beta X_2$ if long-term cash flows are high and zero otherwise. When the CEO is fired due to short-term failure, he retains the options that have already vested, which have a positive value of $\beta_V(A + X_2 - E) = \beta_V X_2$ in case the new CEO succeeds in the long run.

Given the contract in place, the CEO's utility in case he chooses to work, $e = e_H$, is given by

$$U_{CEO} = (s_1(1-I)+a_1)\, p\,(s_2 I + a_2)\,\beta X_2 \\ +\,(1-p\,(s_1(1-I)+a_1))\, p\,(s_2 I + a_2)\,\beta_V X_2 - k. \quad (8)$$

If the CEO chooses to shirk, $e = e_L$, he will be removed in the first period due to poor performance. However, the CEO is still able to reap a reward if some of his options have already vested and if the replacement CEO is successful in the long run. The CEO's expected payoff in case he shirks is thus given by $p\,(s_2 I + a_2)\,\beta_V X_2$, where $p\,(s_2 I + a_2)$ represents the probability that the replacement CEO will be successful in the second period. Note that if the incumbent decides to shirk, he will invest solely in the long-term project, $I = 1$, to maximize the chances that the replacement CEO succeeds. Hence, to encourage the incumbent to choose high effort, it must hold that $U_{CEO} \geq p\,(s_2 + a_2)\,\beta_V X_2$, which can be rewritten as

$$(s_1(1-I)+a_1)\, p\,(s_2 I + a_2)\,(\beta - p\beta_V)\, X_2 - p\beta_V X_2 s_2\,(1-I) - k \geq 0. \quad (9)$$

Condition (9) shows that from an effort incentive perspective it is optimal to rely exclusively on stock option grants with long vesting terms. The long vesting horizon ensures that the CEO forfeits his options when he loses his position due to poor interim performance. The threat of stock option forfeiture effectively motivates the incumbent to deliver high effort.

In contrast, when the contract allows a positive number of options to vest early, $\beta_V > 0$, the CEO is able to reap a reward even when he shirks ($e = e_L$). The larger β_V, the larger is the expected reward for failure, and the lower is the CEO's ex ante incentive to expand effort. Thus, increasing the number of options that vest early is not only directly costly (because the CEO can take home a larger expected pay when fired) but also indirectly because it increases the total amount of options that must be granted to the CEO to maintain effort incentives. However, as shown next, early vesting also has a positive incentive effect in that it improves the CEO's investment decision.

Consider the CEO's capital allocation decision assuming that in equilibrium $e = e_H$. Taking the first-order condition of (8) yields the CEO's optimal investment choice

$$I(\beta_V) = \frac{1}{2} - \frac{1}{2}\frac{s_1 a_2 - s_2 a_1}{s_1 s_2} + \frac{1}{2}\frac{\beta_V s_2}{s_1 s_2 (\beta - p\beta_V)}. \tag{10}$$

The second-order condition for a maximum is $-2s_1 s_2 p X_2 (\beta - p\beta_V) < 0$ which is always satisfied given that $\beta \geq \beta_V$.

While standard arguments predict a positive link between the length of the vesting period and the CEO's investment horizon, condition (10) shows that this link is reversed if CEO turnover is taken into consideration. As discussed in the previous section, stock option grants with extended vesting periods encourage the CEO to focus excessively on short-term investment strategies. However, the board can combat managerial short-termism by allowing a positive fraction of options to vest early. Early vesting in combination with restricted exercising has two positive effects on the CEO's investment decision: First, the CEO will put less weight on short-term results because he retains the options that have already vested even when he is fired due to poor interim performance; second, given that the (ousted) CEO is required to hold his vested options for the long run, the CEO has an additional incentive to focus on long-term results ex ante. Both effects reinforce each other and tilt the CEO's attention away from short-term goals toward long-term goals.

In the optimal solution, the effort incentive constraint in (9) holds as an equality. Solving the equation system (9) and (10) leads to the optimal bundle (β, β_V) that induces $e = e_H$ and I^* (the equilibrium investment level, I^*, is determined below).

Proposition 3 *In the optimal contract, the total number of options granted to the CEO, β, and the number of options that vest early, β_V, are given by*

$$\beta = \frac{s_2 + p\left(s_1 s_2\left(2I^* - 1\right) + \left(s_1 a_2 - s_2 a_1\right)\right)}{p s_2\left(a_1\left(s_2 + a_2\right) + s_1 s_2 (1 - I^*)^2\right)} \frac{k}{X_2}, \text{ and} \tag{11}$$

$$\beta_V = \frac{s_1 s_2\left(2I^* - 1\right) + s_1 a_2 - s_2 a_1}{p s_2\left(a_1\left(s_2 + a_2\right) + s_1 s_2\left(1 - I^*\right)^2\right)} \frac{k}{X_2}. \tag{12}$$

where I^* is the equilibrium long-term investment level.

What remains to be determined is the investment level that arises in equilibrium. The board can induce the CEO to implement the first-best capital allocation $I = I^{FB}$ by choosing $\frac{\beta_V}{\beta} = f^{FB} \equiv \frac{s_2 X_2 - s_1 X_1 - s_1 k_N}{s_2 X_2 - s_1 p X_1 - s_1 p k_N}$ (note that $f^{FB} < 1$). However, this is not optimal given that early vesting negatively affects the CEO's effort incentive as described above. Thus, when setting the vesting terms of the CEO's options, the board faces the following trade off: on one hand, an increase in the number of options that vest early, β_V, tilts the CEO's preferences away from short-term results toward long-term results, leading to an investment decision that is more closely aligned with shareholders' interests. On the other hand, an increase in β_V dilutes the CEO's incentive to work hard which increases the cost of the incentive system. This trade-off results in an optimal contract that induces the CEO to focus excessively on short-term projects relative to first-best, $I^* < I^{FB}$.

