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EXECUTIVE COMPENSATION AND THE OPTIMALITY OF MANAGERIAL ENTRENCHMENT

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ABSTRACT

Firms are more complicated than standard principal-agent theory allows: firms have assets-in-place; firms endure through time, allowing for the possibility of replacing a shirking manager; firms have many managers, constraining the amount of equity that can be awarded to any one manager; and, a firm's owner can transfer some control to a manager, thereby entrenching her. Recognizing these characteristics, we solve for the vesting dates; wage, equity and options components; and control rights of an optimal contract. Managerial entrenchment makes the promise of deferred compensation credible. Deferring compensation by delaying vesting reduces a manager's ability to free-ride on a replacement's effort.

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Executive Compensation and the Optimality of Managerial Entrenchment

Abstract

Firms are more complicated than standard principal-agent theory allows: firms have assets-in-place; firms endure through time, allowing for the possibility of replacing a shirking manager; firms have many managers, constraining the amount of equity that can be awarded to any one manager; and, a firm's owner can transfer some control to a manager, thereby entrenching her. Recognizing these characteristics, we solve for the vesting dates; wage, equity and options components; and control rights of an optimal contract. Managerial entrenchment makes the promise of deferred compensation credible. Deferring compensation by delaying vesting reduces a manager's ability to free-ride on a replacement's effort.

I. Introduction.

The dominant paradigm in corporate finance, following Berle and Means (1932), views the firm as characterized by a separation of ownership and control, with that separation being an inevitable result of size. The Berle and Means thesis has since been interpreted as a principal-agent problem in which the separation of ownership and control means that the owners of the firm must hire an agent. The principal-agent model however describes any relationship in which one party hires another to make a non-verifiable effort choice. It describes the relationship between a patient and a doctor, or between a car owner and a mechanic. It does not distinguish between a homeowner hiring a neighborhood kid to mow her lawn, and the owner of a landscaping company hiring an employee to mow lawns. There is no substantive sense in which the standard principal-agent model addresses any particular feature of the agency problem unique to the firm setting originally considered by Berle and Means.

In this paper we reconsider the principal-agent problem by formally embedding it in a firm. Our model recognizes four characteristics that define a firm. First, a firm may be large in the sense that there may exist assets-in-place. This means that an award of equity to a manager will allow her to free-ride on the existing assets, and not just be compensated with a claim on the value added by her efforts. Second, firms cannot only be large in the sense that they have assets-in-place and many managers, firms can be large through time in that they endure. This allows a shirking, but vested, manager to free-ride on not just the assets-in-place, but also on the efforts of potential future replacement managers. The first two characteristics make inducing effort more difficult (compared to the standard principal-agent problem where there is no incentive to free-ride). The situation is further complicated by the third characteristic: A firm may be large in the sense that there may be more than one manager. Hence the fraction of equity that can be awarded to any single manager may be limited, constraining the use of effort-sensitive compensation. We will show that the final characteristic recognized in our model will be useful in solving this expanded principal-agent problem. This fourth characteristic is the recognition that the notion of 'control' is more subtle than the dichotomy between the agent's control over the effort choice and the principal's control over the contract design. We allow for the possibility that the managerial compensation contract can specify that some control rights, initially held by the principal, be transferred to the agent. In particular, the principal and the initial manager may wish to contract on who has the right to determine when a replacement manager is to be hired. We assume that it is feasible for a principal to cede this authority to the agent/manager; e.g., by an award of sufficient voting stock. Such a transfer 'entrenches' the manager.

The above enrichments of the standard principal-agent model are considered in a setting which is otherwise extremely simple. There is no uncertainty (but there is 'nonverifiability'); the manager makes a simple zero/one effort choice (shirk or work); the principal and the agent are risk-neutral; and the form of the compensation contract is limited to a combination of wages, equity and options. We study the design of the optimal compensation contract for the initial (and any replacement) manager.

Realized compensation must be sensitive to the manager's effort choice in order to create an incentive to work. A contract consisting only of a promised wage will create such an incentive if assets-in-place are so low relative to the promised wage that the wage can only be paid if the agent makes an effort. For higher values of assets-in-place it is potentially cheaper to use equity to induce effort than to make the wage so high that it becomes 'risky'. However, an equity share gives the manager a claim on the assets-in-place and not just on the marginal contribution of her effort. We show how this problem can be overcome by using options that effectively sell the equity share to the manager in return for the exercise price; i.e., awards of equity and awards of options are not equivalent in the sense of inducing effort at the same cost to the principal. When the constraint on the fraction of the equity that can be awarded to the manager proves binding, the contract becomes more expensive (because effort must then be induced, at least in part, with 'risky,' and therefore high, wages), and the project may not be undertaken.

To induce the initial manager not to shirk and quit in order to free-ride requires a penalty for quitting. One simple form of such a penalty is to have all the initial manager's compensation vest at a date at which it is no longer optimal for a replacement to be hired. Any attempt to free-ride by resigning prior to that vesting date would mean the loss of all compensation. More generally, delayed vesting serves as an effective bonding mechanism whenever the gain from free-riding is more than offset by the loss of the non-vested, deferred component of the manager's compensation. But precluding free-riding by the manager through delayed vesting immediately creates an incentive for opportunistic behavior by the principal. The principal will have an incentive to fire the initial manager after she has worked but before she has vested. In order for the principal to precommit to not firing the manager requires further separating ownership and control. This involves contractually ceding to the manager the right to determine when she will be replaced; i.e., entrenching the manager.

The related literature includes Berkovitch and Israel (1996) who model the allocation of the replacement decision between bondholders and equityholders. In their article "the role of risky debt is to provide managers with incentives to exert effort vis its effect on managerial replacement decisions" (p. 212). In Berkovitch and Israel the manager wants to retain her position because of non-transferable 'private benefits.' There is no possible issue of free-riding on a replacement manager's efforts because the initial manager's compensation is in the form of 'private benefits' that would be lost in the event of replacement. Thus the manager always wants to continue.

Our model does not have 'private benefits.' Rather, in our model managerial effort is induced via the design of an executive compensation contract that is sensitive to firm value rather than by the possible loss of 'private benefits.' Other papers that consider the allocation and transfer of control rights within a firm includes Chan, Siegel and Thakor (1990), Berglöf (1994), Hellman (1995), Lazear and Freeman (1996), and Rajan and Zingales (1996). Two empirical literatures are related to our analysis. One considers the relation between firm value and the degree of managerial entrenchment. The other concerns executive compensation: its form and sensitivity to performance. These papers are discussed later.

The paper proceeds as follows. Section II presents the model. Section III analyzes the case where the investment opportunity is short-lived in the sense that there is no opportunity to hire a replacement manager. In section IV the issue of free-riding on a replacement manager arises because we consider a long-lived investment opportunity. We analyze the optimal contract in the absence of entrenchment. Section V reconsiders the long-lived investment opportunity allowing the contract to entrench the manager. We show that compensation costs can be lowered when entrenchment is admitted. Section VI contains extensions and conclusions.

II. The Model

The firm consists of a combination of existing assets-in-place and an investment opportunity. The principal supplies any capital necessary to undertake the project and has the property rights to the investment opportunity, but must procure the services of a manager for the project.[1] The manager provides labor in the form of a zero/one effort choice. An investment opportunity lasts for (up to) two periods in the sense that if effort is not expended at time 0, then the opportunity can be exploited at time 1. But this delay can involve some diminution in value (potentially a complete diminution in value). If effort is not expended at time 0, a replacement manager may

[1] This avoids the contracting issues that would arise between the principal and the suppliers of capital. The principal may be thought of as the initial owner of 100% of the firm or as the representative of a more dispersed ownership structure. In the later case we assume there is no conflict of interest between the principal and the dispersed security holders.

be hired at time 1. Without loss of generality the interest rate in our world of perfect certainty is zero. The sequence of events is depicted on the time line in Figure 1.

time 0.	time 1.	time 2.
The principal designs the compensation contract. The manager makes her effort choice.	Short-Lived Project: No further profitable investment opportunity exists. All payoffs to the manager and the principal are realized.	No further investment opportunity exists.

Long-Lived Project:

The party with managerial control rights determines whether to replace the initial manager.

If a replacement manager is hired, the principal determines the new compensation contract, and the replacement makes her effort choice.

Figure 1. Sequence of Events.

Both the principal and the manager are risk neutral. The principal seeks to design a compensation contract which both attracts the manager to participate and induces the manager to make an effort at the lowest possible cost. A project will be undertaken if the project's NPV exceeds zero, where the NPV is calculated net of the manager's compensation under an optimal contract. The manager's utility function is given by $C - D$, where C is lifetime consumption and D is the disutility of expending effort at any time during the manager's career.

A. Assumptions

A1: **(Managers' Reservation Utilities)** *A manager's reservation utilities are R^y when young and R^o when old, with $R^y > R^o$. Moreover, for simplicity we assume $R^o = 0$.*

The inequality $R^y > R^o$ reflects the manager's career opportunities. The assumption that $R^o = 0$ reflects the fact that the ability of a manager to work is tied to the acquisition of firm specific human capital.[2]

A2: **(Production Technology)** *The investment opportunity cannot be physically separated from the other assets-in-place. The technology is such that the manager's effort is required for the specific project and her effort must be supplied continuously over some period. If a manager either resigns or is fired during the period, then output from her project that period is zero.*

A3: **(Control Rights and Managerial Control Rights)** *The principal begins with (i) the right to structure and offer managerial compensation contracts and (ii) managerial control rights. Managerial control rights consist of the right to fire the existing manager and the right to determine whether compensation contract contingencies have been satisfied.*

A4: **(Entrenchment: The Transfer of Managerial Control Rights)** *At the option of the principal managerial contracts may include a verifiable provision which transfers managerial control rights to the manager so long as she chooses to remain in office.*

When the managerial compensation contract includes a provision transferring managerial control rights to the manager we say that the manager is 'entrenched.' Transfers of managerial control rights mean that it is within the power of the principal to create authority within the organization. In other words managers have the power to make some important decisions specific to their contract while the principal retains all other rights.[3] The right to specify the compensation contract offered to the manager always resides with the principal who begins with all control rights. Assumption A4 describes how a principal may transfer managerial control rights to the manager

[2] At the start of her career a manager can develop this capital within many competing firms. Later in her career her human capital is specific to her previous employer and further human capital cannot be acquired. Under this assumption if a manager shirked during the first period and was again employed at the same firm during the second period, she could still make the effort if she chose to do so. We will show however that given the choice of working now versus later, the manager always (weakly) prefers to work during the first period. Alternatively, $R^o = 0$ can be interpreted as meaning that old managers cannot work. The two interpretations of the assumption result in equivalent behavior in this paper's model. We maintain the first interpretation throughout the bulk of the paper.

[3] An example of another right is the right to issue securities. This right could be used opportunistically by any holder of this right to redistribute wealth. This problem is not unique to our model but is generic in capital structure theory. Assumption A7 below is based on taking the form of outside claims on the firm as given. Therefore whatever mechanisms are invoked in capital structure models to limit such opportunism, for example bond covenants and collateral, are also assumed to be applicable here.

and specifies when the managerial control rights revert to the principal. If a manager acquires managerial control rights, she does not acquire the right to renegotiate with herself (and award herself a higher wage for example). Rather, she gets only the right to determine whether she should remain in office.

A4 assumes that managerial control can be verifiably transferred with a contract provision. In practice ownership of control rights corresponds to ownership of votes. In section VB we alter A4 and impose the requirement that managerial control rights can only be transferred by transferring a minimum number of votes.

A5: **(Contracting Technology)** *Only the following are contractually verifiable: (i) whether the manager forgoes other employment; (ii) transfers of cash or securities between the principal and the manager and between the firm and security holders; and (iii) the transfer of managerial control rights.*

A6: **(Observability of Effort)** *Whether a manager works during a period is not observable until the end of the period.*

Note from A5 that the manager's effort choice is never verifiable. That firm value and managerial effort are not verifiable means that compensation contracts contingent thereon are prohibitively expensive to enforce. A5 rules out, for example, a class of shares that are canceled in the event that the project is delayed. Such a contract is not an enforceable contract since the event under which the shares are canceled is the failure to expend effort (which results in the project's delay) and this event is not verifiable. When firm value is isomorphic to effort, the assumption that effort is not verifiable is equivalent to the assumption that firm value is not verifiable.[4]

Assumptions A2 and A6 together imply that (under an optimal contract) a manager will never be fired during a period thereby precluding opportunistic attempts to fire a manager after she has worked but before she receives the period's compensation. However in the two period

[4] The inability to verify firm value should be viewed as reflecting a larger problem in which many classes of a firm's securities are either non- or thinly-traded; e.g., bank loans, capital leases, and a privately held firm's equity.

model if the principal retains managerial control rights he can opportunistically fire the agent after the first period to prevent further wages accruing and/or additional equity vesting.[5]

A7: **(Enforceable Pecuniary Contracts)** *Only the following pecuniary compensation contracts can be enforced: long positions in equity, stock options and wages.*

A7 reflects a low cost of enforcing contracts of the same form as other claimants on the firm. Contracts between the firm and outside suppliers of capital are determined by factors outside our model, and not by managerial compensation issues per se. The manager can free-ride on the interests of these broad classes to uphold the legal status of her own contract. For example, if the compensation contract involves common stock, the court is unlikely to allow dividends on certain stockholdings (e.g. those held by the manager) to be selectively omitted.

