Stock Option Vesting Conditions, CEO Turnover, and Myopic Investment

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Abstract

This paper analyzes the effects of stock option vesting conditions on the CEO’s incentive to allocate resources between short-term and long-term investment projects. I show that extended vesting periods are not a panacea for providing executives with incentives to focus on long-term projects, but instead can induce myopic behavior. In addition, the model demonstrates that managerial myopia can arise from optimal contracting between executives and long-term oriented shareholders and hence 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 current financial crisis has renewed concerns about myopic managerial behavior in corporations. Many critics have blamed faulty compensation arrangements for providing executives with excessive incentives to focus on short-term results at the expense of long-term value creation (e.g., Bebchuk and Fried 2010; Bhagat and Romano 2010).

This paper studies the design of stock option vesting conditions in optimal contracting and makes two contributions. First, I show that long vesting periods are not a panacea for providing executives with incentives to take long-term value enhancing actions, but instead can backfire and foster myopic behavior. Second, when determining the optimal vesting schedule, shareholders balance the benefits of efficient investment with the cost of inducing managerial effort. This trade-off leads to an optimal pay arrangement that induces the CEO to overinvest in short-term projects. Thus, the model shows that managerial myopia is not necessarily an artifact of faulty pay arrangements and poor corporate governance but can arise from optimal contracting between long-term oriented shareholders (represented by a benevolent board) and executives.

I consider a setting in which a board hires a new CEO whose tasks are to acquire firm specific expertise and to decide how to allocate a fixed amount of resources among a short-term and a long-term project. Following Holmstrom (1982, 1999), I assume that the CEO’s talent is initially unknown to all parties. Based on the firm’s short-term performance, the board draws inferences about the CEO’s talent and replaces him with a new CEO if this is ex post optimal.

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. This follows because short-term investment helps generate valuable information about CEO talent. Intuitively, if the firm invests solely in long-term projects, relatively little is learned about the incumbent’s talent in the short-run, which makes it harder for the board to make timely CEO turnover 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. Assuming that the goal of the department is to generate long-term ground-breaking research, it is still optimal to encourage less important short-term research projects. Pursuing short-term projects distracts from pursuing more valuable long-term projects but it helps generate information about talent in the short-run, leading to more accurate and timely replacement decisions.

When the CEO’s actions are not observable, he must be motivated to work on acquiring firm specific expertise and to make an appropriate investment allocation. In my setting, it is without loss of generality to focus on contracts where the only available incentive instrument is stock options.\footnote{That is, the option contract studied here is optimal in the sense that there is no other more general contract that can yield a higher payoff to shareholders.} Whether the option plan succeeds in providing optimal incentives depends on the details of the vesting schedule. The vesting schedule determines when the CEO has earned the stock options and hence whether or not he can keep them when he voluntarily or involuntary leaves the firm. Given that the CEO does not want to forfeit unvested options, a long vesting horizon biases the CEO in favor of remaining with the firm. This bias is often viewed as a benefit of long vesting periods because CEOs who are known to be of high talent are
discouraged from voluntarily leaving the firm. However, there is also a cost if the CEO’s talent is initially uncertain: Knowing that the board will rely on short-term results in making inferences about the CEO’s talent, the CEO has an incentive to overinvest in myopic projects (from a first-best perspective) to impress the board. As a consequence, extended vesting periods do not necessarily induce the CEO to focus on long-term projects as is often argued (e.g., Cadman et al. 2010), but can actually foster myopic investment behavior.

The board can address this issue by allowing a fraction of the CEO’s options to vest early.² Importantly, permitting early vesting does not imply that the CEO should also be allowed to exercise his options immediately after vesting. In the setting discussed here it is always optimal to restrict the unloading of the options until long-term results are realized. Early vesting in combination with restricted exercising has two positive effects on the CEO’s investment incentives: First, the CEO will put less weight on short-term results because he retains the options that have already vested even when he is replaced due to poor 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.

In principle, by allowing an appropriate fraction of the CEO’s stock options to vest early, the board can eliminate excessive myopia and induce the first-best allocation

²Alternatively, the board can allow accelerated vesting where a fraction of the CEO’s options vest immediately upon termination. In my setting, accelerated vesting is just another form of early vesting and has identical effects. Note that accelerated vesting arrangements, if they are present, are part of the severance agreement. In his study of 179 turnover cases, Yermack (2006) finds that only 13% of the firms had an ex ante severance agreement. In those firms, 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.
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 his options that have already vested even when fired due to poor performance, the incumbent’s incentive to work hard is muted. Similar to severance pay, early vesting constitutes a reward for poor performance. However, different to severance pay, the magnitude of this reward depends on how successful the replacement CEO will be in the long run. Thus, increasing the number of options that vest early is not only directly costly (because the CEO takes home a larger expected pay for failure) but also indirectly because it must be combined with a larger total option grant to maintain effort incentives.