Specifically, assuming an interior solution[10], the equilibrium investment level, de-

[10] The solution is interior as long as k is not too large. Otherwise, if k satisfies $8k\frac{s_1^2 l_2 (a_2 + l_2)}{(s_1 a_2 + s_1 l_2 + l_2 a_1)^2} > p\left(l_2 X_2 - s_1 X_1 - s_1 k_N\right)$, then a corner solution occurs in which the board focuses exclusively on minimizing the cost of inducing effort and ignores the induced investment decision. If this is the case, the board sets $\beta_V = 0$ and the induced investment level is identical to the one determined in the benchmark case, $I^* = I^{NV}$. See the Appendix for details.

noted I^*, is characterized by

$$\begin{aligned} & ps_2X_2 - ps_1X_1 + (s_2(s_1(1-I)+a_1) - s_1(s_2I+a_2))\, pX_2(1-p) - s_1pk_N \\ & - 2ks_1\frac{(a_1+(1-I)s_1)(a_2+s_2I)(a_2+s_2)}{\left(s_2a_1+a_1a_2+s_1s_2(1-I)^2\right)^2} = 0. \end{aligned} \tag{13}$$

Note that the second-order condition for a maximum is satisfied as long as X_2 is sufficiently large.

Comparing the equilibrium condition (13) with the first-best capital allocation specified in (4) leads to the next proposition.

Proposition 4 *In equilibrium, the CEO overinvests in the short-term project relative to first-best,* $I^* < I^{FB}$.

Intuitively, the board finds it optimal to induce overinvestment in the short-term project, $I^* < I^{FB}$, to reduce the cost of the compensation contract. A further increase in the number of options that vest early, β_V, would shift the CEO's investment decision closer to the first-best level but the associated increase in the compensation cost would more than outweigh this benefit. Thus, the model demonstrates that overinvestment in myopic projects is not necessarily evidence of faulty pay arrangements or impatient shareholders but can arise endogenously from optimal contracting between long-term oriented shareholders and executives.

4.3 Alternatives to Restricted Exercising

Bebchuk and Fried (2004; 2010) have long argued in favor of separating the time at which stock options vest from the time at which executives are free to exercise the options and sell the underlying shares. The current model shows that the distinction between these two contract features is especially important when the CEO is subject to being replaced at an interim stage. In this case, it is optimal to motivate the CEO to focus on long-term value creation not through extended vesting periods but through restricted option exercising and short vesting periods.

However, imposing limits on option exercising is not the only way to implement the optimal incentive contract. Alternatively, the board could either set a sufficiently high exercise price and/or require the CEO to publicly disclose his plans to unload options in advance. These contracting features ensure that the CEO will not find it optimal to deviate from the equilibrium outcome outlined in the previous section even when he is free to cash out his options immediately upon vesting. For further details and discussion see the Appendix.

5 Comparative Statics

5.1 Investment Strategy, CEO Pay, and CEO Turnover

The model generates predictions that relate the firm's investment opportunities to the optimal design of executive compensation and the likelihood and quality of CEO turnover.

As established in Section 3, the first-best level of long-term investment, I^{FB}, is an increasing function of the attractiveness of the long-term project relative to the short-term project, X_2/X_1. Using condition (13), it can be shown that the same relation holds in the second-best world; that is I^* increases with X_2/X_1.

A change in the equilibrium investment policy I^* that is caused by a change in X_2/X_1 affects the optimal design of the equity contract. Since an increase in X_2 directly increases the value of the CEO's option package, I focus on the normalized values $\beta^N = \beta/X_2$ and $\beta_V^N = \beta_V/X_2$ in what follows. As discussed in the previous section, if the board wishes to steer the CEO's attention toward the firm's long-term investment opportunities, it has to allow a larger number of options to vest early. The problem with early vesting is that it dilutes ex ante effort incentives and hence requires a larger stock option grant to maintain effort incentives. Formally, these results follow from conditions (11) and (12) which show that the optimal levels of β_V^N and β^N are both increasing in I^*. These conditions also show that in order to induce a higher level of long-term investment (and to maintain effort incentives), β_V^N has to increase faster than β^N. Consequently, the optimal proportion of options that vest early, $f = \beta_V/\beta$, is larger in firms that are more long-term oriented.

Proposition 5 *In firms and industries that have more valuable long-term investment opportunities, such as energy and pharmaceutical firms, (i) the proportion of options that vest early, and (ii) the size of the CEO's stock option grant are larger; that is,* $f = \beta_V/\beta$ *and* β^N *both increase with* X_2/X_1.