A8: **(Constraint on the Fraction of Firm Equity Awarded to a Manager)** *Let the fraction of the firm's stock awarded (potentially through the exercise of executive stock options) to a manager under her compensation contract be denoted by* α*. Assume that* α *is bounded above by* $\overline{\alpha}$*.*

This restriction on α may be thought of as reflecting the fact that the principal is contracting simultaneously with multiple agents. When the firm consists of n projects and n managers, then under A2 (projects cannot be undertaken on a stand-alone basis) one cannot eliminate the principal-agent problem by selling the firm to *the* manager; at most, each manager can hold only $1/n$ of the equity. Alternatively, if votes are linked to shares in some proportion, the constraint may reflect the unwillingness of the principal to transfer so many votes that all control rights are also transferred. Recall that from A4 managerial control rights can be transferred without simultaneously transferring a specific fraction of the claims on residual cash flows, namely equity. When in section VB we consider the problem when managerial control rights can only be transferred by

[5] Recall from A5 that the circumstances surrounding severance are not verifiable. Did she jump voluntarily, or was she pushed? The holder of the managerial control rights has the right to determine the circumstances. Thus severance packages and golden parachutes will not be honored by the principal if he retains managerial control rights. Similarly, if the manager has acquired the managerial control rights, she may opportunistically 'fire' herself. Hence severance payments will not be part of optimal contracts. We observe severance packages and golden parachutes in practice when firm reputation is important in a repeated hiring problem. For simplicity, our model does not consider issues related to repeated hiring and the reputations of the principal and agent.

transferring a minimum fraction of the votes, we recognize that A8 can then preclude the transfer of managerial control rights.

A9: **(Limited Liability)** *Shareholders of the firm have limited liability.*

A10: **(Long-Lived Firms)** *Firms are long-lived in the sense that the principal cannot credibly precommit to destroy the time 1 value of a project not undertaken at time 0.*

A10 implies that a project not undertaken at time 0 may still be undertaken at time 1. The import of this assumption will be seen later when an initial manager's incentive to free-ride on her replacement and the principal's potential responses are explained.

We refer to the value of the firm conditional on a zero effort choice in both periods as the value of 'assets-in-place' and denote this value by V.[6] The following notational conventions refer to the marginal contribution of the manager's effort choice to firm value. Let Δ_1 denote the gross increment in firm value if effort is expended during the first period relative to never-expended. Similarly, Δ_2 denotes the gross increment in firm value if effort is expended during the second (and not the first) period.[7] The minimum cost of hiring a manager who will expend effort is $R^y + D$. At a minimum she must be compensated for her forgone opportunities, R^y, and for the disutility of effort, D. For the problem to be interesting we assume that:

A11: **(Positive NPV Project)** $\Delta_1 > R^y + D$.

We also assume that it is potentially more valuable to undertake the project earlier rather than later.

A12: **(Diminution of Project Value)** $\Delta_1 \geq \Delta_2$.

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[6] Referring to V as the value of assets-in-place is a slight abuse of terminology since the firm also has the option to undertake the investment opportunity. For clarity we wish to distinguish between the value of the firm in the absence of the project and the value-added by the project.

[7] For simplicity we assume that the investment opportunity only requires an input of managerial effort and does not require additional capital. Once combined with managerial effort the existing assets-in-place are both necessary and sufficient to undertake the project.

B. Notation and Definitions

In our notation a superscript will always denote a hiring or contracting date. A subscript will denote a realization date: the date a promised wage is paid, equity or options vest, or an investment payoff is realized. For example, Δ_i denotes the realization of a project's payoff at time i. A managerial compensation contract involves promised wages and equity shares. A wage promised at time j to be paid at time i is denoted W_i^j. Similarly, an equity share contracted for at time j to vest at time i is denoted α_i^j. The pecuniary component of a compensation contract signed at time $j = 0, 1$ is defined to be the specification of a wage and equity share profile $\{W_i^j, \alpha_i^j\}$ with $i = j + 1, j + 2$. For notational simplicity we will sometimes omit the subscripts on W^j and α^j. It is then implicit that the realization date is $j + 1$.

In contracting at time 0, both the initial manager and the principal consider the possibility that a shirking manager may be replaced at time 1. We wish to distinguish between projects where replacement is potentially profitable and those projects for which replacing the manager would not be profitable even if the replacement could be hired and motivated at the minimum possible compensation cost of $R^y + D$.

Definition 1. *A project will be said to be 'short-lived' if $\Delta_2 < R^y + D$. A project will be said to be 'long-lived' if $\Delta_2 \geq R^y + D$.*

The simplest version of a short-lived project occurs when $\Delta_2 = 0$. If not undertaken by the initial manager, a short-lived project is, by definition, a project that is not worthwhile hiring a replacement to manage, and the project will then never be undertaken. A project is long-lived if it *may* still be worthwhile hiring a replacement manager to undertake the project during the second period. We emphasize 'may' since, as will be seen, the actual cost of hiring and motivating a replacement manager can exceed the minimum possible cost of $R^y + D$.

A manager can be hired either under a 'long-term contract' or a 'short-term contract.'

Definition 2. *A 'short-term contract' is a compensation contract in which there is no transfer of managerial control rights as defined in A3 and A4. A 'long-term contract' is a compensation contract in which there is a transfer of managerial control rights*

If a manager is hired at time j under a short-term contract and a wage is promised at time $j+2$ or (some portion of) the stock or option award does not vest until time $j+2$, then the principal will always fire the manager at time $j+1$ whether she has worked or not. Thus for a manager hired under a short-term contract, we need only consider contracts in which all promised wages are due at time $j+1$ and all stock and option awards vest at time $j+1$.

Recalling A7, pecuniary compensation contracts can include not only long positions in equity and wages, they can also include long positions in options. The following definition of an executive stock option shows that it is well-defined by our characterization of the pecuniary component in terms of a wage, equity share profile: $\{W_i^j, \alpha_i^j\}$ with $i = j+1, j+2$.

Definition 3. *An executive stock option corresponds to* $W_i^j < 0$ *and* $\alpha_i^j > 0$.

A contract signed at time j specifying a negative wage to be paid at time i should be interpreted as involving an executive stock option such that at time i the manager pays an exercise price of W_i^j into the firm in exchange for the award of a fraction α_i^j of the firm's shares.

We now turn to the design of the optimal contract in a setting characterized by A1 through A12. For pedagogic reasons we begin by considering optimal contracts given a short-lived project.

III. A Short-Lived Project

We begin by analyzing the problem given a short-lived project because we need only consider short-term contracts. When the project is short-lived the ability to enter a long-term contract does not alter the cost of an optimal contract relative to the cost of an optimal short-term contract. There are two reasons for this. First, if the project is short-lived the initial manager has no opportunity to free-ride on a replacement's efforts since it will never be optimal to hire a replacement. Thus if the work is to be done, she must do it. Second, if a contract will induce her to work, it will induce her to work during the first period of the contract rather than the second. This is shown in Lemma 1.

Lemma 1. (Working now dominates working later.) *Conditional on choosing to work, a* *manager hired at time* 0 *under a long-term contract is always at least as well off working prior to time* 1 *as after.*

Proof: If she works prior to time 1 she has a wage and equity claim on $V + \Delta_1$. If she works after time 1, her claim is backed only by the lesser amount $V + \Delta_2$. Either way she bears the disutility of effort. ∎

Thus when the project is short-lived, a long-term contract that induces a manager to both forgo her outside opportunities and expend effort can be effectively replicated by a short-term contract offering the same total wage (all to be paid at time 1) and the same total equity share (all vesting at time 1).Without loss of generality we therefore assume that managers of short-lived project are hired under short-term contracts.

Recall that the pecuniary component of a short-term contract signed at date 0 is a wage and equity pair, $\{W^0, \alpha^0\}$, where α^0 is restricted to be non-negative. An equity share of α^0 vests at time 1; i.e., vesting is delayed until the end of the contract. Immediate vesting at time 0 is considered in Appendix A. Immediate vesting is shown to be weakly dominated by delayed vesting; the cost of inducing participation and effort is weakly lower with delayed vesting. Delayed vesting has two implications. First, the manager does not vest until after her reservation utility has declined to zero.[8] Second, and more importantly, the manager does not vest until it is economically too late to hire a replacement to undertake the short-lived project. By the definition of a short-lived project, a manager who does not vest until time 1 does not vest until a date at which it is no longer economic to hire a replacement. Thus the initial manager is unable to opportunistically resign in order to free-ride on her replacement's efforts.[9]

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[8] Given immediate vesting a manager could potentially sign and immediately resign. She would then recapture her alternate market opportunities worth R^y and walk away with an equity or option claim on the assets-in-place.

[9] Section IV explicitly considers the problem of opportunistic behavior on the part of an initial manager who vests at a date prior to the final date at which it may be optimal to hire a replacement manager to undertake the project; i.e., section IV considers the case where the initial manager vests at time 1 in a claim on a long-lived project.

A. The Principal's Problem

At time 0 the principal seeks to determine the minimum cost compensation contract that satisfies two conditions: The contract induces the manager to both participate ('the participation constraint') and make an effort ('the effort constraint'). Rationality on the part of the principal ('the principal's rationality constraint') dictates that the project be undertaken if this cost is less than Δ_1. The principal's problem is further complicated by the fact that A8 restricts the equity component of the compensation contract to be such that $\alpha^0 < \overline{\alpha}$ ('the $\overline{\alpha}$ constraint').

A manager will prefer to participate and work rather than not participate (the participation constraint) if:

$$\min[W^0, V + \Delta_1] + \alpha^0 \max[0, V + \Delta_1 - W^0] - D \geq R^y. \quad (1)$$

The participation constraint recognizes the possibility of a 'negative wage.' Recalling Definition 3 a negative wage should be interpreted as paying the exercise price of an executive stock option in exchange for the fraction α^0 of the firm's shares.

A manager who participates will find it optimal to work rather than shirk (the effort constraint) if:

$$\min[W^0, V+\Delta_1] + \alpha^0 \max[0, V+\Delta_1 - W^0] - D \geq \max\left[0, \min[W^0, V] + \alpha^0 \max[0, V - W^0]\right]. \quad (2)$$

The function '$\max\left[0, \min[W^0, V] + \alpha^0 \max[0, V - W^0]\right]$' on the right-hand-side of the effort constraint reflects the fact that the manager will not exercise an out-of-the-money executive stock option. The functions '$\min[W^0, V+\Delta_1]$', '$\min[W^0, V]$', '$\max[0, V - W^0]$' and '$\max[0, V+\Delta_1 - W^0]$' in the participation and effort constraints reflect the firm's limited liability.[10]

[10] It is tempting to interpret the participation and effort constraints in as applicable in a multi-agent setting by considering a principal with n projects each requiring a manager. The natural upper bound on α^0 is then $\overline{\alpha} = 1/n$. From the point of view of any one manager, the value of the assets-in-place is the value of the firm conditional on the effort choice of the other $n-1$ managers. The problem with interpreting constraints (1) and (2) in this manner is that it assumes that only the n'th manager's contract includes a wage component.

The general form of the principal's short-term contracting problem is:

$$\min_{\alpha^0, W^0} \text{ Compensation}$$

$$\begin{aligned} s.t. \quad & \text{Compensation if Work} - D \geq R^y && \text{(participation constraint)} \\ & \text{Compensation if Work} - D \geq \text{Compensation if Shirk} && \text{(effort constraint)} \\ & 0 \leq \alpha^0 \leq \overline{\alpha} && (\overline{\alpha} \text{ constraint}) \end{aligned}$$

Let the (non-unique) pair $\{W^{0*}, \alpha^{0*}\}$ denote the solution to the principal's problem. The following definitions will also be helpful.

Definition 4. *A contract that satisfies the effort constraint and just satisfies the participation constraint will be referred to as a least-cost contract.*

By definition a least-cost contract induces effort. Further, rewriting the participation constraint immediately above when it is just satisfied gives that the manager's compensation when she works is exactly equal to the minimum possible cost of $R^y + D$. Thus any feasible least-cost contract is an optimal contract and costs $R^y + D$. We will show that in the absence of an $\bar{\alpha}$ constraint a least-cost contract can always be achieved. But, as will also be shown, the presence of an $\overline{\alpha}$ constraint can make all least-cost contracts infeasible. The cost of an optimal contract will then exceed least-cost.

Definition 5. *The $\overline{\alpha}$ constraint will be said to be binding when it rules out all least-cost contracts.*

The A7 restriction that $\alpha^0 \geq 0$ implies that a contract with $W^0 > \Delta_1$ would violate the principal's rationality constraint. Thus we only consider wage levels such that $W^0 < \Delta_1$. When $W^0 < \Delta_1$ the participation constraint simplifies to:

$$\alpha^0 \geq \frac{R^y + D - W^0}{V + \Delta_1 - W^0}. \tag{3}$$

From (3) we see that a wage of at least $R^y + D$ will induce participation even absent an equity share. Conversely, an equity stake of at least $\frac{R^y+D}{V+\Delta_1}$ will induce participation absent a wage.