Consequently, when designing the optimal vesting schedule, the board balances the desire to induce appropriate investment decisions with the desire to effectively induce managerial effort. This trade-off leads to an optimal contract that endogenously biases the CEO toward allocating excessive resources to the short-term project (from a first-best perspective). Thus, the model shows 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). One implication of this analysis is that regulatory intervention that attempts to curtail myopic behavior in organizations, for example by imposing restrictions on minimum vesting periods, can actually foster myopic behavior.

The model suggests that the link between vesting conditions and the CEO’s investment horizon depends crucially on whether or not the CEO is subject to potential dismissal at an interim stage. Specifically, the model predicts that in firms in which the incumbent CEO is concerned about being fired, for example because he is a rel-
atively new hire and hence has not yet established that he is the right person to run the firm, both the fraction of stock options that vest early and the level of myopic investment are larger than in firms in which forced turnover is not a concern.

In addition, the model generates predictions that relate the firms’ investment opportunities to executive pay and CEO turnover. Specifically, the model predicts that in firms that have valuable long-term investment opportunities (such as pharmaceutical or energy companies), (i) the fraction of the CEO’s option package that vests early is larger (to shift the CEO’s preferences toward long-term investment), (ii) the CEO obtains a larger option grant (to maintain effort incentives), the probability of CEO turnover is higher (because good-type CEOs are more likely fired due to poor short-term results), and (iv) the CEO in charge in the long-run is less likely a high talent compared to firms that have less valuable long-term investment opportunities.

Section 2 discusses related studies. Section 3 outlines the model and Section 4 analyzes the first-best case. Section 5 presents the main results and Section 6 provides a discussion and empirical predictions. Section 7 concludes. All proofs are in the appendix.

2 Related Studies

Studies that analyze the role of vesting conditions in executive pay arrangements are scarce. One exception is Brisley (2006) who analyzes the effects of stock option vesting terms on the executives’ willingness to adopt risky projects. The current paper contributes to the understanding of the role of vesting conditions by analyzing the effects of vesting terms on the CEO’s incentive to engage in myopic behavior and exert productive effort.
Myopic behavior has been discussed 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 managers overinvest in myopic projects at the detriment of long-term firm value. In contrast to these studies, the current model adopts an optimal contracting approach and analyses the trade-off between encouraging the CEO to invest in long-term projects and to deliver productive effort in a setting with forced CEO turnover. One implication of this trade-off is that the optimal contract that maximizes long-term firm value endogenously induces the CEO toward overinvesting in myopic projects.

Bolton, Scheinkman, and Xiong (2006) also analyze optimal contracting and myopic behavior but in a very different setting. Specifically, Bolton et al. (2006) consider a speculative stock market, where investors have heterogeneous beliefs about the firm’s fundamental long-term value. Given that incumbent shareholders benefit from selling stock to overconfident investors at an intermediate date, they wish to induce executives to take actions that increase speculation and short-term stock prices at the detriment of long-term firm value.3

Von Thadden (1995) studies contracting between an entrepreneur and an outside investor and determines conditions under which it is infeasible to implement the preferred long-term investment project (when also a short-term project is available) due

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3 Other studies that analyze contracting and myopic behavior include Feltham and Xie (1992), Dutta and Gigler (2002), Goldman and Slezak (2006). However, these articles consider settings in which CEO pay can only be tied to a short-term performance measure, such as an interim earnings report or interim stock price. Using short-term measures as a means to induce productive effort simultaneously induces the CEO to manipulate these measures (e.g., by engaging in earnings manipulation) at the expense of long-term firm value.
to the threat of early project termination by the investor. In this setting, inducing long-term investment is hindered by the fact that the entrepreneur can only be rewarded for long-term success if the project is not terminated at an earlier stage. In contrast, in the present model, not the project is terminated but the incumbent CEO is fired, which allows the board to link the incumbent’s pay to the long-term consequences of his investment decision even when he is dismissed at an intermediate stage. The reason why the board does not fully eliminate overinvestment in myopic projects in the current paper is that the board has to balance the benefits of efficient investment with the cost of inducing managerial effort. This trade off is absent in Von Thadden (1995) because the entrepreneur chooses the contract that maximizes his own payoff (keeping the investor at his reservation utility) and hence is not concerned about restricting his own rents. Finally, my model differs from Von Thadden (1995) in that it focuses on stock option pay arrangements and on the effects of vesting conditions on investment and effort decisions.

3 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 not replaced, 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.

**Initial contract:** 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. At stage $t_0$, the board hires a CEO and offers him an incentive pay plan. The CEO is protected by limited liability which means 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. This includes stock compensation because stock is equivalent to an option with an exercise price of zero. 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 (see the Appendix for details). 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 the beginning of the game, denoted $\beta$, the exercise price, denoted $E$, and the fixed salary, denoted $\alpha$. Note that the fixed salary is always zero in the optimal solution and hence is omitted in what follows. The board determines the terms and conditions under which the options vest and may be exercised. Note that the vesting date does not necessarily coincide
with the date at which the options can be exercised. Specifically, let $\beta_V$ denote 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, let $\beta_E$ denote the number of already vested options that can be exercised at $t_1$. The remaining options ($\beta - \beta_E$), can be exercised at $t_2$. Note that upon vesting, the CEO owns the stock options. Thus, if fired at date $t_1$, the CEO retains the options that have already vested ($\beta_V$) 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 has identical effects as early vesting.