The firm's investment strategy, I^*, also determines the probability and quality of CEO turnover. Given that the board finds it optimal to remove the incumbent in case of short-term failure, the equilibrium probability of CEO turnover is $R = 1 - (a_1 + s_1(1 - I^*))$. When the level of long-term investment, I^*, increases, the expected performance in the short run declines and forced CEO turnover becomes more likely. A higher CEO turnover rate, in turn, increases the chances that a talented CEO is accidentally removed, which lowers the average quality of the CEO in charge in the long run. To see this formally, note that the probability that the second period CEO is a good type is a function of I^* and given by

$$\begin{aligned} Q &= (a_1 + s_1(1 - I^*))\,(p + (1-p)p) + (1 - (a_1 + s_1(1 - I^*)))p, \\ &= p + (a_1 + s_1(1 - I^*))\,p(1-p). \end{aligned}$$

Proposition 6 *In firms and industries with more valuable long-term investment opportunities, (i) the likelihood of forced CEO turnover is higher, and (ii) the average quality of the CEO in charge in the long run is lower; that is, R increases and Q decreases with X_2/X_1.*

5.2 The Cost of CEO Turnover

When the incumbent is fired after first-period failure, the board may need to make a quick replacement decision and hence may rely on an insider as a replacement. The insider could be someone who worked side by side with the incumbent in the first period. Hiring an insider may not only be less time consuming but may also be associated with less costs because the insider has already acquired (to some extent) firm specific human capital; that is, k_N is lower for an inside hire than for an outside hire. Consequently, the direct cost of CEO turnover is smaller in firms that have a well developed insider succession plan than in firms that do not have such a plan. Applying the implicit function theorem on (13) shows that the optimal level of long-term investment, I^*, declines with the cost of CEO turnover, k_N. This result follows because for smaller values of k_N, the board is less concerned about the cost of accidentally replacing a good-type CEO, and hence is less eager to distort the capital allocation toward the short-term project to reduce the probability of incurring this cost. As a result, the model predicts that firms that are well prepared for the incidence of CEO turnover place greater emphasis on long-term projects than firms that are less prepared.

The change in the equilibrium level of investment I^* that is associated with a change in k_N affects optimal contracting and the probability and quality of CEO turnover, as discussed in the previous section.

Proposition 7 *In firms in which the cost of CEO replacement, k_N, is smaller (e.g., firms with a well developed insider succession plan), (i) the level of long-term investment, I^*, (ii) the proportion of options that vests early, $f = \beta_V/\beta$, (iii) the size of the CEO's stock option grant, β, and (iv) the likelihood of forced CEO turnover, R, are larger; and (v) the average quality of the CEO in charge in the long run, Q, is smaller.*

Implication (v) is especially interesting because it suggests that in firms in which the board carefully develops a CEO succession plan, the expected probability of having a high talent in the long run is smaller than in firms that do not have such a plan. The reason for this result is that the board, knowing that CEO turnover is associated with less frictions, wishes to focus more on long-term investments, which reduces the information content of short-term cash flows and hence increases the probability that good-type CEOs are accidentally fired.

5.3 Board Dependence

In the model discussed so far, the board is assumed to behave in the shareholders' best interests. However, in reality, boards may not be completely independent from management and hence may benefit from being friendly to executives. This feature can be modeled by assuming that the board derives some utility from the incumbent CEO's well-being. In particular, the board's preferences can then be stated as:

$$U_{Board} = (1 - \widehat{\delta})V + \widehat{\delta}U_{CEO}, \tag{14}$$

where $\widehat{\delta}$ is the weight the board places on the incumbent CEO's utility, U_{CEO}, and $(1 - \widehat{\delta})$ is the weight placed on firm value, V, which is determined by total expected cash flows minus executive pay.[11] Thus, the setting discussed in the main part of the paper is obtained by assuming that $\widehat{\delta} = 0$. Given that utility functions are unique only up to a positive linear transformation, it is without loss of generality to describe (14) as

$$U_{Board} = V + \delta U_{CEO},$$

where $\delta = \widehat{\delta}/(1-\widehat{\delta})$. The parameter δ is interpreted as the level of board dependence; the larger δ, the more dependent is the board on the incumbent CEO and the higher is the weight the board places on CEO utility relative to firm value. In what follows, I restrict attention to $\delta < 1$. Otherwise, for $\delta > 1$, the board cares more about the CEO's interests than about shareholders' interests and transfers all profits from operations to the CEO.

As discussed previously, when choosing the optimal vesting schedule, the board balances the benefits of efficient resource allocation with the costs of the CEO's compensation scheme (CEO rents). This trade-off leads to an optimal contract that induces the CEO to overinvest in the myopic project relative to first-best, $I^* < I^{FB}$. If the board is dependent on the CEO ($\delta > 0$), it still faces the same trade-off but is now less concerned about curtailing CEO rents and hence is relatively more interested in implementing efficient investment decisions. Specifically, for $\delta > 0$, the condition that determines the equilibrium investment level changes from (13) to

$$\begin{aligned} &ps_2X_2 - ps_1X_1 + \left(s_2\left(s_1(1-I)+a_1\right) - s_1\left(s_2I+a_2\right)\right)pX_2(1-p) - s_1pk_N \quad (15)\\ &-(1-\delta)2ks_1\frac{\left(a_1+(1-I)\,s_1\right)\left(a_2+s_2I\right)\left(a_2+s_2\right)}{\left(s_2a_1+a_1a_2+s_1s_2\,(1-I)^2\right)^2} = 0. \end{aligned}$$

Condition (15) shows that the equilibrium long-term investment, $I^*(\delta)$, is increas-

[11] Other papers that use a similar characterization of board dependence are Drymiotes (2007), Kumar and Sivaramakrishnan (2008), and Laux and Mittendorf (2010).

ing in the level of dependence, δ, until it reaches $I^*(1) = I^{FB}$ (for $\delta = 1$, the board completely ignores the cost of CEO compensation and hence induces first-best investment).

Based on this analysis, the model predicts that the level of long-term investment is greater in firms in which the board has closer ties to the CEO (δ is larger). Similar to the previous two sections, a change in the equilibrium investment level causes changes in the optimal equity contract and the probability and quality of CEO turnover.