When $W^0 < \Delta_1$ the effort constraint in (2) simplifies to:

$$\alpha^0 \geq \begin{cases} \frac{D-W^0}{V+\Delta_1-W^0}, & \text{if } W^0 < -\frac{D}{\Delta_1-D}V; \\ \frac{D}{\Delta_1}, & \text{if } W^0 \in [-\frac{D}{\Delta_1-D}V, V]; \\ \frac{V+D-W^0}{V+\Delta_1-W^0}, & \text{if } W^0 \in [V, V+\Delta_1]. \end{cases} \quad (4)$$

To understand (4) consider various levels of W^0. When $W^0 < -\frac{\Delta_1}{\Delta_1-D}V$, the exercise price of the option is such that if the manager's equity share equals $\frac{D-W^0}{V+\Delta_1-W^0}$, her option finishes in-the-money by the amount D if she works and exactly at-the-money if she shirks. Given a higher equity share she strictly prefers to work rather than shirk. When $W^0 \in [-\frac{\Delta_1}{\Delta_1-D}V, 0]$ the exercise price of the option is such that if the manager's equity share equals $\frac{D}{\Delta_1}$, her option always finishes in-the-money, and it finishes in-the-money by D dollars more if she works. When $W^0 \in [0, V]$, the promised (positive) wage can be paid whether or not the manager adds Δ_1 to firm value by working. Thus her equity stake alone motivates her to make an effort. This requires that her share of the increase in firm value if she works, $\alpha^0\Delta_1$, exceed her disutility of effort, D; i.e., $\alpha^0 \geq \frac{D}{\Delta_1}$. (Note that A11, $\Delta_1 > R^y + D$, implies that $\frac{D}{\Delta_1} < 1$.) When the promised wage exceeds V, it can only be paid in full if the manager makes an effort. Therefore since the wage is performance sensitive, the other performance sensitive compensation component, α^0, can be reduced while still satisfying the effort constraint. When the promised wage equals $V + D$, the effort constraint will be satisfied even for $\alpha^0 = 0$.

B. A Characterization of the Optimal Time 0 Contract given a Short-Lived Project

Figure 2 depicts the participation and effort constraints for varying levels of V. The solution to the principal's problem, presented in the next subsection, is based on this figure. This subsection is devoted to explaining the figure. Figure 2 is reflects the following Lemma.

Lemma 2. *If the participation and effort constraints intersect, they do so in the horizontal section of the effort constraint.*

Proof: To establish Lemma 2 we show that the effort and participation constraints cannot intersect in either of the upward sloping sections of the effort constraint. The two upward sloping sections correspond to wage levels in the following ranges: $W^0 < -\frac{D}{\Delta_1 - D}V$, and $W^0 \in (V, V+D)$. For $W^0 < -\frac{D}{\Delta_1 - D}V$, the α^0 level just satisfying the participation constraint exceeds the α^0 level just satisfying the effort constraint. For $W^0 < -\frac{D}{\Delta_1 - D}V$, the effort constraint is:

$$\alpha^0 \geq \frac{D - W^0}{V + \Delta_1 - W^0}. \tag{5a}$$

The participation constraint is:

$$\alpha^0 \geq \frac{R^y + D - W^0}{V + \Delta_1 - W^0}. \tag{5b}$$

The right-hand-side of (5*b*) always exceeds that of (5*a*).

For $W^0 \in (V, V+D)$, the α^0 level just satisfying the participation constraint is respectively greater than, equal to, and less than the α^0 level just satisfying the effort constraint when R^y is greater than, equal to, and less than V. For $W^0 \in (V, V+D)$ the effort constraint is:

$$\alpha^0 \geq \frac{V + D - W^0}{V + \Delta_1 - W^0}. \tag{5c}$$

The right-hand-side of (5*b*) exceeds (is less than) that of (5*c*) if $R^y > V$ (if $R^y < V$). When $R^y = V$ the participation and effort constraints overlap exactly for $W^0 \in (V, V+D)$. ∎

As V increases one moves in turn from the setting in Figure 2(a) to that in 2(b), and then to 2(c). An increase in V is equivalent to an increase in the range of wages that can be paid in full even absent any managerial effort. Similarly, the wage level $V + D$, the level that is necessary to induce a manager with zero α^0 to make an effort, also increases by exactly the increase in V. For $W^0 > 0$ an increase in V shifts the effort constraint horizontally to the right. The effect of an increase in V on the participation constraint is to cause the constraint to pivot around the point $\{W^0 = R^y + D, \alpha^0 = 0\}$. This follows since a contract of the form $\{W^0 = R^y + D, \alpha^0 = 0\}$ will just satisfy the participation constraint irrespective of V. The equity stake that will just induce participation when the wage is less than $R^y + D$ is decreasing in V. Thus, the constraint rotates downwards as V increases.

As shown in Figure 2(a), when $V < R^y$, any contract that induces the manager to participate also induces her to make an effort. When the promised wage exceeds the value of the assets-in-place by at least the disutility of effort, D, a wage alone will induce effort: The all-wage contract just satisfying the effort constraint is $\{W^0 = V + D, \alpha^0 = 0\}$. Provided $V < R^y$, the all-wage contract just satisfying the participation constraint, $\{W^0 = R^y + D, \alpha^0 = 0\}$, will more than satisfy the effort constraint. Thus when $V < R^y$, a least-cost contract need not involve $\alpha^0 > 0$.

Figures 2(b) and 2(c) are both situations where $V > R^y$. By Lemma 2, for $V < R^y$ the participation and effort constraints intersect in the horizontal portion of the effort constraint. The intersection wage level, $\mathcal{W}$, is given by:

$$\mathcal{W} = \frac{\Delta_1 R^y - DV}{\Delta - D}. \tag{6}$$

The set of least-cost contracts is the set of $\{W^0, \alpha^0\}$ pairs lying on the participation constraint with $\alpha^0 \geq \frac{D}{\Delta_1}$; equivalently, with $W^0 \leq \mathcal{W}$. Thus when $V > R^y$, all least-cost contracts must involve equity. Least-cost cannot be achieved with an all-wage contract. Figure 2(b) depicts the situation when $R^y < V < \frac{\Delta_1}{D} R^y$, and hence the $\mathcal{W}$ value given by (6) is positive. A least-cost contract may then involve a positive wage. Figure 2(c) depicts the situation where V is so high that $\mathcal{W}$ is negative ($V > \frac{\Delta_1}{D} R^y$), and hence the equity component of a least-cost contract must take the form of an executive stock option.

To see intuitively why a least-cost contract involves a 'negative wage' when $R^y < V < \frac{\Delta_1}{D} R^y$, consider as an alternate contract a zero wage, all equity contract. Under such a contract the manager will receive a fraction α^0 of both the assets-in-place and the increment in firm value if she chooses to work. Suppose that V is exactly equal to $\frac{\Delta_1}{D} R^y$ and set $\alpha^0 = \frac{D}{\Delta_1}$. The value of the fraction of the increment to firm value achieved by working, $\alpha^0 \Delta_1$, exactly compensates the manager for the disutility of her effort, D; i.e.,

$$\alpha^0 \Delta_1 = \frac{D}{\Delta_1} \Delta_1 = D.$$

That same fraction of the assets-in-place, $\alpha^0 V$, exactly compensates the manager for having forgone her outside opportunities worth R^y; i.e.,

$$\alpha^0 V = \alpha^0 \frac{\Delta_1}{D} R^y = \frac{D}{\Delta_1} \frac{\Delta_1}{D} R^y = R^y.$$

For values of the assets-in-place larger than $\frac{\Delta_1}{D}R^y$, that same equity fraction continues to exactly compensate the manager for the disutility of effort. But now she is overcompensated for having forgone R^y. This zero wage contract can not then be an optimal contract. By charging the agent a 'strike price' to receive her equity share (i.e., adding a negative wage component to the compensation scheme) the cost of the contract can be reduced to the least-cost level without affecting the manager's incentive to work.

From Figures 2(a), (b) and (c) we see that, absent an $\overline{\alpha}$ constraint, least-cost contracts always exist. But in the presence of an $\overline{\alpha}$ constraint, the cost of the optimal contract may exceed least-cost.

Lemma 3. *The $\overline{\alpha}$ constraint will be binding whenever both (i) $\overline{\alpha} < \frac{D}{\Delta_1}$ and (ii) $V > R^y$ are satisfied.*

Proof: Inspection of Figures 2(b) and 2(c) reveals that when $V > R^y$, all least-cost contracts involve $\alpha^0 > \frac{D}{\Delta_1}$. ∎

The next subsection formalizes the above discussion of the design and cost of an optimal contract given a short-lived project.

C. The Design and Cost of the Optimal Time 0 Contract given a Short-Lived Project

An optimal contract must contain an effort-sensitive component: an executive stock option, a non-option award of equity, or an effort-sensitive wage. An effort-sensitive wage is 'risky' in the sense that the promised wage can only be paid in full if the manager works. Proposition 1 states when an optimal time 0 contract given a short-lived project *may* contain a particular component, and when a particular component *must* be contained in an optimal contract.

Proposition 1. (The Form of the Optimal Time 0 Contract for a Short-Lived Project)

1. Executive Stock Options: $\{W^0 < 0, \alpha^0 > 0\}$.

An optimal contract may involve executive stock options if either

$$\text{(i) } V < \frac{\Delta_1}{D}R^y \text{ and } \overline{\alpha} > \frac{R^y + D}{V + \Delta_1}, \text{ or } \text{(ii) } V > \frac{\Delta_1}{D}R^y \text{ and } \overline{\alpha} > \frac{D}{\Delta_1}.$$

An optimal contract must involve executive stock options if

$$V > \frac{\Delta_1}{D} R^y \text{ and } \overline{\alpha} > \frac{D}{\Delta_1}.$$

2. *A Non-Option Equity Award:* $\{W^0 \geq 0, \alpha^0 > 0\}$.

   An optimal contract may always involve a non-option equity award.

   An optimal contract must involve executive stock options if

$$R^y < V < \frac{\Delta_1}{D} R^y \text{ and } V\frac{D}{\Delta_1} < \overline{\alpha} < \frac{R^y + D}{V + \Delta_1}.$$

3. *An Effort-Sensitive Wage:* $\{W^0 > V, \alpha^0 \geq 0\}$.

   An optimal contract may involve an effort-sensitive wage if either

$$(iii)\ V < R^y, \quad \text{or} \quad (iv)\ V > R^y \text{ and } \overline{\alpha} < \frac{D}{\Delta_1}.$$

   An optimal contract must involve an effort-sensitive wage if either

$$(v)\ V < R^y \text{ and } \overline{\alpha} < \frac{R^y + D - V}{\Delta_1}, \quad \text{or} \quad (vi)\ V > R^y \text{ and } \overline{\alpha} < \frac{D}{\Delta_1}.$$

Proof: With the exception of the condition in (v), under which an optimal contract *must* contain an effort-sensitive wage, Proposition 1 follows by direct inspection of Figure 2. We prove the claim in condition (v) by contradiction. Suppose that $V < R^y$, $\overline{\alpha} < \frac{R^y + D - V}{\Delta_1}$, and that the W^0 value of a candidate optimal contract is such that $W^0 \leq V$; i.e., the wage component is not effort-sensitive. To be optimal the contract must satisfy the participation constraint. Substituting even the largest value for $W^0 \leq V$, namely $W^0 = V$, into the participation constraint in (3) reveals that the equity component of this candidate optimal contract, α^0, would have to at least satisfy:

$$\alpha^0 \geq \frac{R^y + D - V}{\Delta_1}.$$

But this value for α^0 violates the $\overline{\alpha}$ constraint, and the candidate optimal contract is infeasible. ∎

An immediate corollary to Proposition 1 describes when effort can be induced by a wage alone.

Corollary. *An optimal contract for a short-lived project* <u>*may*</u> *involve a wage alone,* $\{W^0 > V, \alpha^0 = 0\}$, *if either (i)* $V < R^y$ *or (ii)* $V > R^y$ *and* $\overline{\alpha} < \frac{D}{\Delta_1}$.

Proposition 1 includes the important result that a non-option award of stock and an executive stock option are not equivalent contracts. The difference turns on one of the characteristics of the principal-agent problem in the setting of a large firm, namely the existence of assets-in-place. When $\overline{\alpha} > \frac{D}{\Delta_1}$ and $V > R^y$, Proposition 1 states that an optimal contract must include a positive equity share, $\alpha^0 > 0$. However, an equity share cannot avoid giving the manager a claim on the assets-in-place. When the size of the equity share necessary to motivate her to work, overcompensates her relative to her outside opportunities, an optimal contract requires that she buy her equity share with a 'negative wage.'[11]

Having characterized the optimal contract we turn to its cost. Let $C^j(SL)$ denote the cost of an optimal short-term contract signed at time j when the project is short-lived, SL. Proposition 2 sets out the optimal contract cost $C^0(SL)$. (If a long-lived project is not undertaken at time 0, it becomes, by default, a short-lived project at time 1, and $C^1(SL)$ is the cost of then hiring a manager under an optimal contract.)