**Effort choice:** After the CEO is hired and signed the contract, 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 CEO because this cost only occurs in case of CEO turnover.

**Investment and cash flows:** At the same time the initial CEO chooses his effort level, he makes an investment decision. 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.\footnote{\textsuperscript{4}}

To focus on dysfunctional myopic behavior, I assume that the long-term project is strictly more productive than the short-term project, that is, $s_2X_2 - s_1X_1 > s_1k_N$. Otherwise, for $s_2X_2 - s_1X_1 < s_1k_N$, 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 hence retains him. Conditional on observing short-term failure, $x_1 = 0$, the board revises 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.

\footnote{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.}
Otherwise, if it is efficient to 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. Thus, replacement is optimal at date \( t_1 \) if and only if

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

Condition (1) can be simplified to

\[
\frac{p(1-p)(a_1 + s_1 (1-I))}{p(1-s_1(1-I)-a_1) + (1-p)} (a_2 + s_2 I) X_2 > k_N. \tag{5}
\]

Thus, the direct cost of replacing the incumbent, represented by \( k_N \), cannot be too large to ensure that CEO turnover is ex post efficient when \( x_1 = 0 \).

4 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.

\(^5\)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 CEO would voluntarily leave the firm to make room for the replacement CEO.
The board’s expected utility can be written as

\[ U_{\text{Board}} = (s_1(1-I) + a_1) p X_1 + (s_2 I + a_2) p X_2 - k \]  

(2)

\[ + (s_2 I + a_2) X_2 (s_1(1-I) + a_1) p(1-p) - (1-p(s_1(1-I) + a_1)) k_N. \]

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

\[ \Pr [x_1 = 0] \left( \frac{p(1-p)(a_1 + s_1(1-I))}{(p(1-s_1(1-I) - a_1) + (1-p))} (a_2 + s_2 I) X_2 - k_N \right), \]  

(3)

where \( \Pr [x_1 = 0] = (p(1-s_1(1-I) - a_1) + (1-p)) \) 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 low short-term results. 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

\[ I_{FB}^{FB} = \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_1 s_2} + \frac{1}{2} \frac{s_2 X_2 - s_1 X_1 - s_1 k_N}{s_1 s_2 X_2 (1-p)}, \]  

(4)

which can be rewritten to

\[ I_{FB}^{FB} = \left[ \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_1 s_2} - \frac{1}{2} \frac{s_1 k_N}{s_1 s_2 X_2 (1-p)} \right] + \frac{1}{2} \frac{s_2 X_2 - s_1 X_1}{s_1 s_2 X_2 (1-p)}. \]  

(5)

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

\[ -2X_2 p s_1 s_2 (1-p) < 0. \]

The term in square brackets in (5) represents the level of \( I \) that maximizes the ex ante value of the replacement option. 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.

Investing in the short-term project is beneficial because it leads to better CEO turnover decisions. Intuitively, if the firm invests solely in the long-term project, relatively little is learned about CEO talent in the short run. By allocating capital to the myopic project, the first-period cash flows become more informative about CEO talent because good-type CEOs are more likely to reveal their type by succeeding in the short-run. Consequently, the likelihood that a good-type CEO is mistakenly replaced declines with the level of short-term investment. To see this formally note that \( \Pr[F = G|x_1 = 0] = \frac{p(1-s_1(1-I)-a_1)}{(p(1-s_1(1-I)-a_1)+(1-p))} \) declines with \( 1 - I \).

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 CEO turnover increases the expected probability of having a talented CEO in charge of the second period, 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 turnover option: it increases the information content of the short-term result 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 \( (I^{FB} \text{ declines}) \) 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 the 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 the short-term result, $x_1$, 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 $a_1$. 
5 Main Results

I now consider the original setting in which the CEO’s actions are unobservable. The board therefore needs 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.

5.1 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 \( \beta \) 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 \( \beta X_2 \).
The CEO’s ex ante utility in case he chooses high effort, \( e = e_H \), can now be stated as

\[
U^N_{CEO}(\beta) = p(s_1(1 - I) + a_1)(s_2I + a_2)\beta X_2 - k. 
\] (6)

If the CEO shirks and chooses low effort, \( e = e_L \), short-term cash flows will be low for sure, 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 \( U^N_{CEO}(\beta) \geq 0 \). To ensure participation (and high effort) the board simply chooses the number of options, \( \beta \), such that the expected compensation equals the cost of effort, \( U^N_{CEO}(\beta) = 0 \).