Proposition 8 *In firms in which the board has stronger ties to the CEO, (i) the level of long-term investment, I^*, (ii) the proportion of options that vests early, $f = \beta_V/\beta$, (iii) the size of the CEO's stock option grant, β, and (iv) the likelihood of forced CEO turnover, R, are larger; and (v) the average quality of the CEO in charge in the long run, Q, is smaller.*

Note that while board dependence shifts the level of long-term investment, $I^*(\delta)$, closer to the first-best level, I^{FB}, it is nevertheless optimal for shareholders to have a fully independent board in charge. Only an independent board considers the full cost of CEO pay and hence optimally balances investment efficiency with CEO rents.

5.4 The Role of CEO Turnover

The effects of stock option vesting terms on the CEO's investment horizon depends crucially on whether or not the CEO is subject to being replaced at an interim stage. To develop additional empirical predictions, consider a firm in which the board finds it optimal to always retain the incumbent CEO even when short-term performance is poor; that is condition (1) is not satisfied. In the absence of potential CEO turnover, it is first-best optimal to invest exclusively in the long-term project, $I^{FB} = 1$ (see the discussion in Section 3). As in the original setting, the board's task is to design a contract that effectively induces effort and motivates efficient investment. However, in the absence of CEO turnover, these two goals are not in conflict. Both goals can be achieved simultaneously by rewarding the CEO for long-term success. Such a pay plan not only shifts the CEO's attention toward long-term investment but also ensures that the CEO cannot benefit from shirking ($e = e_L$) which minimizes the cost of inducing effort.[12] To link CEO pay to the firm's long-term performance, the board can either grant options with long vesting periods ($\beta_V = 0$) or place restrictions on the exercising of options that have already vested ($\beta_E = 0$). Either pay plan induces long-term investment and implements the first-best outcome.

In contrast, in firms in which timely CEO turnover is important for the firm's future success, the optimal investment strategy and the optimal design of the contract become more subtle as discussed in the main part of the paper. These findings suggest that empirical studies that investigate the determinants of vesting schedules and investment strategies should distinguish between firms in which CEO turnover plays an important role (referred to as TO firms) and firms in which CEO replacement is not an issue at least in the near future (referred to as NTO firms). Timely CEO turnover is crucial in firms in which the incumbent CEO is a relatively new hire (maybe from the outside) with uncertain talent or fit and/or in firms that have recently changed their business strategy and where it is unclear if the incumbent is still a good match. These firms are natural candidates to comprise TO firms. In contrast, NTO firms are firms in which the CEO has already established that he is the right person for this position; replacing the CEO is very costly; and/or, the incumbent CEO is well

[12] Similar to the discussion in Section 4.1, if the contract only rewards long-term success, the CEO is unabale to obtain any rents in equilibrium and the cost of inducing effort is simply k.

entrenched.

The model predicts that TO firms invest more heavily in short-term projects than NTO firms. There are two reasons for this result. As discussed in Section 3, investment in short-term projects generates timely feedback about CEO talent, which enables the board to make better replacement decisions. Thus, the above prediction holds even in a first-best scenario in which effort is observable. Second, when effort is unobservable, the board in TO firms (but not in NTO firms) faces a trade-off between inducing efficient investment and inducing managerial effort. To reduce the cost of CEO compensation, the board further increases the focus on short-term investment.

Proposition 9 *The level of short-term investment* $(1-I)$ *is larger in* TO *firms than in* NTO *firms. This is the case even in the first-best scenario in which the CEO's effort choice is observable.*

If one assumes that NTO firms rely on stock option vesting terms (and not on exercising restrictions) as a means to link CEO pay to long-term performance, the model generates a second prediction: In TO firms, the fraction of the CEO's stock options that vests early is larger than in NTO firms. Allowing early vesting can be optimal in TO firms because it shifts the CEO's attention away from short-term investments towards more profitable long-term investments. This beneficial effect is absent in NTO firms.

Proposition 10 *If* NTO *firms rely on stock option vesting terms as a means to link pay to long-term performance, the model predicts that the fraction of executive stock options that vest early is larger in* TO *firms than in* NTO *firms.*

6 Conclusion

This paper analyzes the effects of stock option vesting schedules on executives' incentives to engage in myopic behavior and deliver productive effort. Lengthening the vesting period of equity grants is usually viewed as an effective means to extend executives' investment horizon. However, if the incumbent is subject to potential replacement at an intermediate stage, long vesting periods can backfire and encourage myopic behavior. This follows because the CEO is concerned about forfeiting unvested stock options in case of dismissal and hence has an incentive to overinvest in short-term projects to boost the board's perception about his ability.

The board can addresses this issue by allowing a positive fraction of the executives' options to vest early. The fact that an option has vested does not imply that the CEO should also be allowed to immediately exercise it. In the optimal contract, the board restricts the CEO's freedom to cash out options after vesting. The combination of early vesting and restricted exercising effectively shifts the CEO's emphasis away from short-term results (because he can keep the options that have already vested even when fired) toward long-term results (because his initial actions affect his pay in the long run even when removed at an intermediate date).

In principal, by choosing the appropriate number of options that vest early, the board can eliminate excessive myopia and induce the first-best allocation of resources. However, this is in general not optimal because early vesting is also associated with a cost for shareholders. Given that the CEO can keep the options that have already vested when fired due to poor performance, the CEO's incentive to work hard is muted ex ante.

The optimal vesting schedule therefore amounts to balancing the desire to induce appropriate investment decisions with the desire to induce effort. This trade-off leads to an optimal pay plan that encourages the CEO to focus excessively on short-term projects relative to first best. Consequently, the model demonstrates that managerial myopia is not necessarily an artifact of faulty pay arrangements or impatient shareholders but can result from optimal contracting in a multitask agency setting.