Proposition 2. (The Cost of the Optimal time 0 Contract for a Short-Lived Project) *The cost of the optimal contract is:*

$$C^0(SL) = \begin{cases} R^y + D; & \text{if } V < R^y, \\ R^y + D; & \text{if } V > R^y \text{ and } \frac{D}{\Delta_1} < \overline{\alpha}, \\ V + D; & \text{if } V > R^y \text{ and } \frac{D}{\Delta_1} > \overline{\alpha}. \qquad (\overline{\alpha} \textit{ constraint binding}) \end{cases} \tag{7}$$

Proof: When the $\overline{\alpha}$ constraint is not binding, the optimal contract is a least-cost contract. Lemma 3 provides the condition under which the $\overline{\alpha}$ constraint will be binding; namely that both (i) $\overline{\alpha} < \frac{D}{\Delta_1}$ and (ii) $V > R^y$ are satisfied. When the $\overline{\alpha}$ constraint is binding, inspection of Figures 2(b) and 2(c) reveals that optimal contracts are those contracts involving an effort-sensitive wage that just satisfy the effort constraint (while also satisfying the $\overline{\alpha}$ constraint). When (4) is satisfied as an equality the effort constraint is just satisfied. When α^0 is so determined by (4), the cost of

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[11] Recall that we have assumed that the vesting of the equity component of the time 0 contracts characterized by Proposition 1 is delayed until time 1. The difference between a non-option award of stock and an executive stock option becomes more extreme when vesting in stock and options is immediate and occurs at time 0. Proposition A2 of Appendix A shows that when vesting is immediate, all least-cost contracts that award an equity share to the manager do so only in the form of executive stock options that are valueless if the manager signs and resigns immediately.

a compensation contract is:

$$
\begin{aligned}
&W^0 + \alpha^0(V + \Delta_1 - W^0) \\
&= W^0 + \frac{V + D - W^0}{V + \Delta_1 - W^0}(V + \Delta_1 - W^0) \\
&= V + D. \quad \blacksquare
\end{aligned}
$$

The cost of an optimal contract for a short-lived project is depicted in Figure 3. Figure 3(a) depicts the case where $\overline{\alpha} < \frac{D}{\Delta_1}$, the situation where effort cannot be induced through the equity component alone. At least part of the effort must be induced through an effort-sensitive wage. When $V > R^y$, a contract with $\alpha^0 < \overline{\alpha}$ that just satisfies the participation constraint will not induce effort; the assets-in-place available to back the promised wage are so large that any difference in the wage actually received if the manager makes an effort does not adequately compensate her for the disutility of effort. To induce her to work requires a higher promised wage resulting in a contract more expensive than least-cost. To motivate the manager requires a wage plus equity package that can be thought of as promising her all the assets-in-place plus an additional amount equal to D. She can only receive the additional amount if she works.

Figure 3(b) depicts the case where $\overline{\alpha} > \frac{D}{\Delta_1}$, the situation where a least-cost contract can be achieved for all V. For example, an equity share of $\frac{D}{\Delta_1}$ and a wage of zero would exactly compensate the manager for the disutility of effort. Adjusting the wage, positively or negatively, can then induce least-cost participation.

In the absence of an $\overline{\alpha}$ constraint the principal will always find it optimal to hire a manager to undertake the project (by A10 the value of the project exceeds the least-cost compensation cost). But when the $\overline{\alpha}$ constraint is binding and $C^0(SL) = V + D > \Delta_1$, then the principal will forgo the project. Thus when assets-in-place are sufficiently large and the presence of multiple managers makes the $\overline{\alpha}$ constraint so tight that it becomes binding, a socially valuable project, a project with $\Delta_1 > R^y + D$, will not undertaken by the principal.

Minimizing this social loss provides a natural theory for the existence of debt. The loss could be avoided if the assets-in-place could be separated from the investment opportunity. But A2 states that this is technologically impossible. However claims to the assets-in-place can be effectively separated from claims on the investment opportunity if the cash flows from the combination of existing assets-in-place plus the project accrue throughout the period in such a way that a debt claim maturing prior to the wage payment can be issued. The earlier maturity of the debt can guarantee that the manager's compensation is backed only by the increment in firm value if she works. Appendix B provides the details of this argument and shows that in this case debt financing can make least-cost compensation contracts feasible. Note that this theory of debt reflects internal firm incentive problems rather than conflicts with outside investors. Space constraints preclude the further consideration of the role of debt in this paper.

D. Summary of Results for a Short-Lived Project

'Large' firms have assets-in-place. Our results show that when there is no $\overline{\alpha}$ constraint, the form of an optimal executive compensation contract depends on the size of the assets-in-place. As shown in Figure 2, when assets-in-place are small an optimal contract need not involve any equity. The promised wage component of an optimal contract can only be honored if the manager works and hence the wage received is sensitive to the manager's effort. At higher levels of assets-in-place, least-cost contracts must involve an equity component. When assets-in-place are higher still, all least-cost contracts take the form of an executive stock options.[12]

'Large' firms have more than one manager. When the resultant $\overline{\alpha}$ constraint proves binding the manager must be rewarded, at least in part, with a promised wage component that is 'risky' in that the realized wage is sensitive to her effort. This can only be accomplished with positive wages,

[12] The work of Clinch (1991), Smith and Watts (1992), and Gaver and Gaver (1993, 1995) documents that equity and options are a more important component of executive compensation contracts when a firm's 'growth-opportunities' are large relative to its 'assets-in-place.' Our model appears to predict the opposite. But the term 'assets-in-place' in our model refers to all other assets of the firm beyond the particular project to be managed. These other assets may take the form that this empirical literature labels as 'growth-opportunities.' The empirical literature considers 'assets-in-place' to be those assets the optimal management of which involves an observable or verifiable effort choice. The empirical literature considers 'growth opportunities' to be those assets whose optimal management involves an agency problem because the necessary effort is not observable or contractible. Expenditures on R&D are used as an empirically proxy for 'growth opportunities.' See also Bizjak, Brickley and Coles (1993).

and hence executive stock options are ruled out, irrespective of the size of assets-in-place (though for the $\overline{\alpha}$ constraint to be binding in the first place requires that $V > R^y$). The $\overline{\alpha}$ constraint on the design of the contract can mean that a project which would otherwise be undertaken may be forgone.

For a short-lived project, the possibility of hiring a replacement does not arise and so the issue of transferring managerial control rights is moot. When the project is long-lived the issue of hiring a replacement manager can arise. In section IV we consider a long-lived project with an initial manager hired under a short-term contract. In section V we consider using a long-term contract to hire the initial manager of that same long-lived project.

IV. A Long-Lived Project and a Short-Term Contract

This section studies the case where the investment opportunity is long-lived and the executive compensation contract involves no transfer of managerial control rights. Because there is no transfer the principal is free to fire the manager after one period. Consequently an optimal contract for the initial manager will not involve wages promised at time 2, or stock or options that do not vest until time 2.

When a project is long-lived it remains potentially valuable after the first period even if the initial manager shirks. When the initial manager is fully vested at time 1 there is an incentive to shirk and free-ride on her replacement. From the point of view of the initial manager, work on her part increases firm value not by the full amount Δ_1, but only by the difference between Δ_1 and what a replacement would add net of the replacement's compensation. In order to determine the optimal short-term contract with a manager at time 0, we must proceed recursively and first determine the compensation contract for a potential replacement manager hired at time 1. In determining the optimal contract for a replacement manager, we must be explicit as to the priority of the claims held by the initial and replacement managers. For tractability we assume:

A13: **(Seniority of Replacement Manager's Claims in Reorganization)** *If the initial manager shirks there is no cash available at time 1 to pay W_1^0, and there is a reorganization in* *which potential replacement managers are offered a wage and an equity package that is senior to any other claim on the firm.*

This assumption can be motivated as analogous to the notion of 'debtor in possession.' At time 1 the firm is unable to pay any promised wage due a shirking manager. If in the subsequent reorganization, the firm is to continue with a replacement manager, the replacement's claim is made senior to all existing claims. The assumption makes the cost of compensating a replacement manager independent of the design of the initial manager's compensation package. We also assume:

A14: **(Seniority of Initial Manager's Claims in Reorganization)** *In a reorganization the claims of an initial shirking manager maintain their original priority relative to the stockholders.*

If the initial manager shirks, she retains her equity claim and any promised wage is replaced by a debt claim to that amount with the debt maturing at time 2 (equivalently, replaced by the proceeds of a bond issue by the firm with a time 2 maturity and face value equal to the wage promised the shirker).

A. Hiring a Replacement Manager at Time 1

As of time 1 the project is short-lived, and therefore the analysis of a replacement manager's optimal compensation package is the same as the section III analysis of optimal contracting given a short-lived project, except that Δ_2 replaces Δ_1 throughout.[13] By analogy with Proposition 2, the cost of an optimal contract for the replacement manager, $C^1(SL)$ is:

$$C^1(SL) = \begin{cases} R^y + D; & \text{if } V < R^y, \\ R^y + D; & \text{if } V > R^y \text{ and } \frac{D}{\Delta_2} < \overline{\alpha}, \\ V + D; & \text{if } V > R^y \text{ and } \frac{D}{\Delta_2} > \overline{\alpha}. \quad (\overline{\alpha} \text{ constraint binding}) \end{cases} \tag{8}$$

A replacement manager will be hired whenever $\Delta_2 > C^1(SL)$.

[13] In compensating the replacement manager there may be a constraint on using equity; i.e., a constraint that $\alpha^1 < \overline{\alpha}$. For simplicity, the upper bound on the equity claim available to offer a manager at time 1 is assumed to be the same as that available to offer a manager at time 0. In the event that the $\overline{\alpha}$ constraint was binding at time 0, the question arises of how the replacement manager can be compensated with equity? The answer is that all shareholders would be willing to issue a sufficient amount of new equity (and hence dilute their own holdings) whenever by doing so the replacement manager can be hired at a cost less than Δ_2. This is consistent with our simplifying assumption that the replacement's claims are senior to existing claims.

B. *A Characterization of the Time 0 Problem*

We now turn to examining the decision problem facing a candidate initial manager. If the initial manager works no replacement need be hired. Hence the participation constraint ('sign and work' beats 'don't sign') is the same as that for a short-lived project considered in section III. Now consider the effort constraint. If the initial manager shirks, a replacement manager is hired whenever $\Delta_2 > C^1(SL)$. An initial manager who shirks will earn

$$\max\left[0, \min[W^0, V + \max[0, \Delta_2 - C^1(SL)]] + \alpha_0 \max[0, V + \max[0, \Delta_2 - C^1(SL)] - W^0\right].$$

Thus the effort constraint given the possibility of free-riding becomes:

$$\min[W^0, V + \Delta_1] + \alpha_0 \max[0, V + \Delta_1 - W^0] - D$$
$$\geq \max\left[0, \min[W^0, V + \max[0, \Delta_2 - C^1(SL)]] + \alpha_0 \max[0, V + \max[0, \Delta_2 - C^1(SL)] - W^0]\right].$$

From the point of view of the initial manager the assets-in-place are not V; they are $V + \max[0, \Delta_2 - C^1_S]$. Since the opportunity to free-ride only exists when $\Delta_2 > C^1(SL)$ it is convenient to define the value of the option to replace a shirking manager.

Definition 6. *Let* $\mathcal{O} := \max[0, \Delta_2 - C^1_S]$, *which we will refer to as the 'replacement option value.'*

The value $\mathcal{O}$ measures the marginal contribution to firm value of the option to replace a shirking manager. Under a short-term contract an initial manager views the assets-in-place as $V + \mathcal{O}$, and the increment that she adds by working as only $\Delta_1 - \mathcal{O}$. According to A3 the party with managerial control rights determines whether to exercise the replacement option. Under a short-term contract the principal retains that right.

The initial manager's ability to free-ride on the efforts of a replacement manager depends on whether the replacement option has value *and* on whether the initial manager's compensation package gives her a valuable claim on that option. Using Definition 6, the effort constraint can be written as:

$$\alpha^0 \geq \begin{cases} \frac{D - W^0}{V + \Delta_1 - W^0}, & \text{if } W^0 < -\frac{D}{\Delta_1 - \mathcal{O} - D}(V + \mathcal{O}); \\ \frac{D}{\Delta_1 - \mathcal{O}}, & \text{if } W^0 \in [-\frac{D}{\Delta_1 - \mathcal{O} - D}(V + \mathcal{O}), V + \mathcal{O}]; \\ \frac{V + \mathcal{O} + D - W^0}{V + \Delta_1 - W^0}, & \text{if } W^0 \in [V + \mathcal{O}, V + \mathcal{O} + \Delta_1]. \end{cases} \tag{9}$$

Note that replacing V in (4) with $V + \mathcal{O}$, and replacing Δ_1 in (4) with $\Delta_1 - \mathcal{O}$ gives the effort constraint for a short-lived project in (9).

As C^1_S increases, $\mathcal{O}$ decreases. The increase in the cost of hiring a replacement reduces the incentive for the initial manager to free-ride. We will show that as $\mathcal{O}$ decreases, the effort constraint for the initial manager converges towards that of a short-lived project. In fact, when $\mathcal{O}$ is zero there is no possibility of free-riding on a replacement and the effort constraint in (9) becomes identical to the effort constraint when the project is short-lived (4).

When a replacement manager cannot be hired at least cost (because $\overline{\alpha} < \frac{D}{\Delta_2}$ and $V > R^y$ and hence $\overline{\alpha}$ constraint binds), the value of the replacement option is:

$$\mathcal{O} = \max[0, \Delta_2 - C^1(SL)] = \max[0, \Delta_2 - (V + D)].$$

Substituting for $\mathcal{O}$ in the effort constraint in (9) results in Figure 4. The effort and participation constraints will always intersect in the horizontal section of the effort constraint.[14] Whether the wage at the intersection point is positive or negative depends on the parameter values.