Consider now the CEO’s optimal investment decision, denoted \( I^N \). Taking the first-order condition of (6) with respect to \( I \) leads to

\[
I^N = \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_1 s_2}. 
\] (7)

Condition (7) shows that the long-term equity contract discussed here is not effective in inducing the CEO to focus on the firm’s long-term goals. Instead, the CEO has strong incentives to pay attention to the firm’s short-term performance to reduce the probability of being fired and forfeiting his unvested equity. Consequently, the long vesting horizon of the option grant biases the CEO toward overinvesting in the short-term project.

Comparing the CEO’s investment choice, \( I^N \), with the first-best investment level, \( I^{FB} \), leads to the next proposition.

**Proposition 2** Long-term vesting conditions \( (\beta_V = 0) \) induce the CEO to underinvest in the long-term project, \( I^N < I^{FB} \).
When the CEO makes his investment decision, he only takes into consideration the effect of \( I \) on the joint probability that both periods succeed and ignores the effects of \( I \) on the project’s returns and the firm’s expected cost of CEO turnover. Given that investing in the long-term project is strictly more profitable than investing in the short-term project, \( s_2X_2 - s_1X_1 > s_1kN \), the CEO underinvests in the long-term project if the board relies on stock option grants with long vesting periods.

5.2 Optimal Vesting Schedule

In this section, I determine the optimal stock option contract \( c \). As will become clear later, it is always optimal to require the CEO to hold his options until long-term cash flows are realized. Thus, in the optimal contract it holds that \( \beta_E = 0 \).

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 simplicity, I assume in what follows that \( E = A \). If the first period succeeds, the CEO is retained and the value of his options in case of long-term success is given by \( \beta(A + X_2 - E) = \beta X_2 \). When the CEO is fired due to short-term failure, he retains the options that have already vested, which have a 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

\[
U_{CEO} = (s_1(1-I) + a_1)p(s_2I + a_2)\beta X_2 + (1-p(s_1(1-I) + a_1))p(s_2I + a_2)\beta_v X_2 - k. \tag{8}
\]

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 given by $p(s_2I + a_2)\beta_V X_2$, where $p(s_2I + a_2)$ represents the probability that the replacement CEO will succeed 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 is successful. Hence, to encourage the CEO 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

$$(s_1(1 - I) + a_1)p(s_2I + a_2)(\beta - p\beta_V)X_2 - p\beta_V X_2s_2(1 - I) - k \geq 0.$$ (9)

Condition (9) shows that if the number of options that vest early, $\beta_V$, increases, the CEO’s incentive to acquire firm specific human capital declines. This result follows because early vesting provides the CEO with an opportunity to reap a reward even when he shirks ($e = e_L$). The larger the number of options that vest early, $\beta_V$, the higher is the expected reward for poor short-term performance and the lower is the CEO’s incentive to work hard. Thus, to maintain incentives for effort, any increase in the number of options that vest early, $\beta_V$, must be accompanied by an increase in the total number of options granted to the CEO, $\beta$. As a consequence, an increase in $\beta_V$ is not only directly costly to shareholders (because the CEO can take home a larger pay for poor performance) but also indirectly through the accompanied increase in $\beta$. 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 the CEO chooses $e = e_H$. Taking the first-order condition of (8) yields the CEO’s optimal investment choice

$$I(\beta_V) = \frac{1}{2} - \frac{1}{2} \frac{s_1a_2 - s_2a_1}{s_1s_2} + \frac{1}{2} \frac{\beta_1s_2}{s_1s_2(\beta - p\beta_V)}.$$ (10)
The second-order condition for a maximum is 

\[ -2s_1s_2pX_2(\beta - p\beta_V) < 0 \]

which is always satisfied given that in equilibrium it holds that \((\beta - \beta_V) > 0\) (see the appendix).

While standard arguments predict a positive link between the length of the vesting period and the CEO’s investment horizon, this link is reversed if the CEO is concerned about being removed at an intermediate stage. Specifically, condition (10) shows that if the board allows a larger number of options to vest early (\(\beta_V\) increases), the CEO shifts resources from the short-term project to the long-term project. There are two effects associated with early vesting: first, the CEO will put less weight on short-term results because he can keep the options that have already vested in case he is replaced due to poor performance; second, given that the vested options cannot be exercised until final cash flows are realized, the CEO has an additional incentive to focus on the firm’s long-term success. 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 \((\beta, \beta_V)\) 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, \(\beta\), and the number of options that vest early, \(\beta_V\), are given by

\[
\beta = \frac{s_2 + p(s_1s_2(2I^* - 1) + (s_1a_2 - s_2a_1))}{ps_2(a_1(s_2 + a_2) + s_1s_2(1 - I^*)^2)} \frac{k}{X_2}, \quad \text{and}
\]

\[
\beta_V = \frac{s_1s_2(2I^* - 1) + s_1a_2 - s_2a_1}{ps_2(a_1(s_2 + a_2) + s_1s_2(1 - I^*)^2)} \frac{k}{X_2}.
\]

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 \( \frac{\beta_V}{p} = f^{FB} \equiv \frac{s_3X_3-s_1X_1-s_1k_N}{s_2X_2-s_1pX_1-s_1pN} \) (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, \( \beta_V \), 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 \( \beta_V \) dilutes the CEO’s incentive to work hard which increases the cost of the incentive system. This trade-off leads to an optimal contract that implements an equilibrium level of \( I \) that is lower than the first best level, \( I^* < I^{FB} \).