Appendix

Optimal Unrestricted Contract

Consider a general contract $(B_{SS}, B_{FS}, B_{SF}, B_{FF})$, where B_{SS} is the pay to the CEO if $x_1 = X_1$ and $x_2 = X_2$, B_{FS} is the pay if $x_1 = 0$ and $x_2 = X_2$, B_{SF} is the pay if $x_1 = X_1$ and $x_2 = 0$, and B_{FF} is the pay if $x_1 = x_2 = 0$. It is straightforward to show that it is always optimal to set $B_{FF} = 0$.

Given this pay plan, the CEO's utility for $e = e_H$ can be stated as

$$\begin{aligned} U_{CEO} &= (s_1(1-I)+a_1)\,p\,((s_2 I + a_2)\,B_{SS} + (1-(s_2 I + a_2))\,B_{SF}) \\ &\quad + (1 - p\,(s_1(1-I)+a_1))\,p\,(s_2 I + a_2)\,B_{FS} - k. \end{aligned} \tag{16}$$

The CEO's effort incentive constraint is given by (recall, if the CEO chooses $e = e_L$, then he also chooses $I = 1$)

$$U_{CEO} \geq p\,(s_2 + a_2)\,B_{FS},$$

which can be written as

$$\begin{aligned} &(s_1(1-I)+a_1)\,p\,((s_2 I + a_2)\,(B_{SS} - pB_{FS}) + (1 - s_2 I - a_2)\,B_{SF}) \\ &-pB_{FS}s_2\,(1-I) - k = 0, \end{aligned} \tag{17}$$

because it is always binding in equilibrium.

To obtain the CEO's investment choice, take the first-order condition on (16) which yields

$$(-s_1(s_2 I + a_2) + s_2(s_1(1-I) + a_1))\, p\,(B_{SS} - pB_{FS} - B_{SF}) - s_1 p B_{SF} + p B_{FS} s_2 = 0. \tag{18}$$

The Lagrangian of the principal's optimization problem (P) is now as follows:

$$\begin{aligned}
&\underset{B_{SS},B_{SF},B_{FS},I}{\text{Max}} \quad L = \\
&(s_1(1-I) + a_1)\, p\,((s_2 I + a_2)(X_1 + X_2 - B_{SS}) + (1 - (s_2 I + a_2))(X_1 - B_{SF})) \\
&+ (p(1 - s_1(1-I) - a_1) + (1-p))\, p\,(s_2 I + a_2)(X_2 - B_{FS}) \\
&- (p(1 - s_1(1-I) - a_1) + (1-p))\, k_N \\
&+ \lambda\,((s_1(1-I) + a_1)\, p\,((s_2 I + a_2)(B_{SS} - pB_{FS}) + (1 - s_2 I - a_2) B_{SF}) - pB_{FS} s_2 (1-I) - k) \\
&+ \mu\,((-s_1(s_2 I + a_2) + s_2(s_1(1-I) + a_1))\, p\,(B_{SS} - pB_{FS} - B_{SF}) - s_1 p B_{SF} + p B_{FS} s_2),
\end{aligned}$$

where λ is the Lagrangian multiplier associated with the effort incentive constraint (17) and μ is the multiplier associated with the investment decision constraint (18).

The necessary conditions for a solution to (P) include:

$$\frac{\partial L}{\partial I} = 0, \ \frac{\partial L}{\partial B_j} \leq 0, \ B_j \geq 0, \text{ and } \frac{\partial L}{\partial B_j} B_j = 0, \text{ for all } j = SS, FS, SF.$$

There are three cases that need to be considered, which are discussed below. Before analyzing each case, it is instructive to provide a brief summary: In the first case, it is shown that if $s_2 X_2 - s_1 X_1 \leq s_1 k_N$, then there are no incentive frictions and the optimal contract achieves the first-best outcome. To focus on non-trivial solutions, I exclude this case in the main part of the paper (see Section 2). In the second case, it is shown that for $p(s_2 X_2 - s_1 X_1 - s_1 k_N) \geq 8k \frac{s_1^2 s_2 (a_2 + s_2)}{(s_1 a_2 + s_1 s_2 + s_2 a_1)^2}$ there exists an interior solution in which the board balances the cost of inducing effort against the desire to induce efficient investment. This case is the main focus of the paper. Finally, in the third case, it is shown that for

$$0 < p\left(s_2 X_2 - s_1 X_1 - s_1 k_N\right) < 8k \frac{s_1^2 s_2 \left(a_2 + s_2\right)}{\left(s_1 a_2 + s_1 s_2 + s_2 a_1\right)^2},$$

the board implements a corner solution. In that case, the CEO's effort cost is relatively high such that it becomes optimal for the board to focus exclusively on minimizing the cost of inducing effort and to ignore the induced investment decision.

Case 1: Assume that in the optimal solution to (P) it holds that $B_{SS} > 0$ and $B_{SF} > 0$. In this case, it must be that $\frac{dL}{dB_{SS}} = 0$ and $\frac{dL}{dB_{SF}} = 0$, which implies that $\lambda = 1$ and $\mu = 0$.