The replacement option takes on its maximal value when a replacement manager can be hired at least-cost:

$$\mathcal{O} = \max[0, \Delta_2 - C^1(SL)] = \Delta_2 - (R^y + D).$$

Again the effort and participation constraints are as portrayed in Figure 4. It is instructive to compare Figure 4 to Figure 2. Whatever the technological length of the project, the participation constraint remains the same. However the feasible set of contracts is altered by the fact that the project is long-lived because the effort constraint is affected by the existence of the option to replace a shirking manager. The presence of $\mathcal{O}$ moves the effort constraint up and to the right for positive values of W^0 and up and to the left for negative values of W^0.

The replacement option associated with a long-lived project can effect both the terms of an optimal short-term contract entered into at time 0 and the cost of that contract. To illustrate

[14] The effort and participation constraints cannot intersect in either of the upward sloping sections of the effort constraint. The proof of this is analogous to the proof of Lemma 1.

these effects consider the scenario depicted in Figure 5. The figure shows the effort constraints facing the managers of two different firms. The two firms share the same exogenous parameters V, D, R^y, Δ_1 and $\overline{\alpha}$. The firms differ with respect to Δ_2, the delayed value of the project if it is not undertaken until time 1. For one firm the project is short-lived; if delayed it is no longer profitable to undertake the project. For the other firm the project is long-lived, and in fact $\mathcal{O} > 0$.

For the firm with the short-lived project, the parameter values are such that the effort constraint takes the form depicted in Figure 2(a), where a least-cost contract can be achieved and an optimal time 0 contract could involve a positive wage. But for the firm with the long-lived project, the effort constraint is as depicted in Figure 4(c). Although the $\overline{\alpha}$ constraint is not binding at time 0 for the short-lived project, it is binding at time 0 for the long-lived project. As a result a least-cost contract is not feasible. Even if the $\overline{\alpha}$ constraint was weaker and was not binding on the firm with the long-lived project, then although both firms could achieve least-cost, the optimal contract for the firm facing the long-lived project would have to include executive stock options; i.e., 'negative wages.'.

D. The Design and Cost of the Optimal Short-Term Contract given a Long-Lived Project

Given a short-term contract and a long-lived project the initial manager views the assets-in-place as $V + \mathcal{O}$ and her contribution to firm value if she works as $\Delta_1 - \mathcal{O}$. When $\mathcal{O} > 0$ it may be harder to motivate the initial manager with a wage, since the potential sensitivity of the realized wage to effort is reduced by $\mathcal{O}$ relative to the situation where project is short-lived. It may also be harder to motivate the initial manager with an equity claim, since the increase in the value of the firm if she works is reduced by $\mathcal{O}$ relative to the situation where project is short-lived.

Replacing V by $V + \mathcal{O}$, and Δ_1 by $\Delta_1 - \mathcal{O}$, in Propositions 1 and 2 gives the form and cost of an optimal short-term contract for a long-lived project. Since the manager of a long-lived project could be hired under either a short-term or long-term contract we use the notation $C^0(LL, ST)$ and $C^0(LL, LT)$ to denote the respective costs when the project is long-lived of optimal short-term contracts and optimal long-term contracts signed at time 0. Lemma 4 focuses on when executive stock options *must* be included in an optimal short-term contract given a long-lived project.

Lemma 4. **(The Form of the Optimal Short-Term Contract for a Long-Lived Project)** *Executive Stock Options:* $\{W^0 < 0, \alpha^0 > 0\}$.

An optimal short-term contract *must* *involve executive stock options if:*

$$V + \mathcal{O} > \frac{\Delta_1 - \mathcal{O}}{D} R^y \text{ and } \overline{\alpha} > \frac{D}{\Delta_1 - \mathcal{O}}.$$

Lemma 5. **(The Cost of the Optimal Short-Term Contract for a Long-Lived Project)** *The cost of the optimal short-term contract is:*

$$C^0(LL, ST) = \begin{cases} R^y + D; & \text{if } V + \mathcal{O} < R^y, \\ R^y + D; & \text{if } V + \mathcal{O} > R^y \text{ and } \frac{D}{\Delta_1 - \mathcal{O}} < \overline{\alpha}, \\ V + \mathcal{O} + D; & \text{if } V + \mathcal{O} > R^y \text{ and } \frac{D}{\Delta_1 - \mathcal{O}} > \overline{\alpha}. \quad (\overline{\alpha} \text{ constraint binding}) \end{cases} \tag{10}$$

Propositions 3 and 4 compare the form and cost of an optimal short-term contract when the project is short- versus long-lived.

Proposition 3. *For a long-lived project and a short-term contract, the time 0 equity fraction,* α^0*, required to induce effort from the initial manager for any given* W^0 *is at least as great as that necessary when the project is short-lived. When the replacement option has value,* $\mathcal{O} > 0$*, the equity fraction is strictly greater. When a shirking manager would not be replaced,* $\mathcal{O} = 0$ *and the required equity fraction is the same in the two cases.*

Proof: Compare the effort constraint in (4) to the corresponding constraint in (9). ∎

Proposition 4. *For given values of* V*,* Δ_1*,* R^y*,* D *and* $\overline{\alpha}$*, the cost of an optimal short-term contract is always at least as high when the replacement option has value as it is when there is no opportunity to free-ride; i.e.,* $C^0(LL, ST) \geq C^0(SL)$*.*

Proof: Compare Lemma 5 and Proposition 2. ∎

In Propositions 3 and 4, and in Lemmas 4 and 5, the replacement option $\mathcal{O}$ can be characterized in one of three ways. If a replacement can be hired at least-cost, $\mathcal{O} = \Delta_2 - C^1(SL) = \Delta_2 - (R^y + D)$, which by the definition of a long-lived project exceeds zero). If a replacement will be hired but at greater than least-cost, then $\mathcal{O} = \Delta_2 - C^1(SL) = \Delta_2 - (V + D)$. Finally, if it is prohibitively expensive to hire a replacement $\mathcal{O} = 0$. What remains is to determine $\mathcal{O}$ and hence the cost of an optimal short-term contract, $C^0(LL, ST)$ purely in terms of the exogenous parameters. The analysis is contained in Appendix C which derives Figure 6. Figure 6 shows how $C^0(LL, ST)$ varies with both V and $\overline{\alpha}$ for given values of the other exogenous parameters. Moving from Figure 6(a) through to Figure 6(b) corresponds to successively weakening the $\overline{\alpha}$ constraint.

Comparing Figures 6 and 3 we see that when the replacement option has value, the cost of compensating the initial manager strictly increases for values of V corresponding to the shaded regions of Figure 6. The height of the shaded region corresponds to the increase in cost. Interestingly, tightening the $\overline{\alpha}$ constraint can lead to a *reduction* in $C^0(LL, ST)$. The reason is that tightening the $\overline{\alpha}$ constraint can increase the cost of hiring a replacement, but that increase will in turn reduce $\mathcal{O}$. Reducing the initial manager's ability to free-ride can reduce the cost of the optimal short-term contract at time 0. In the extreme, if a binding $\overline{\alpha}$ constraint at time 1 results in a zero value for the replacement option, then a technologically long-lived project is economically short-lived. The same $\overline{\alpha}$ constraint that precludes hiring a replacement may in fact not even be binding at time 0.[15]

E. Summary of Results for a Long-Lived Project and a Short-Term Contract

In this section we have recognized that firms are not only large, they are long-lived. Given a long-lived firm, a replacement manager may be hired when a project is long-lived. One might think that the managerial control right to hire a replacement would be of some value to the principal. However the principal is always at least as well off, and potentially better off, if he can precommit to never exercising this option. The reason is that the replacement option introduces the possibility of free-riding by the initial manager. From her point of view $\mathcal{O}$ is part of the assets-in-place since the principal is unable to separate the time 0 investment opportunity from the delayed investment opportunity. The existence of a valuable replacement option alters the form of the initial manager's

[15] When although the project is long-lived, $\mathcal{O} = 0$ because the $\overline{\alpha}$ constraint binds at time 1, the intersection of the effort constraint and α-axis occurs at $\alpha = \frac{D}{\Delta_2}$ at time 1, and at $\alpha = \frac{D}{\Delta_1}$ at time 0.

effort constraint because the payoff from shirking is a claim on both V and $\mathcal{O}$. To induce effort by the initial manager can then require that she receive even greater compensation for working than would be necessary in the absence of an option to replace a shirking manager.

Interestingly, if the $\overline{\alpha}$ constraint is binding on a replacement manager, it can reduce the cost of hiring an initial manager. Increasing the cost of hiring a replacement reduces the value of the replacement option. It may make hiring the replacement prohibitively expensive, in which case the replacement option has no value. When the replacement option does have value it may still be possible to make long-lived projects economically short-lived by designing a compensation package for the initial manager such that her *claim* on the replacement option is valueless. Designing such a contract is the subject of section V.

V. A Long-Lived Project and a Long-Term Contract

This section studies the case where the investment opportunity is long-lived and the executive compensation contract involves a transfer of managerial control rights. The manager hired under a long-term contract has the authority to decide whether a replacement should be hired at time 1; i.e., the initial manager is entrenched. Subsection A analyzes the case of a long-term contract maintaining A4; i.e., maintaining the assumption that managerial control rights can be transferred via a verifiable contract provision. Subsection B then considers the more realistic setting where managerial control can only be transferred via the award of a minimum number of voting shares at time 1 (before any decision to exercise the replacement option is made). Subsection C contains a discussion of the results.

A. *Contractual Transfer of Managerial Control Rights*

Suppose managerial control rights have been transferred via a provision in the contract. Under a long-term contract an award of equity or an executive stock option could vest at either time 1 or time 2. There can also be credible promises of wages at both times 1 and 2. In this section we show that when under a long-term contract vesting is (credibly) delayed until time 2, the cost of compensating the manager is (weakly) lower than it is under a short-term contract. Under a short-term contract the initial manager must, by default, vest at time 1.

Proposition 5. (Form of the Optimal Long-Term Contract for a Long-Lived Project) *The set of optimal long-term contracts for a long-lived project includes* $\{\alpha_1^0 = W_1^0 = 0, \alpha_2^0 = \alpha^{0*}, W_2^0 = W^{0*}\}$, *where* α^{0*} *and* W^{0*} *are the equity component and wage of an optimal contract for a short-lived project having the same exogenous parameters* V, Δ_1, R^y, D *and* $\overline{\alpha}$.

Proof: When the manager's compensation comes entirely at time 2, it is never in her interest to sign, shirk and resign at time 1—she forgoes the R^y of her youth and gains nothing. The remaining possibilities are: (i) sign the contract at time 0 and work during the first period; (ii) sign and shirk during both periods; (iii) sign, shirk during the first period, and then work; and (iv) don't sign. Strategy (i) dominates strategy (iii) according Lemma 1. Thus to induce effort the contractual payoff from working during the first period must dominate the payoff from shirking in both periods; i.e., the contract must be such that strategy (i) dominates strategy (ii). But this is exactly the effort constraint in (2) associated with a short-lived project with the same values of V, Δ_1, R^y, D and $\overline{\alpha}$. The contract must also induce the manager to sign and work in preference to not signing. But this is exactly the participation constraint in (1) associated with a short-lived project with the same values of V, Δ_1, R^y, D and $\overline{\alpha}$. ∎

What makes a long-lived and a short-lived project different is the possibility of exercising a replacement option. Contractually converting a long-lived project into an economically short-lived project requires removing the possibility of this option being exercised. This means that (i) the initial manager must not quit and (ii) she must not be fired. To guarantee that the manager does not quit the contract must provide incentives not to quit. Proposition 5 illustrates the extreme case where all rights to compensation vest at time 2. More generally, so long as the value of all claims vesting at times 1 and 2 on $V + \Delta_1$ exceeds the value of claims vesting at time 1 on $V + \mathcal{O}$, the manager will not be tempted to quit at time 1. To precommit to not firing the manager requires entrenching the manager with a long-term contract whenever any part of her promised compensation vests at time 2. Otherwise the principal will simply fire the manager at time 1 whether she has worked or not. Delayed vesting in promised time 2 compensation provides an incentive not to quit only when that promise is credible; i.e., when the manager is entrenched.

From Proposition 5 we immediately have an expression for the cost of an optimal long-term contract for a long-lived project, $C^0(LL, LT)$.

Proposition 6. (Cost of the Optimal Long-Term Contract for a Long-Lived Project) *The cost of the optimal long-term contract for a long-lived project, $C^0(LL, LT)$, is the same as the cost of the optimal contract for a short-lived project, $C^0(ST)$. with the same exogenous parameters V, Δ_1, R^y, D and $\overline{\alpha}$. $C^0(ST)$ is set out Proposition 2.*

When the project is long-lived, the principal faces a choice between an optimal long-term contract where he surrenders managerial control rights and an optimal short-term contract where he retains those rights.

Proposition 7. (The Optimality of Entrenchment) *An optimal long-term contract weakly dominates an optimal short-term contract; i.e., $C^0(LL, LT) \leq C^0(LL, ST)$ for all V and $\overline{\alpha}$, and $C^0(LL, LT) < C^0(LL, ST)$ for some V and $\overline{\alpha}$.*

Proof: By Proposition 6, the cost of an optimal long-term contract for a long-lived project, $C^0(LL, LT)$, is the same as the cost of an optimal contract for a short-lived project, $C^0(SL)$, with the same values of V, Δ_1, R^y, D and $\overline{\alpha}$. From Proposition 4 we know that $C^0(SL) \leq C^0(LL, ST)$; i.e., the cost of an optimal contract for a short-lived project is never greater than the cost of an optimal short-term contract for a long-lived project. ∎

Recall that the shaded regions in Figure 6 show the difference between $C^0(LL, ST)$ and $C^0(SL) = C^0(LL, LT)$, and hence the additional cost associated with short-term rather than long-term contracting when the project is long-lived.