Specifically, assuming an interior solution\(^6\), the equilibrium investment level, denoted \( I^* \), is characterized by

\[
ps_2X_2 - ps_1X_1 + (s_2 (s_1(1-I)+a_1) - s_1 (s_2I + a_2))pX_2(1-p) - s_1pk_N
-2ks_1 (a_1 + (1-I)s_1)(a_2 + s_2I)(a_2 + s_2)
\left( \frac{1}{a_1a_2 + s_1s_2 (1-I)^2} \right) = 0. \tag{13}
\]

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, \( I^* < I^{FB} \).

\(^6\)The solution is interior as long as \( k \) is not too large. Otherwise, if \( k \) satisfies \( 8k \frac{s_2^2l_2(a_2+l_2)}{(s_1a_2+s_1l_2+l_2a_1)^2} > p(l_2X_2 - s_1X_1 - s_1k_N) \), 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 previous benchmark case, \( I^* = I^{NV} \). See the Appendix for details.
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, $\beta_V$, would shift the 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.

6 Discussion and Empirical Implications

6.1 The Role of Forced CEO Turnover

The model shows that the link between vesting conditions and the executives’ investment horizon depends crucially on whether or not the CEO is subject to being replaced in case of poor interim performance. Assume for the moment that condition (1) is not satisfied such that it is ex post optimal to retain the incumbent even when short-term performance is poor. This is the case, for example, if the a priori probability that the incumbent is a good fit and/or the cost of replacing the incumbent is high. In this situation, it is optimal to induce the CEO to invest exclusively in the long-term project because the board is no longer concerned about the information content of the interim cash flows. This can be done by granting the CEO stock options with long vesting periods. In general, long vesting periods are not only useful in pushing the CEO’s attention toward long-term firm performance but also in retaining highly talented executives because the CEO would forfeit his unvested options when leaving the firm. However, if the CEO faces a risk of early dismissal
(as assumed in the model), long vesting periods backfire and induce the CEO to focus excessively on short-term projects to reduce the probability of forfeiting unvested equity compensation.

Empirical studies that investigate the determinants of vesting schedules should therefore distinguish between firms in which the incumbent is concerned about losing his position and firms in which forced turnover is not an issue. The concern for early dismissal is probably greater if the incumbent is a relatively new hire (maybe from outside the firm) and hence first has to establish that he is the right person for this job than if he is well established and entrenched. The model predicts that in firms in which the CEO is subject to potential dismissal both the fraction of stock options that vest early and the level of myopic investment are larger than in firms in which forced turnover is not a concern.

The empirical predictions that follow refer only to firms in which incumbent CEOs face a risk of being fired at an intermediate date (i.e., condition (1) is satisfied as assumed in the model).

6.2 Investment Strategy and CEO pay

The model generates predictions regarding the determinants of the optimal vesting schedule. Conditions (11) and (12) show that the fraction $f = \beta_v/\beta$ of options that vest early is a positive function of the long-term investment level $I^*$. This follows because if the board wishes to induce the CEO to put greater emphasis on the firm’s long-term performance, it needs to rely on contracts that allow a larger fraction of options to vest early.

Clearly, the equilibrium investment in long-term projects, $I^*$, is larger for firms and industries that have more valuable long-term investment opportunities such as
energy and pharmaceutical firms (where $X_2/X_1$ is relatively large). Thus, the model suggests that in firms with highly valuable long-term investment opportunities, (i) the board allows a larger proportion of options to vest early and, (ii) the total number of stock options granted to the incumbent is larger than in firms with less valuable long-term investment opportunities. Prediction (ii) follows because early vesting dilutes ex ante effort incentives. Thus, in order to maintain effort incentives, the board needs to offer a larger total option grant.

6.3 Investment Strategy and CEO Turnover

The firm’s investment strategy also affects the quality and likelihood of CEO turnover. An increase in the level of short-term investment renders short-term results more informative about the incumbent’s talent and enables the board to make better CEO replacement decisions. Specifically, for larger short-term investments, bad news in the first period are a stronger signal that the incumbent CEO is a low talent, reducing the probability that good-type CEOs are accidentally fired. This result leads to the following two predictions. In firms and industries with valuable long-term investment opportunities (where $I^*$ is relatively large), (i) the likelihood of CEO turnover is higher, and (ii) the CEO in charge of the second period is less likely a high talent than in firms with less valuable long-term investment opportunities (where $I^*$ is smaller).