Substituting $\lambda = 1$ and $\mu = 0$ into $\frac{dL}{dB_{FS}}$ yields $-pa_2 - ps_2 < 0$, implying that $B_{FS} = 0$. Solving (17) and (18) and using $B_{FS} = 0$ yields the optimal payments B_{SS} and B_{SF} :

$$\begin{aligned} B_{SF} &= k \frac{s_1 s_2 \left(1 - 2I\right) - s_1 a_2 + s_2 a_1}{s_2 p\left(\left(s_1 \left(1 - I\right) + 2a_1\right) s_1 \left(1 - I\right) + a_1^2\right)}, & (19) \\ B_{SS} &= k \frac{s_1 s_2 \left(1 - 2I\right) - s_1 a_2 + s_2 a_1 + s_1}{\left(s_1 \left(1 - I\right) + a_1\right)^2 p s_2}. & (20) \end{aligned}$$

Note that since $B_{FS} = 0$, it follows from the effort incentive constraint (17) that the CEO is not able to obtain a rent in equilibrium; that is, he is kept at his reservation utility $U_{CEO} = 0$. This can be confirmed by noting that the expected pay to the CEO (using (19) and (20)) equals the cost of effort:

$$\left(s_1(1 - I) + a_1\right) p\left(\left(s_2 I + a_2\right) B_{SS} + \left(1 - \left(s_2 I + a_2\right)\right) B_{SF}\right) = k.$$

Substituting (19), (20), $B_{FS} = 0$, $\lambda = 1$, and $\mu = 0$, into $\frac{dL}{dI} = 0$ yields

$$I = \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_1 s_2} + \frac{1}{2} \frac{s_2 X_2 - s_1 X_1 - s_1 k_N}{s_1 s_2 X_2 \left(1 - p\right)},$$

which is the first-best investment level, I^{FB}.

Due to the nonnegativity constraint, it must hold that $B_{SF} \geq 0$ and $B_{SS} \geq 0$ for $I = I^{FB}$. The pay B_{SF} in (19) is nonnegative for $I = I^{FB}$ if $-\frac{s_2 X_2 - s_1 X_1 - s_1 k_N}{X_2(1-p)} \geq 0$. If this is the case, B_{SS} in (20) is also nonnegative. This discussion leads to the following lemma.

Lemma 1 *If $ps_2X_2 - ps_1X_1 - ps_1k_N \leq 0$, the solution to (P) is first-best and described by (19), (20), $B_{FS} = 0$, $I^* = I^{FB}$, and $U_{CEO} = 0$.*

Case 2: Assume now that in the optimal solution to (P) it holds that $B_{SS} > 0$ and $B_{FS} > 0$. In this case, it must hold that $\frac{dL}{dB_{SS}} = 0$ and $\frac{dL}{dB_{FS}} = 0$, which yields

$$\lambda = s_1 \frac{s_2^2 I^2 + 2s_2 I a_2 + a_2^2}{s_2 \left(s_1 s_2 + s_2 a_1 + a_1 a_2 - 2s_1 s_2 I + s_1 I^2 s_2\right)}, \tag{21}$$

$$\mu = -\frac{-\left(s_2^2 I + a_2^2\right) s_1 (1-I) - s_1 a_2 s_2 \left(1 - I^2\right) - \left(a_2 + s_2 I\right) a_1 \left(s_2 + a_2\right)}{s_2 \left(s_1 s_2 + s_2 a_1 + a_1 a_2 - 2s_1 s_2 I + s_1 I^2 s_2\right)}. \tag{22}$$

Substituting (21) and (22) into $\frac{dL}{dB_{SF}} = 0$ yields

$$\frac{dL}{dB_{SF}} = -p \frac{s_2 a_1^2 + a_1^2 a_2 + s_1^2 (1-I)^2 (s_2 + a_2) + (s_2 s_1 + s_1 a_2) 2a_1 (1-I)}{a_1 (a_2 + s_2) + s_1 s_2 (1-I)^2},$$

which is negative; hence, $B_{SF} = 0$.

Substituting $B_{SF} = 0$ into the two incentive constraints (17) and (18) and solving for B_{SS} and B_{FS} yields

$$B_{SS} = \frac{s_2 + p\left(s_1 s_2 (2I - 1) + (s_1 a_2 - s_2 a_1)\right)}{p s_2 \left(a_1 (s_2 + a_2) + s_1 s_2 (1-I)^2\right)} k, \tag{23}$$

$$B_{FS} = \frac{s_1 s_2 (2I - 1) + s_1 a_2 - s_2 a_1}{p s_2 \left(a_1 (s_2 + a_2) + s_1 s_2 (1-I)^2\right)} k. \tag{24}$$

Substituting (23), (24), $B_{SF} = 0$, (21), and (22) into $\frac{dL}{dI} = 0$ gives the equilibrium investment level, which is determined by

$$\frac{dL}{dI} = ps_2X_2 - ps_1X_1 + \left(s_2 \left(s_1(1-I) + a_1\right) - s_1 \left(s_2 I + a_2\right)\right) pX_2(1-p) \tag{25}$$
$$-s_1 p k_N - 2ks_1 \frac{\left(a_1 + (1-I) s_1\right)\left(a_2 + s_2 I\right)\left(a_2 + s_2\right)}{\left(s_2 a_1 + a_1 a_2 + s_1 s_2 (1-I)^2\right)^2} = 0.$$

Note that this equation is identical to the condition in (13).

Due to the nonnegativity constraint, it must hold that $B_{FS} \geq 0$ and $B_{SS} \geq 0$. B_{FS} is nonnegative if the numerator in (24) is nonnegative; that is, if

$$s_1 s_2 (2I - 1) + s_1 a_2 - s_2 a_1 \geq 0. \tag{26}$$

If this is the case, then B_{SS} is also nonnegative. Condition (26) can be rewritten as

$$I \geq I^T \equiv \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_2 s_1}. \tag{27}$$

Substituting I^T, defined in (27), into (25), gives

$$\frac{dL}{dI} = p (s_2 X_2 - s_1 X_1 - s_1 k_N) - 8k \frac{s_1^2 s_2 (a_2 + s_2)}{(s_1 a_2 + s_1 s_2 + s_2 a_1)^2}.$$

If, for $I = I^T$, it holds that $\frac{dL}{dI} \geq 0$, then it holds that $I^* \geq I^T$ and condition (27) is satisfied in equilibrium.