Figure 3 can now be thought of as depicting the cost of an optimal contract whenever the initial manager's claim on the replacement option has no value; i.e., Figure 3 depicts both $C^0(SL)$ and $C^0(LL, LT)$. The initial manager's claim will have no value if either the replacement option itself has no value (as with a short-lived project), or because, although the project is long-lived and the option has value, the manager's claim thereon under a long-term contract does not vest until it is too late for her to exercise the option. In other words the optimal long-term contract dominates the optimal short-term contract when the project is long-lived because under the optimal long-term contract the long-lived project becomes economically short-lived; i.e., the initial manager is never replaced.

B. Transfer of Managerial Control Rights via an Award of Voting Stock

The ability to contractually transfer managerial control rights through a verifiable contract provision may be limited.[16] Therefore in this subsection we consider transferring managerial control by awarding voting stock. Instead of A4 we now adopt:

A4′: (Votes and The Transfer of Managerial Control Rights) *Managerial control rights can only be transferred if at least the fraction $\underline{\alpha}$ of the equity is awarded to the manager prior to the possible exercise of the replacement option at time 1.*

Corresponding to the empirical evidence, the fraction of votes necessary to transfer managerial control rights may be small, certainly less than the fraction necessary to acquire all control rights.[17] Whatever the fraction of votes necessary to transfer managerial control rights, the important consideration for our analysis is whether $\underline{\alpha}$ is greater than or less than $\overline{\alpha}$. We consider these two possibilities in turn.[18]

When entrenchment via a transfer of votes is feasible, $\overline{\alpha} > \underline{\alpha}$, the cost of an optimal contract is the same as that when entrenchment can be achieved via a verifiable contract provision. This is an immediate implication of the following proposition:

[16] Still, 37 of the 147 employment agreements of senior executive of Fortune 500 firms for the year 1980 studied in Kole (1994a) contain a provision guaranteeing employment. In seven cases the guarantee lasts more than five years.

[17] Dennis, Dennis and Sarin (1994) document that managers can become entrenched with ownership stakes as low as 1%. See also Mikkelson and Partch (1994).

[18] If residual cash flow rights and votes are bundled as one share-one vote, the upper bound on the award of cash flow claims $\overline{\alpha}$ is also an upper bound on the award of votes. Even when cash flow rights and votes attach separately to non-voting and voting stock, the existence of multiple managers will still constrain the maximum fraction of votes that can be awarded to any one manager. For simplicity, we assume that this bound is also equal to $\overline{\alpha}$.

Proposition 8. *When the transfer of managerial control rights can only be accomplished under A4′ and $\overline{\alpha} > \underline{\alpha}$, then all optimal long-term contracts are equivalent to* $\{W_1^0 = -\frac{\underline{\alpha}}{1-\underline{\alpha}}(V + \Delta_1), \alpha_1^0 = \underline{\alpha}, W_2^0 = W^{0*} - W_1^0, \alpha_2^0 = \alpha^{0*} - \underline{\alpha}\}$, *where* α^{0*} *and* W^{0*} *are the equity component and wage of an optimal contract for a short-lived project having the same exogenous parameters* V, Δ_1, R^y, D *and* $\overline{\alpha}$.

Proof: We must design the compensation package such that (i) the initial manager is entrenched at time 1 and (ii) that the value of her claims if she shirks and resigns at time 1 is less than the value of her claims if she works and remains with the firm until fully vested at time 2. The simplest way to do this is to design the claim on the firm that entrenches her to be such that it has zero value if she shirks and then chooses to resign and be replaced. One simple way of doing this is to award the manager an equity fraction $\underline{\alpha}$ which vests at time 1 and a wage W_1^0 with the wage satisfying

$$W_1^0 + \underline{\alpha}(V + \Delta_1 - W_1^0) = 0.$$

This implies $W_1^0 < 0$; i.e., that the manager becomes entrenched via an executive stock option that is 'out-of-the-money' if the manager shirks and resigns at time 1. If the manager worked and then left the firm at time 1 her option would finish 'at-the-money.' The real payoff to this option is that it entrenches her and gives her the right to remain with the firm until she is fully vested at time 2. Having achieved entrenchment without giving the manager a valuable claim on the replacement we are back in the setting of Proposition 5 and the remainder of the contract therefore consists of the following: $\alpha_2^0 = \alpha^{0*} - \underline{\alpha}$ and $W_2^0 = W^{0*} - W_1^0$. ∎

Notice that since the contract component of Proposition 8 that vests at time 1 is an executive stock option, the optimal W_2^0 of Proposition 8 exceeds the optimal $W_2^0 = W^{0*}$ of Proposition 5 by exactly the amount of the strike price. In other words when managerial control rights can only be verifiably transferred by transferring voting stock, the optimal contract can have the manager buy those votes at time 1 by exercising a stock option, with the purchase/exercise price returned at time 2.[19] The return of the purchase price forms part of the wage component the manager receives

[19] The exercise price of the option vesting at time 1 is set so that it is at-the-money when

at time 2 and hence the time 2 wage will be larger.

The option contract of Proposition 8 is just one of many entrenchment contracts that would motivate the manager without giving her an incentive to free-ride. Another alternative is restricted stock. Restricted stock has the voting and dividends rights of regular stock, but throughout the restriction period the sale of the stock is limited and the stock is forfeited if the executive quits or is fired. When the manager's holdings of voting rights are sufficient to entrench her, the delayed vesting associated with restricted stock can preclude free-riding.

When entrenchment is not feasible, $\overline{\alpha} < \underline{\alpha}$, the principal faces a choice of using a short-term contract to induce effort at time 0 or not hiring a manager at time 0 and delaying the project until time 1. Recall that we are considering a long-lived project where, by definition, $\Delta_2 \geq R^y + D$.

Proposition 9. *When $\overline{\alpha} < \underline{\alpha}$, undertaking the project at time 1 dominates undertaking the project at time 0 if and only if $\Delta_2 - C^1(SL) \geq \Delta^1 - C^0(LL, ST)$.*

Proof: The benefit to the principal from delaying and undertaking the project at time 1 is $\Delta_2 - C^1(SL)$. The benefit from undertaking the project at time 0 is $\Delta_1 - C^0(LL, ST)$. ∎

Note that Proposition 9 conditions on undertaking the project. When a least-cost contract cannot be achieved, it may not be rational for the principal to undertake the project at either date.[20]

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exercised. In fact, the exercise price could be higher still and the option would still be exercised since the payoff from exercising is not just the shares received immediately, but also the receipt of the compensation that will not vest until time 2. Huddart (1994) and Huddart and Lang (1995) empirically document "early exercise" of executive stock options. They attribute "early exercise" to executives' risk aversion and the inalienable nature of the option. Desired entrenchment is a possible additional reason for the "early exercise" of employee stock options.

[20] Proposition 9 adds an additional feature to the problem of the optimal timing of investment analyzed in Abel, Dixit, Eberley and Pindyck (1995). The literature on optimal timing has not to date been concerned with the agency costs associated with the need to hire a manager. Proposition 9 shows that when the manager cannot be entrenched, it may be optimal to delay investment. Delay reduces the cost of undertaking the investment by removing the opportunity to free-ride on a replacement.

VI. Conclusions and Extensions

This paper has considered the principal-agent problem in the setting of a long-lived firm with assets-in-place and many managers. The solution to a standard principal-agent problem is a compensation contract that is sensitive to performance. The difficulty of course is that effort is not contractible. When the project is long-lived, the problem is that performance-sensitive compensation is sensitive to effort per se and not to the identity of a particular manager. A manager hired to oversee a long-lived project will be less tempted to resign and free-ride on her replacement's effort when resignation means the loss of non-vested compensation. To guarantee that the initial manager will have the opportunity to vest, and thereby receive compensation sensitive to her own effort choice, requires that she be entrenched. That is, when the project is long-lived the principal can find it optimal to cede the authority to make the replacement decision (managerial control rights) to the manager.

A researcher studying a manager in the second period of a long-term contract (i.e., 'late' in her career) would observe an entrenched manager making no effort and receiving compensation not apparently linked to performance. In fact, such entrenchment can be part of an optimal contract. In contrast to this implication of our model, a number of papers view entrenchment as an inadvertent byproduct of misdesigned compensation contracts that use voting equity and options to induce effort. See for example, Mørck, Shleifer and Vishny (1988), McConnell and Servaes (1990), Hermalin and Weisbach (1991), and Hubbard and Paluis (1995).[21] This view of entrenchment raises questions since corporate charters could prohibit voting shares being used to motivate managers, requiring instead that pay be linked to performance via non-voting shares. Our model shows that entrenching managers with votes can be desirable when it is necessary to make credible the promise of deferred compensation.

Another implication of our model is that the performance sensitivity of the optimal contract can exist but be more complicated than a simple period by period correlation. Our model links

[21] For empirical work that does not take this view see Kole (1994b) and Mehran (1995).

compensation to effort made earlier in a manager's career. The model with three dates, 0, 1 and 2, was chosen for its tractability: The project arrives at date 0; the next opportunity to undertake the project occurs at date 1, though it may not be profitable to do so; finally, at date 2 it is never optimal to undertake the project. For simplicity, it was assumed that the project could be completed within a period. More generally, there is a date at which it is no longer profitable for the principal to hire a manager to undertake the project. Vesting must come after this date if the free-rider problem is to be avoided. The optimal time till vesting could be either shorter or longer than the time necessary to complete the project. The timing of the link between pay and performance depends on this vesting date (or, in the case of sequential project arrival, on a series of vesting dates). The vesting dates depend on the project technology that determines how fast the project's payoffs decay through time, and on the cost of a replacement manager. It is not clear that pay and performance should be linked within one year, or indeed what the appropriate horizon is. The empirical investigation of the strength of the relation between compensation and current and past performance is marked by disagreement. Jensen and Murphy (1990) report a statistically insignificant relation between current compensation and the second and third lags of corporate performance.[22] Boschen and Smith (1995) document a significant relation between compensation and each of the zero'th through third lags of performance and conclude that "the cumulative response of pay to performance is roughly 10 times that of the contemporaneous response" (p. 577).[23]

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[22] The link with contemporaneous and first-lagged performance while significant is so small that Jensen and Murphy view their results as inconsistent with formal agency models of optimal contracting. However Garen (1994), Haubrich (1994) and Haubrich and Popova (1995) argue that the data are in fact consistent with formal agency models.

[23] A further implication of the model concerns 'age discrimination.' Suppose that a firm with a long-lived project faces a choice between hiring a young or an old manager, each of whom could make an effort. If a firm wants to hire a manager under a long-term contract, that manager must be a young manager in the sense that that manager will outlive the replacement option. When the manager cannot precommit to outlive the replacement option, she will not value deferred compensation as highly as a younger manager. Whether it is cheaper to hire an older manager with a short-term contract or a younger manager with a long-term contract depends on their relative reservation utilities. It is possible that old managers will only be hired to manage short-lived projects.

We are pursuing two extensions of this model of agency problems in a firm setting. Our first extension concerns a multiperiod model where an entrenched manager has a choice of reinvesting or distributing the net cash flows realized through time. The manager faces a trade-off between adopting a suboptimal investment policy (relative to the optimum absent an agency problem) in order to maintain control and adopting the optimal policy that would maximize the value of the firm, and hence her own shares. The agency cost of a suboptimal investment policy will be bounded whenever the manager would prefer to give up control of the firm rather than pursue an investment policy that causes a large loss on her own equity position. In other words, a policy of entrenching the manager initially with votes and compensating her with claims on residual cash flows, as outlined in this paper, is 'self-correcting' over time in the sense that the manager has a built-in incentive not to deviate too far from first-best.

Imbedding the agency problem within a firm setting suggests the second extension: Constructing a theory of the firm. In this paper we have taken the $\overline{\alpha}$ constraint as exogenous. The constraint can be interpreted as an inverse measure of the number of projects within the firm that each require a manager. Clearly it would be desirable to endogenize $\overline{\alpha}$. This raises the question of how many projects should optimally be combined within one firm. There may be a technological benefit of increasing the number of projects due to economies of scale. However, there can be diseconomies due to rising agency costs as the number of managers in the firm increases. The marginal agency cost of hiring an additional manager is increasing because of the additional cost of inducing effort when all managers have an increased opportunity to free-ride because of the increase in firm size.

Appendix A Comparison of immediate and delayed vesting for short-lived projects

Consider a short-lived project. We continue to assume that the wage component contracted on at time 0 is payable at time 1. Our notational convention for such a wage is W_1^0. The equity component of a compensation contract could vest at either time 0 (immediate vesting) or time 1 (delayed vesting). Consistent with our notational convention, we denote the equity component when vesting is immediate by α_0^0.