6.4 The Role of Turnover Cost

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. For example, 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 already has acquired (to some extent) firm specific human capital; that is, \( k_N \) is lower for an insider than for an outsider. Thus, if the board has made sure that there is an insider who is readily available to replace the incumbent if necessary, the direct cost of CEO turnover is smaller for the firm. A smaller turnover cost, in turn, increases the equilibrium long-term investment level, \( I^* \) (see (13)). This 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 myopic project to reduce this cost. Thus, the model predicts that in firms in which the direct cost of CEO turnover is smaller (e.g., firms with a well developed insider succession plan), (i) the level of myopic investment is smaller, (ii) the CEO turnover rate is higher, (iii) the CEO in charge of the second period is less likely to be a high talent, (iv) the board allows a larger fraction of the incumbent’s options to vest early, and (v) the total option package of the incumbent CEO is larger than in firms in which the direct cost of CEO turnover is larger. Implication (iii) 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 probability of short-term success and hence increases the probability that good-type CEOs are accidentally fired.

### 6.5 The Role of 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:

\[ U_{\text{Board}} = (1 - \tilde{\delta})V + \tilde{\delta}U_{\text{CEO}}, \]  

where \( \tilde{\delta} \) is the weight the board places on the incumbent CEO’s utility, \( U_{\text{CEO}} \), and \( (1 - \tilde{\delta}) \) is the weight placed on firm value, \( V \), which is determined by total expected cash flows minus executive pay.\(^7\) Thus, the setting discussed in the main part of the paper is obtained by assuming that \( \tilde{\delta} = 0 \). Given that utility functions are unique only up to a positive linear transformation, it is without loss of generality to describe (14) as

\[ U_{\text{Board}} = V + \delta U_{\text{CEO}}, \]

where \( \delta = \tilde{\delta}/(1 - \tilde{\delta}) \). The parameter \( \delta \) is interpreted as the level of board dependence; the larger \( \delta \), 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 hence 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 compensation plan that induces a level of myopic investment that is greater than the first-best level, \( I^* < I^{FB} \) (see condition (13)). If the board is dependent on the CEO (\( \delta > 0 \)),

\(^7\) Other papers that use a similar characterization of board dependence are Drymiotes (2007), Kumar and Sivaramakrishnan (2008), and Laux and Mittendorf (2010).
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

$$ps_2 X_2 - ps_1 X_1 + (s_2 (s_1 (1 - I) + a_1) - s_1 (s_2 I + a_2)) p X_2 (1 - p) - s_1 p k N$$

$$-(1 - \delta) 2 k s_1 \frac{(a_1 + (1 - I) s_1) (a_2 + s_2 I) (a_2 + s_2)}{(s_2 a_1 + a_1 a_2 + s_1 s_2 (1 - I)^2)^2} = 0.$$ 

This implies that the equilibrium long-term investment, $I^*(\delta)$, is increasing in the level of dependence, $\delta$, 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 in firms in which the board is more dependent on the CEO ($\delta$ is larger), (i) there is less myopic investment, (ii) the probability of CEO turnover is greater (because the CEO is less likely to succeed in the short-run), (iii) the average quality of the CEO in charge of the second period is smaller, (iv) a larger fraction of the incumbent CEO’s options vests early, and (v) the CEO’s total stock option grant is larger.

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.

7 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 of extending
executives’ investment horizon. However, if the incumbent is subject to potential replacement at an intermediate stage, long vesting periods backfire and encourage myopic behavior. This follows because the CEO is concerned about the forfeiture of 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 address this issue by allowing a positive fraction of the executives’ option compensation to vest early, that is, prior to the replacement decision. Short vesting periods do not imply, however, that the CEO should also be allowed to unload his options immediately after vesting. To link CEO pay to the long-term goals of the firm, it is optimal to restrict the unloading of the options after vesting. The combination of early vesting and long holding periods effectively shift 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. Thus, an increase in the fraction of options that vest early is not only directly costly (because the CEO can take home a positive expected compensation when fired) but also indirectly because it increases the total amount of options granted to the CEO to maintain effort incentives.

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 a compensation package that endogenously biases the CEO toward overinvesting in myopic projects. Consequently, the model demonstrates that managerial myopia is not necessarily an artifact of poor corporate governance and faulty pay arrangements but can result from optimal contracting in a multitask agency setting.

Appendix

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

\[
U_{CEO} = \left( s_1(1 - I) + a_1 \right) p \left( (s_2 I + a_2) B_{SS} + (1 - (s_2 I + a_2)) B_{SF} \right) + (1 - p(s_1(1 - I) + a_1)) p(s_2 I + a_2) B_{FS} - k. \tag{15}
\]

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

\[
(s_1(1 - I) + a_1) p \left( (s_2 I + a_2) (B_{SS} - pB_{FS}) + (1 - s_2 I - a_2) B_{SF} \right) - pB_{FS} s_2 (1 - I) - k = 0, \tag{16}
\]

because it is always binding in equilibrium.