Lemma 2 *If* $p (s_2 X_2 - s_1 X_1 - s_1 k_N) \geq 8k \frac{s_1^2 s_2 (a_2 + s_2)}{(s_1 a_2 + s_1 s_2 + s_2 a_1)^2}$, *the solution to* (P) *is described by (23), (24),* $B_{SF} = 0$, *(25),* $U_{CEO} > 0$, *and* $I^* < I^{FB}$.

The payments B_{SS} and B_{FS} defined in (23) and (24) can be replicated by the stock option contract described in the main part of the paper by choosing β and β_V such that $\beta X_2 = B_{SS}$ and $\beta_V X_2 = B_{FS}$. What remains to be shown is that in equilibrium $\beta_V < \beta$ because the number of options that vest early cannot exceed the total option grant.

Using (23) and (24), the condition $\beta_V < \beta$ is satisfied if

$$p s_2 + (s_2 (a_1 + s_1 (1 - I)) - s_1 (s_2 I + a_2)) p (1 - p) > 0. \tag{28}$$

Using the equilibrium condition (25), it can be shown that for $I = I^*$, condition (28) is satisfied.

Case 3: Assume now that in the optimal solution to (P) it holds that $B_{SS} > 0$, $B_{FS} = B_{SF} = 0$. In this case, it must be that $\frac{dL}{dB_{SS}} = 0$, $\frac{dL}{dB_{FS}} < 0$, and $\frac{dL}{dB_{SF}} < 0$. B_{SS} is determined by (17) and given by

$$B_{SS} = \frac{k}{p\left(s_1\left(1-I\right)+a_1\right)\left(s_2 I + a_2\right)}. \tag{29}$$

Due to $B_{FS} = 0$, the CEO is not able to obtain an economic rent in equilibrium, $U_{CEO} = 0$. This can also be confirmed by noting that the expected CEO pay (using (29) and $B_{FS} = B_{SF} = 0$) is given by $(s_1(1-I)+a_1)\,p\,(s_2 I + a_2)\,B_{SS} = k$.

Substituting $B_{FS} = B_{SF} = 0$ and (29) into the incentive constraint (18) and rearranging yields

$$I = \frac{1}{2} - \frac{1}{2}\frac{s_1 a_2 - s_2 a_1}{s_2 s_1}. \tag{30}$$

Solving the equation system $\frac{dL}{dB_{SS}} = 0$ and $\frac{dL}{dI} = 0$, and using (30) and $B_{FS} = B_{SF} = 0$ yields

$$\mu = \frac{1}{2}\frac{s_2 X_2 - s_1 X_1 - s_1 k_N}{s_1 s_2 B_{SS}} \text{ and } \lambda = 1. \tag{31}$$

Using (31), (30), and (29), it holds that

$$\frac{dL}{dB_{FS}} = -p\left(a_2+s_2\right) + p^2 \frac{1}{8}\frac{1}{k}\frac{\left(s_2 X_2 - s_1 X_1 - s_1 k_N\right)}{s_1^2}\frac{\left(s_1 a_2 + s_1 s_2 + s_2 a_1\right)^2}{s_2}, \tag{32}$$

$$\frac{dL}{dB_{SF}} = -\frac{1}{8}\frac{p^2}{k}\frac{\left(s_2 X_2 - s_1 X_1 - s_1 k_N\right)}{s_1}\frac{\left(s_1 a_2 + s_1 s_2 + s_2 a_1\right)^2}{s_2^2}. \tag{33}$$

Hence, conditions $\frac{dL}{dB_{FS}} < 0$ and $\frac{dL}{dB_{SF}} < 0$ are satisfied if

$$p\left(s_2 X_2 - s_1 X_1 - s_1 k_N\right) - 8k\frac{s_1^2 s_2\left(a_2+s_2\right)}{\left(s_1 a_2 + s_1 s_2 + s_2 a_1\right)^2} < 0, \tag{34}$$

$$p\left(s_2 X_2 - s_1 X_1 - s_1 k_N\right) > 0. \tag{35}$$

This analysis leads to the next lemma.

Lemma 3 *If (34) and (35) are satisfied, the solution to (P) is described by $B_{FS} = B_{SF} = 0$, (29), (30), $U_{CEO} = 0$, and $I^* < I^{FB}$.*

Note that the solution characterized in the above lemma is a corner solution. Intuitively, if (34) is satisfied, the CEO's effort cost is so high that it becomes optimal for the board to focus exclusively on minimizing the cost of inducing effort and to ignore the induced investment decision. The board minimizes the cost of inducing effort by choosing $B_{FS} = 0$, which keeps the CEO at his reservation utility, $U_{CEO} = 0$. This pay scheme can be replicated by the stock option contract described in the main part of the paper by choosing $\beta = \frac{B_{SS}}{X_2}$ and $\beta_V = 0$.

Alternatives to Restricted Exercising

I show next that the optimal contract can be implemented with an equity pay plan even when the CEO is allowed to exercise his options immediately after vesting as long as the board sets a sufficiently high exercise price and/or requires executives to disclose their intention to exercise options and sell the underlying shares prior to the selling date.