When vesting is delayed the effort constraint takes the form: 'sign and work' must dominate 'sign and shirk.' We will henceforth refer to this constraint as 'the no-shirk constraint.' Irrespective of the vesting date, 'sign and work' must dominate 'sign and shirk' if the manager is to find it optimal to expend effort. Thus when vesting is immediate 'the no-shirk constraint' given in (4) must be satisfied, except that α_0^0 now replaces α_1^0:

$$\alpha_0^0 \geq \begin{cases} \frac{D-W_1^0}{V+\Delta_1-W_1^0}, & \text{if } W_1^0 < -\frac{D}{\Delta_1-D}V; \\ \frac{D}{\Delta_1}, & \text{if } W_1^0 \in [-\frac{D}{\Delta_1-D}V, V]; \\ \frac{V+D-W_1^0}{V+\Delta_1-W_1^0}, & \text{if } W_1^0 \in [V, V+\Delta_1]. \end{cases} \tag{A1}$$

When vesting is immediate, there is an additional restriction on the compensation contract that must be satisfied before effort will be expended: the contract must be such that 'sign and work' also dominates 'sign and resign.' We term this additional restriction 'the no-quit constraint':

$$\min[W_1^0, V+\Delta_1]+\alpha_0^0\max[0, V+\Delta_1-W_1^0]-D \geq R^y+\max\left[0. \min[W_1^0+\alpha_0^0(V-W_1^0), \alpha_0^0 V]\right]. \tag{A2}$$

(When vesting is delayed, a 'no-quit constraint' must also be satisfied. But when vesting is delayed the payoff to signing and resigning is simply the recapture of one's outside opportunities, R^y; i.e., the same as that to not participating at all. Hence the participation constraint subsumes the 'no quit constraint' when vesting is delayed.) To understand the right-hand-side of ($A2$), first recall assumption A2 which states that a manager can not be replaced within the period. When $W_1^0 > 0$, signing and resigning leaves the vested manager with not only her outside market opportunities worth R^y but an equity claim on the assets-in-place, that claim being worth $\alpha_0^0 V$. When $W_1^0 < 0$, a manager who signs and resigns is vested in a stock option worth $\max[0, W_1^0 + \alpha_0^0(V - W_1^0)]$. The 'no-quit constraint' in $(A2)$ can be expressed as:

$$\alpha_0^0 \geq \begin{cases} \frac{R^y+D-W_1^0}{V+\Delta_1-W_1^0}; & \text{if } W_1^0 < -\frac{R^y+D}{\Delta_1-(R^y+D)}V, \\ \frac{R^y+D}{\Delta_1}; & \text{if } W_1^0 \in [-\frac{R^y+D}{\Delta_1-(R^y+D)}V, 0], \\ \frac{R^y+D-W_1^0}{\Delta_1-W_1^0}; & \text{if } W_1^0 \in [0, V+\Delta_1]. \end{cases} \tag{A3}$$

The effort constraint is the outer envelope of the 'no-shirk constraint' in $(A1)$ and the 'no-quit constraint' in $(A3)$. Figure A1 depicts the participation, no-shirk and no-quit constraints given immediate vesting. When $V < R^y$ the 'no-shirk constraint' lies everywhere below the 'no quit constraint.' When $V > R^y$ the two constraints intersect. (Figure A1 depicts the situation when $V < \frac{\Delta_1}{\Delta_1 - D}R^y$, in which case the intersection wage exceeds V. The intersection wage is less than V when $V > \frac{\Delta_1}{\Delta_1 - D}R^y$.)

Since the effort constraint with delayed vesting is equivalent to the 'no shirk' component of the effort constraint applicable when vesting is immediate, the effort constraint with immediate vesting is always at least as restrictive as the effort constraint when vesting is delayed. Proposition A1 is an immediate implication of this observation.

Proposition A1. *Immediate vesting never dominates delayed vesting.*

Proof: First consider the case when $V < R^y$. Comparing $(A1)$ and $(A3)$ reveals that if $V < R^y$, an all wage contract $\{W_1^0 = R^y + D, \alpha_i^0\}$ is least cost whether $i = 0$ or $i = 1$; i.e., whether vesting is immediate or delayed. Clearly, when a least-cost contract does not contain an equity component, its vesting date is irrelevant. Now consider the case when $V > R^y$. When vesting is delayed we have from Lemma 3 that a least-cost contract exists so long as $\overline{\alpha} > \frac{D}{\Delta_1}$. Inspection of Figure A1 reveals that when $V > R^y$, a least-cost contract with immediate vesting exists only so long as $\overline{\alpha} > \frac{R^y+D}{\Delta_1}$. Thus an $\overline{\alpha}$ constraint can be binding when vesting is immediate, yet not binding when vesting is delayed. The converse statement is never true. When $V > R^y$ and $\overline{\alpha} < \frac{D}{\Delta_1}$, in which case the $\overline{\alpha}$ constraint is binding with both delayed and immediate vesting, the cost of the optimal contract is $V + D$ irrespective of the vesting period. ∎

Proposition A2. *When vesting is immediate, least-cost contracts take one of two forms: (i) an option that is valueless if the manager signs and resigns immediately, (ii) an all-wage contract.*

Proof: First consider values of $W_1^0 < -\frac{R^y+D}{\Delta_1-(R^y+D)}V$. The reader may verify that a contract of the form $\{W_1^0 < -\frac{R^y+D}{\Delta_1-(R^y+D)}V, \alpha_0^0 = \frac{R^y+D-W_1^0}{V+\Delta_1-W_1^0}\}$ will be valueless if the manager signs and resigns; the executive stock option will finish out-of-the-money. Under such a contract the manager has R^y if she doesn't sign, and she only has R^y if she signs and immediately resigns. (If she signs and shirks she has nothing.) This contract will just satisfy both the participation and effort constraints, and hence is least-cost.

Now consider $W_1^0 > -\frac{R^y+D}{\Delta_1-(R^y+D)}V$. The reader may verify that the compensation cost exceeds least-cost when $W_1^0 \in [-\frac{R^y+D}{\Delta_1-(R^y+D)}V, R^y + D)$ and the α_0^0 value is chosen to just satisfy the 'no-quit constraint.' However, the all wage contract $\{W_1^0 = R^y + D, \alpha_0^0 = 0\}$, which just satisfies both the participation constraint and the 'no-quit constraint,' will be a least-cost contract provided it also satisfies the 'no-shirk' component of the effort constraint. This all wage contract will in fact satisfy the 'no-shirk' component whenever $V < R^y$. ∎

Appendix B A theory of debt based on agency costs

Consider a short-lived project with a binding $\overline{\alpha}$ constraint. From Lemma 3 we have that when $\overline{\alpha} < \frac{D}{\Delta_1}$, the $\overline{\alpha}$ constraint will be binding if the assets-in-place technologically bundled with the investment project are worth more than R^y. But if that same project could be implemented on a stand alone basis (i.e., if instead $V = 0$), a manager could be hired at least-cost. We wish to consider the implications of issuing debt maturing prior to the wage payment in order to effectively separate the cash flows to the assets-in-place from the cash flows to the incremental project. For expositional purposes we model this as if the debt matured at the end of the period, but was senior to the wage claim. In order to actually be able to repay debt maturing prior to the wages, it must be that sufficient cash flows arrive during the period. (For consistency with A6, the incremental cash flow due to making an effort would then have to arrive at the end of the period.)

Proposition B1. *Suppose the $\overline{\alpha}$ constraint is binding on an unlevered firm. An otherwise equivalent levered firm could hire a manager at least-cost provided the face value of its debt, B, satisfied $B \in [V - R^y, V + \Delta_1 - R^y - D]$.*

Proof: Given an outstanding debt issue (senior to the wage), the participation and effort constraints take the respective forms:

$$\min[W^0, \max[0, V - B + \Delta_1]] + \alpha^0 \max[0, V - B + \Delta_1 - W^0] - D \geq R^y \tag{B1}$$

and

$$\min[W^0, \max[0, V - B + \Delta_1]] + \alpha^0 \max[0, V - B + \Delta_1 - W^0] - D \geq$$
$$\max\left[0, \min[W^0, \max[0, V - B]] + \alpha^0 \max[0, V - B - W^0]\right]. \tag{B2}$$

For values of $B \in [V - R^y, V + \Delta_1 - R^y - D]$,

$$V - B < R^y, \tag{B3a}$$

and

$$V - B + \Delta_1 > R^y + D > 0. \tag{B3b}$$

Given $(B3b)$ the participation and effort constraints simplify to:

$$\min[W^0, V - B + \Delta_1] + \alpha^0 \max[0, V - B + \Delta_1 - W^0] - D \geq R^y. \tag{B1'}$$

and

$$\min[W^0, V - B + \Delta_1] + \alpha^0 \max[0, V - B + \Delta_1 - W^0] - D \geq$$
$$\max\left[0, \min[W^0, \max[0, V - B]] + \alpha^0 \max[0, V - B - W^0]\right]. \tag{B2'}$$

Now consider a wage satisfying $W^0 \in [V - B, V - B + D]$. Since $D < \Delta_1$, wages in this range will also satisfy the inequality $W^0 < V - B + \Delta_1$. For such wage levels the participation and effort constraints further simplify to:

$$W^0 + \alpha^0[V - B + \Delta_1 - W^0] - D \geq R^y. \tag{B1''}$$

and

$$W^0 + \alpha^0[V - B + \Delta_1 - W^0] - D \geq \max[0, V - B]. \tag{B2''}$$

Given $(B3a)$, it follows that for all α^0 values such that the participation constraint $(B1'')$ is just satisfied when $W^0 \in [V - B, V - B + D]$, it is the case that the effort constraint $(B2'')$ is also satisfied. Hence all such $\{W^0, \alpha^0\}$ combinations are least-cost contracts. This set contains the pair $\{W^0 = D + R^y, \alpha^0 = 0\}$, which clearly satisfies any $\overline{\alpha}$ constraint. By continuity, $\{W^0, \alpha^0\}$ pairs in this set in a neighborhood of $\{W^0 = D + R^y, \alpha^0 = 0\}$ will also satisfy the $\overline{\alpha}$ constraint. ∎

Appendix C. Discussion of optimal short-term contracts for long-lived projects

$C^0(LL, ST)$ is depicted in Figure 6 as a function of the $\overline{\alpha}$ constraint and the value of the assets-in-place, V. Moving from Figure 6(a) through to Figure 6(d) corresponds to successively loosening the $\overline{\alpha}$ constraint. Loosening the $\overline{\alpha}$ constraint can affect the compensation of both a replacement manager and the initial manager. Moreover these changes in compensation cost are linked as follows. If loosening the $\overline{\alpha}$ constraint lowers the cost of hiring a replacement, it increases the incentive for the initial manager to free-ride. This shifts the initial manager's effort constraint up. Whether this leads to an increase in the cost of compensating the initial manager depends on whether the $\overline{\alpha}$ constraint has moved up even more. The various possibilities are considered in Figure 6.

First consider the setting depicted in Figure 6(a): the case when $\overline{\alpha} < \frac{D}{\Delta_1}$. When $\overline{\alpha} < \frac{D}{\Delta_1}$ it follows immediately that $\overline{\alpha} < \frac{D}{\Delta_2}$ and so, unless $V < R^y$, the $\overline{\alpha}$ constraint is binding on a replacement manager. When $V < R^y$ and a replacement can be hired at least-cost, we see from Figure 4(a) that a least-cost contract can be achieved for the initial manager provided $V + \mathcal{O} = V + [\Delta_2 - (R^y + D)] < R^y$; i.e., provided $V < 2R^y + D - \Delta_2$.[C1] When $V < R^y$ but $V > 2R^y + D - \Delta_2$, the cost of compensating the initial manager is $V + \mathcal{O} + D = V + [\Delta_2 - (R^y + D)] + D$. When $V > R^y$, the $\overline{\alpha}$ constraint is binding on a replacement manager and $C^1(SL) = V + D$. For $V + D < \Delta_2$, a replacement will be hired. We see from Figures 4(b) and (c) that the $\overline{\alpha}$ constraint will then be binding on the initial manager who will be hired at a cost of $V + \mathcal{O} + D = V + [\Delta_2 - (V + D)] + D = \Delta_2$. For $V + D > \Delta_2$, a replacement will not hired. We see from Figures 2(b) and (c) that the $\overline{\alpha}$ constraint will again be binding on the initial manager and the cost of hiring the initial manager

[C1] Figure 6 is drawn to reflect the situation when $2R^y + D - \Delta_2 > 0$. Since $2R^y + D - \Delta_2 < R^y$, nothing of substance is altered when $2R^y + D - \Delta_2 < 0$. The $C^0(LL, ST)$ axis is simply shifted to a point between $2R^y + D - \Delta_2$ and R^y.

will be $V + D$.

Figure 3(a) depicts the cost of the optimal time 0 contract when the project is short-lived for the case when $\overline{\alpha} < \frac{D}{\Delta_1}$. Comparing Figures 6(a) and 3(a) we see that the replacement option implicit in a long-lived project can increase the cost of compensating the initial manager relative to the situation where the project is short-lived.

Turning to Figure 6(b), the $\overline{\alpha}$ constraint is looser than in 6(a). Although looser, $\overline{\alpha}$ is still less than $\frac{D}{\Delta_2}$ and hence the $\overline{\alpha}$ constraint will be binding on a replacement whenever $V > R^y$. When $V > R^y$ it will still be optimal to hire a replacement manager provided that $V < \Delta_2 - D$. For $V \in [R^y, \Delta_2 - D]$ it is the case that as V increases, the value of the replacement option, and hence the incentive to free-ride thereon, decreases. For values of $V \in [R^y, \Delta_2 - D]$ that are greater than a critical level, $\mathcal{V}$, the $\overline{\alpha}$ constraint will then become non-binding on the initial manager. This critical value $\mathcal{V}$ is given by the solution to:

$$\overline{\alpha} = \frac{D}{\Delta_1 - [\Delta_2 - (\mathcal{V} + D)]}.$$

When $V > \Delta_2 - D$ a replacement will never be hired at time 1, $\mathcal{O} = 0$, and least-cost compensation of the initial manager can be achieved.