To obtain the CEO’s investment choice, take the first-order condition on (15)
which yields

\[-s_1 (s_2 I + a_2) + s_2 (s_1(1 - I) + a_1)) p (B_{SS} - pB_{FS} - B_{SF}) - s_1 pB_{SF} + pB_{FS}s_2 = 0.\]

(17)

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

\[
\text{Max}_{B_{ss}, B_{sf}, B_{fs}, I} L =
(s_1(1 - I) + a_1) p ((s_2 I + a_2) (X_1 + X_2 - B_{SS}) + (1 - (s_2 I + a_2)) (X_1 - B_{SF}))
+(p (1 - s_1(1 - I) - a_1) + (1 - p)) p (s_2 I + a_2) (X_2 - B_{FS})
-(p (1 - s_1(1 - I) - a_1) + (1 - p)) k_N
+\lambda ((s_1(1 - I) + a_1) p ((s_2 I + a_2) (B_{SS} - pB_{FS}) + (1 - s_2 I - a_2) B_{SF}) - pB_{FS}s_2 (1 - I) - k)
+\mu ((-s_1 (s_2 I + a_2) + s_2 (s_1(1 - I) + a_1)) p (B_{SS} - pB_{FS} - B_{SF}) - s_1 pB_{SF} + pB_{FS}s_2),
\]

where \(\lambda\) is the Lagrangian multiplier associated with the effort incentive constraint (16) and \(\mu\) is the multiplier associated with the investment decision constraint (17).

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

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

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 \(ps_2 X_2 - ps_1 X_1 - ps_1 k_N \leq 0\), 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 3). In the second case, it is shown that for \(p (s_2 X_2 - s_1 X_1 - s_1 k_N) \geq 8k \frac{s_1^2 (s_2 + s_2) (s_2 + s_2 + a_1)}{(s_1 a_2 + s_1 a_2 + s_2 a_1)^2}\) 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

$$0 < p (s_2X_2 - s_1X_1 - s_1k_N) < 8k \frac{s_1^2s_2(a_2 + s_2)}{(s_1a_2 + s_1s_2 + s_2a_1)^2},$$

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 (16) and (17) and using \(B_{FS} = 0\), yields the optimal payments \(B_{SS}\) and \(B_{SF}\)

$$B_{SF} = k \frac{s_1s_2(1 - 2I) - s_1a_2 + s_2a_1}{s_2p((s_1(1 - I) + 2a_1)s_1(1 - I) + a_I^2)},$$

$$B_{SS} = k \frac{s_1s_2(1 - 2I) - s_1a_2 + s_2a_1 + s_1}{(s_1(1 - I) + a_I)^2 ps_2}.$$  \hspace{1cm} (18)

Note that since \(B_{FS} = 0\), it follows from the effort incentive constraint (16) 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 (18) and (19)) equals the cost of effort;

$$(s_1(1 - I) + a_1)p ((s_2I + a_2) B_{SS} + (1 - (s_2I + a_2)) B_{SF}) = k.$$  \hspace{1cm} (17)

Substituting (18), (19), \(B_{FS} = 0\), \(\lambda = 1\), and \(\mu = 0\), into \(\frac{dL}{dI} = 0\) yields

$$I = \frac{1}{2} - \frac{1}{2} \frac{s_1a_2 - s_2a_1}{s_1s_2} + \frac{1}{2} \frac{s_2X_2 - s_1X_1 - s_1k_N}{s_1s_2X_2(1 - p)}.$$
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 (18) is nonnegative for \( I = I^{FB} \) if \( \frac{-s_2X_2-s_1X_1-s_1k_N}{X_2(1-p)} \geq 0 \). If this is the case, \( B_{SS} \) in (19) 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 (18), (19), \( B_{FS} = 0, I = I^{FB} \), 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

\[
\lambda = \frac{s_2^2I^2 + 2s_2Ia_2 + a_2^2}{s_2(s_1s_2 + s_2a_1 + a_1a_2 - 2s_1s_2I + s_1I^2s_2)}, \quad (20)
\]

\[
\mu = \frac{-s_2^2I + a_2^2}{s_2(s_1s_2 + s_2a_1 + a_1a_2 - 2s_1s_2I + s_1I^2s_2)} - \frac{(a_2+s_2I)1(s_2+a_2)}{s_2(s_1s_2 + s_2a_1 + a_1a_2 - 2s_1s_2I + s_1I^2s_2)}. \quad (21)
\]

Substituting (20) and (21) into \( \frac{dL}{dB_{SF}} = 0 \) yields

\[
\frac{dL}{dB_{SF}} = -p \frac{s_2a_1^2 + a_2^2 + s_1^2(1-I)^2(s_2+a_2) + (s_2s_1 + s_1a_2)2a_1(1-I)}{a_1(a_2+s_2) + s_1s_2(1-I)^2},
\]

which is negative; hence, \( B_{SF} = 0 \).