Consider the optimal contract determined in Section 4.2, but assume that the CEO is allowed to unload his stock options immediately after vesting. For simplicity assume that the firm pays out dividends to shareholders prior to the earliest date at which some of the options vest.

Recall that in the optimal contract it must hold that $E \geq A$ to ensure that the options have no value in case of long-term failure. This is the case, for example, if the exercise price equals the stock price at the option grant date.

First note that if the CEO continues to choose the equilibrium investment I^* (determined in condition (13)), then he strictly prefers to hold his vested options until date t_2 rather than exercise them prematurely at date t_1 if $E > A$ and is indifferent between the two alternatives if $E = A$. To see this formally note that the CEO's payoff when exercising one option and selling the underlying stock at date t_1

is $Q^S_{sell}(I^*) = (s_2 I^* + a_2) X_2 + A - E$ in case of first-period success and $Q^F_{sell}(I^*) = p(s_2 I^* + a_2) X_2 + A - E$ in case of first-period failure (and subsequent CEO turnover). The CEO's expected payoff if he holds the option until date t_2 and exercises it if and only if the firm succeeds in the long run is $Q^S_{keep}(I^*) = (s_2 I^* + a_2)(X_2 + A - E)$ in case of first-period success and $Q^F_{keep}(I^*) = p(s_2 I^* + a_2)(X_2 + A - E)$ in case of first-period failure (note, for $E \geq A$ the CEO's options have no value if the firm fails in the long run). Comparing these payoffs shows that for $E \geq A$ it holds that $Q^S_{keep} \geq Q^S_{sell}$ and $Q^F_{keep} \geq Q^F_{sell}$. Intuitively for $E > A$ it is strictly optimal to wait and see if the firm succeeds in the long run before deciding whether or not to exercise the options. For simplicity, assume that the CEO always holds his options until date t_2 if $A = E$.

However, the question is not whether the CEO finds it optimal to unload his options early given that he sticks with the equilibrium investment level I^*. Rather, the question is whether he finds it optimal to deviate from I^* and exercise options prematurely, given that the market's conjecture about the investment level is I^*. If the CEO plans to cash out his options immediately upon vesting, he chooses the level of I that maximizes

$$\begin{aligned} U^N_{CEO} &= (s_1(1-I)+a_1)\, p \left(\beta_V Q^S_{sell}(I^*) + (\beta - \beta_V)(s_2 I + a_2)(X_2 + A - E)\right) \\ &\quad + (1 - p(s_1(1-I)+a_1))\, \beta_V Q^F_{sell}(I^*) - k. \end{aligned}$$

The CEO's optimal investment level is now given by:

$$I_N = \frac{1}{2} - \frac{1}{2}\frac{s_1 a_2 - s_2 a_1}{s_2 s_1} - \frac{1}{2}\frac{s_1 \beta_V (1-p) X_2 (s_2 I^* + a_2)}{s_2 s_1 (\beta - \beta_V)(X_2 + A - E)}. \tag{36}$$

Comparing (36) with (10) shows that $I_N < I^*$.

After first-period success, the CEO exercises his vested options at date t_1 if and only if

$$Q^S_{sell}(I^*) = (s_2 I^* + a_2) X_2 + A - E > Q^S_{keep}(I_N) = (s_2 I_N + a_2)(X_2 + A - E),$$

which can be simplified to

$$E - A < \frac{s_2 (I^* - I_N) X_2}{(1 - (s_2 I_N + a_2))}. \tag{37}$$

Similarly, after first period failure (which triggers replacement), the CEO exercises his vested options prematurely if and only if

$$Q_{sell}^F(I^*) = p (s_2 I^* + a_2) X_2 + A - E > Q_{keep}^F(I_N) = p (s_2 I_N + a_2) (X_2 + A - E),$$

which can be simplified to

$$E - A < \frac{p s_2 (I^* - I_N) X_2}{(1 - p (s_2 I_N + a_2))}. \tag{38}$$

Hence, if conditions (37) and (38) are satisfied, then the CEO has indeed an incentive to deviate from the equilibrium strategy by choosing I_N and exercising options prematurely.

However, for $E - A \geq \frac{s_2 (I^* - I_N) X_2}{(1 - (s_2 I_N + a_2))}$, the two conditions (37) and (38) are not satisfied and the CEO no longer has an incentive to deviate from the equilibrium outcome. Note that a sufficient condition for $E - A > \frac{s_2 (I^* - I_N) X_2}{(1 - (s_2 I_N + a_2))}$ is $E - A > \frac{s_2 X_2}{(1 - a_2)}$. By setting a sufficiently high exercise price, the board can ensure that the CEO chooses investment I^* and holds his vested options for the long run. Thus, in this case, the optimal contract is implemented even without imposing limits on option exercising.

Another alternative to exercising restrictions is to require the CEO to publicly disclose his intention to unload vested options in advance. To see this assume that conditions (37) and (38) are satisfied. Then, in the absence of advanced disclosure rules, the CEO would find it optimal to deviate from the equilibrium strategy. However, if the CEO has to disclose his plans to unload options, the announcement to do so signals to the market that the CEO has chosen investment I_N instead of I^* (recall that for $I = I^*$ the CEO has no incentive to unload options early). Consequently, the stock price at date t_1 will be adjusted to reflect the market's new conjecture about I. This stock price adjustment eliminates the CEO's incentive to exercise options prematurely; that is, $Q^S_{sell}(I_N) \leq Q^S_{keep}(I_N)$ and $Q^F_{keep}(I_N) \leq Q^F_{keep}(I_N)$. Thus, in the presence of pretrading disclosure rules, the optimal contract can be implemented even when the CEO is free to unload his options immediately after vesting.

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