Substituting \( B_{SF} = 0 \) into the two incentive constraints (16) and (17) and solving for \( B_{SS} \) and \( B_{FS} \) yields

\[
B_{SS} = \frac{s_2 + p(s_1s_2(2I-1) + (s_1a_2 - s_2a_1))}{ps_2(a_1(a_2+s_2) + s_1s_2(1-I)^2)}k, \quad (22)
\]

\[
B_{FS} = \frac{s_1s_2(2I-1) + s_1a_2 - s_2a_1}{ps_2(a_1(a_2+s_2) + s_1s_2(1-I)^2)}k. \quad (23)
\]

Substituting (22), (23), \( B_{SF} = 0, (20) \), and (21) into \( \frac{dL}{dI} = 0 \) gives the equilibrium investment level, which is determined by

\[
\frac{dL}{dI} = ps_2X_2 - ps_1X_1 + (s_2(s_1(1-I) + a_1) - s_1(s_2I + a_2))pX_2(1-p) \quad (24)
\]

\[-s_1pk_N - 2ks_1 \frac{(a_1 + (1-I)s_1)(a_2 + s_2I)(a_2 + s_2)}{(s_2a_1 + a_1a_2 + s_1s_2(1-I)^2)^2} = 0.
\]
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 (23) is nonnegative; that is, if

$$s_1 s_2 (2I - 1) + s_1 a_2 - s_2 a_1 \geq 0. \tag{25}$$

If this is the case, then $B_{SS}$ is also nonnegative. Condition (25) can be rewritten as

$$I \geq I^T \equiv \frac{1}{2} - \frac{1}{2} \frac{s_1 a_2 - s_2 a_1}{s_2 s_1}. \tag{26}$$

Substituting $I^T$, defined in (26), into (24), 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 (26) 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 (22), (23), $B_{SF} = 0$, (24), $U_{CEO} > 0$, and $I^* < I^{FB}$.

The payments $B_{SS}$ and $B_{FS}$ defined in (22) and (23) can be replicated by the stock option contract described in the main part of the paper by choosing $\beta$ and $\beta_V$ 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 (22) and (23), the condition $\beta_V < \beta$ is satisfied if

$$p s_2 + (s_2 (a_1 + s_1 (1 - I)) - s_1 (s_2 I + a_2)) p (1 - p) > 0. \tag{27}$$

Using the equilibrium condition (24), it can be shown that for $I = I^*$, condition (27) 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 (16) and given by

\[
B_{SS} = \frac{k}{p(s_1(1-I) + a_1)(s_2I + a_2)}. \tag{28}
\]

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 (28) and \(B_{FS} = B_{SF} = 0\)) is given by \((s_1(1-I) + a_1)p(s_2I + a_2)B_{SS} = k.\)

Substituting \(B_{FS} = B_{SF} = 0\) and (28) into the incentive constraint \((17)\) and rearranging yields

\[
I = \frac{1}{2} - \frac{1}{2} \frac{s_1a_2 - s_2a_1}{s_2s_1}. \tag{29}
\]

Solving the equation system \(\frac{dL}{dB_{SS}} = 0\) and \(\frac{dL}{dI} = 0,\) and using (29) and \(B_{FS} = B_{SF} = 0\) yields

\[
\mu = \frac{1}{2} \frac{s_2X_2 - s_1X_1 - s_1k_N}{s_1s_2B_{SS}} \text{ and } \lambda = 1. \tag{30}
\]

Using (30), (29), and (28), it holds that

\[
\frac{dL}{dB_{FS}} = -p(a_2 + s_2) + p\frac{1}{8k} \frac{s_2X_2 - s_1X_1 - s_1k_N}{s_1} \frac{(s_1a_2 + s_1s_2 + s_2a_1)^2}{s_2}, \tag{31}
\]

\[
\frac{dL}{dB_{SF}} = -p\frac{2}{8k} \frac{s_2X_2 - s_1X_1 - s_1k_N}{s_1} \frac{(s_1a_2 + s_1s_2 + s_2a_1)^2}{s_2^2}. \tag{32}
\]

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

\[
p(s_2X_2 - s_1X_1 - s_1k_N) - 8k \frac{s_1^2s_2(a_2 + s_2)}{(s_1a_2 + s_1s_2 + s_2a_1)^2} < 0, \tag{33}
\]

\[
p(s_2X_2 - s_1X_1 - s_1k_N) > 0. \tag{34}
\]

This analysis leads to the next lemma.

**Lemma 3** If (33) and (34) are satisfied, the solution to \((P)\) is described by \(B_{FS} = B_{SF} = 0, (28), (29), U_{CEO} = 0,\) and \(I^* < I^{FB}.\)
Note that the solution characterized in the above lemma is a corner solution. Intuitively, if (33) 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 $\beta = \frac{B_{SS}}{X}$ and $\beta_V = 0$.

References