Further loosening the $\overline{\alpha}$ constraint we move to Figure 6(c). One might think that the initial manager's contract would now be least-cost over an even wider range of V. Comparing Figures 6(ci) and 6(cii) to Figure 6(b) we see that while this can happen, it need not. In both 6(ci) and 6(cii), $\overline{\alpha} > \min[\frac{D}{\Delta_2}, \frac{D}{\Delta_1 - [\Delta_2 - (R^y + D)]}]$. In 6(ci), $\overline{\alpha} > \frac{D}{\Delta_2}$ and the $\overline{\alpha}$ constraint is never binding on the replacement. The consequence of this is that for $V > R^y$ the cost of compensating the replacement manager is reduced relative to the cost in 6(b). This means that the incentive for the initial manager to free-ride has increased: shifting the $\overline{\alpha}$ constraint up has also shifted the effort constraint up. In fact, the effort constraint has moved up by more than the $\overline{\alpha}$ constraint has, since in 6(ci) $\overline{\alpha}$ remains less than $\frac{D}{\Delta_1 - [\Delta_2 - (R^y + D)]} = \frac{D}{\Delta_1 - \mathcal{O}}$. The cost of compensating the initial manager rises as a result. In contrast the cost of compensating the initial manager falls in Figure 6(cii) relative to 6(b). In the setting depicted in Figure 6(cii), $\overline{\alpha} < \frac{D}{\Delta_2}$. Here for $V > R^y$ ($V < R^y$), the $\overline{\alpha}$

constraint is binding (is not binding) on the replacement. The cost of hiring a replacement is the same as that in the setting depicted in Figure 6(b). The value of the initial manager's claims on the replacement option is not changed by the loosening of the $\overline{\alpha}$ constraint, and the initial manager's effort constraint does not move up. The only effect on the initial manager's compensation then comes through the loosening of the $\overline{\alpha}$ constraint. It is now so loose that least-cost compensation of the initial manager can be achieved for all V.

Finally consider Figure 6(d). In the setting of Figure 6(d), $\overline{\alpha} > \frac{D}{\Delta_2}$ and hence (as is in Figure 6(ci)) the $\overline{\alpha}$ constraint is never binding on the replacement. Although for $V > R^y$, the loosening of the $\overline{\alpha}$ constraint means that the initial manager's effort constraint moves up relative to the situation in Figures 6(b) and 6(cii), the $\overline{\alpha}$ constraint moves up even more. In fact, the $\overline{\alpha}$ constraint is now so loose that it is never binds the initial manager.

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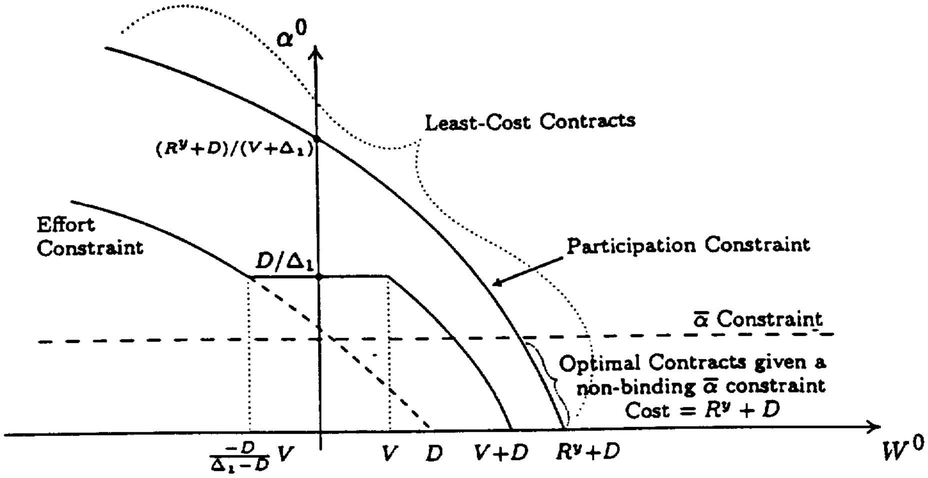

Figure 2(a) $V < R^y$

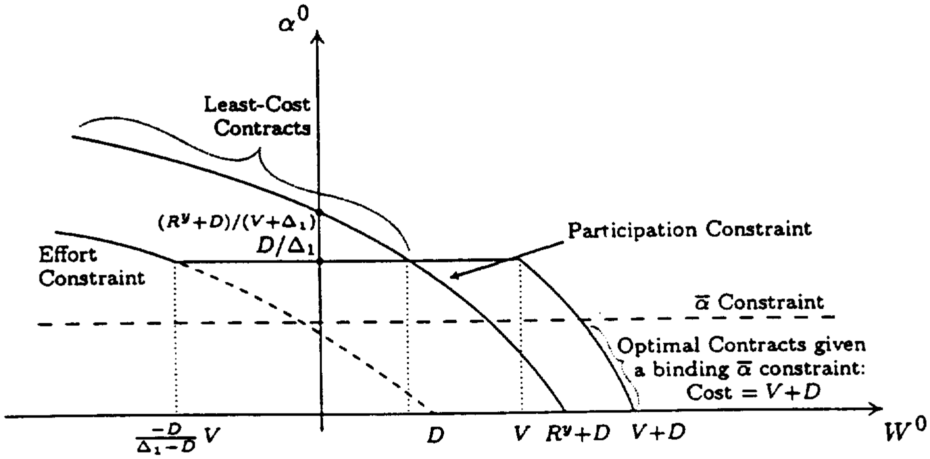

Figure 2(b) $R^y < V < \frac{\Delta_1}{D} R^y$

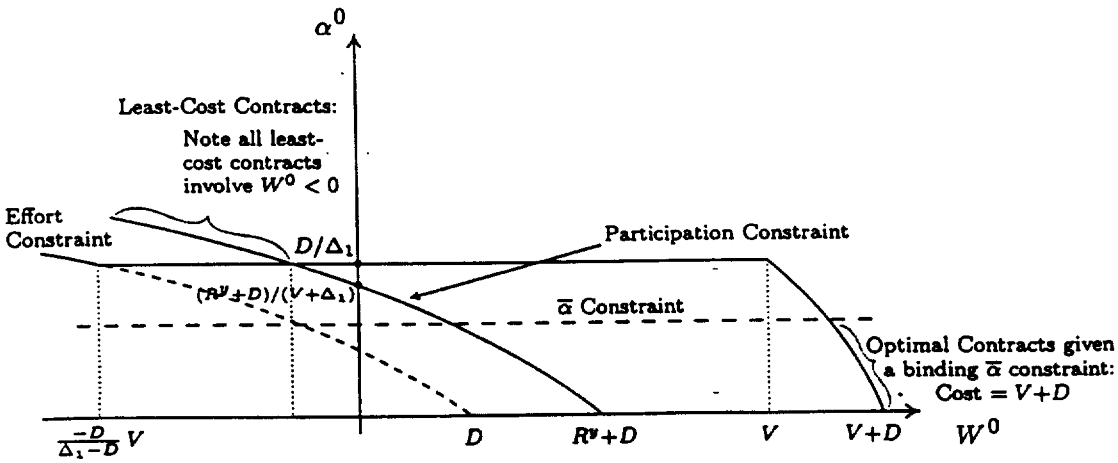

Figure 2(c) $\frac{\Delta_1}{D} R^y < V$

Figure 2. Time 0 compensation contracts, $\{\alpha^0, W^0\}$, given a short-lived project and vesting at time 1. α^0 is the manager's equity share. W^0 is the wage. A negative wage corresponds to an executive stock option.

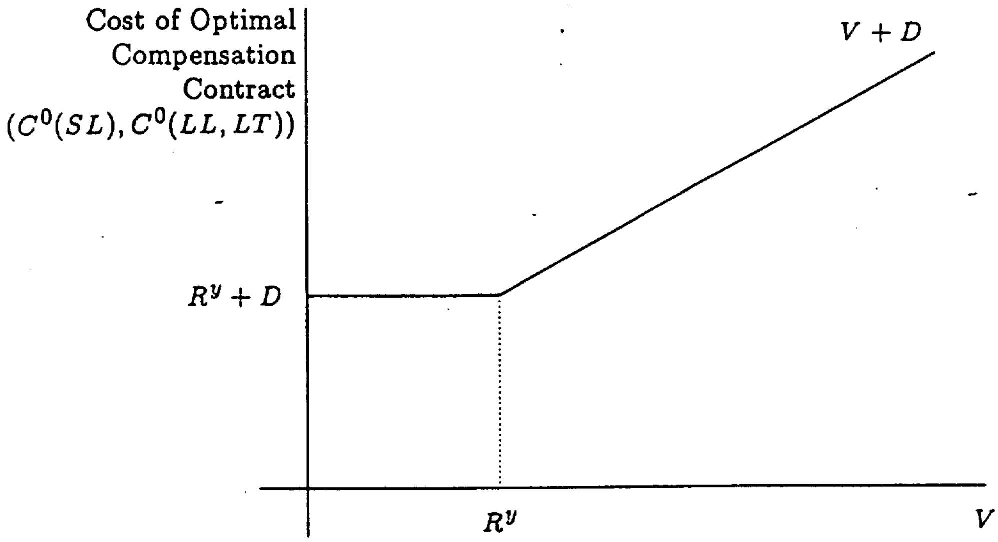

Figure 3a. $\overline{\alpha} < \frac{D}{\Delta_1}$

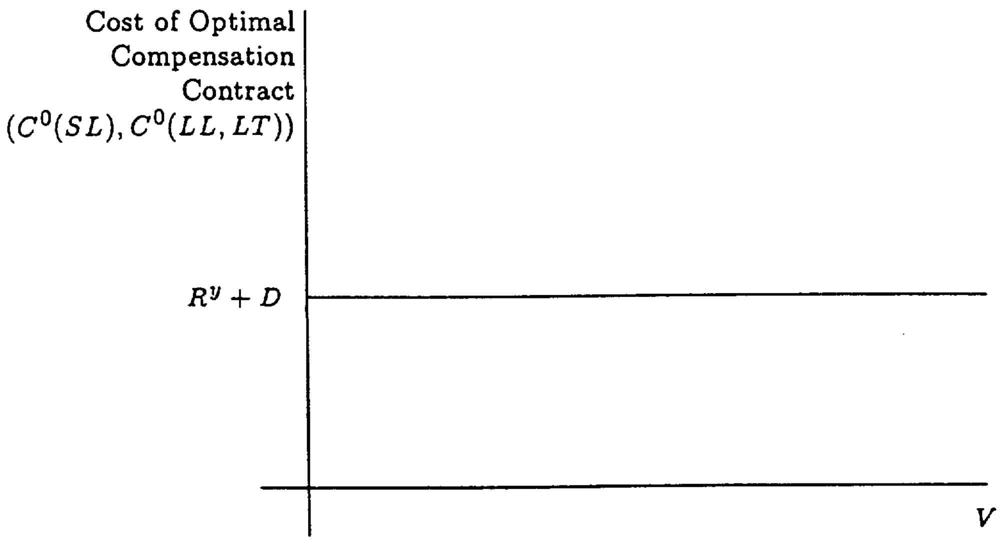

Figure 3b. $\overline{\alpha} > \frac{D}{\Delta_1}$

Figure 3. Cost of optimal time 0 compensation contracts, when the initial manager will never be replaced. The initial manager will never be replaced if either the project is short-lived, in which case we denote the cost by $C^0(SL)$; or, although the project is long-lived, the initial manager is hired under an optimal long-term contract, in which case we denote the cost by $C^0(LL, ST)$.

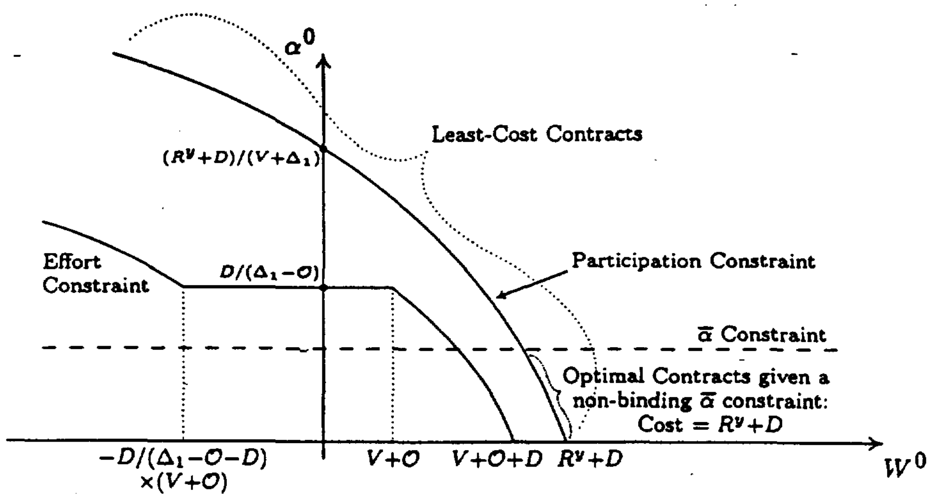

Figure 4(a) $V + \mathcal{O} < R^y$

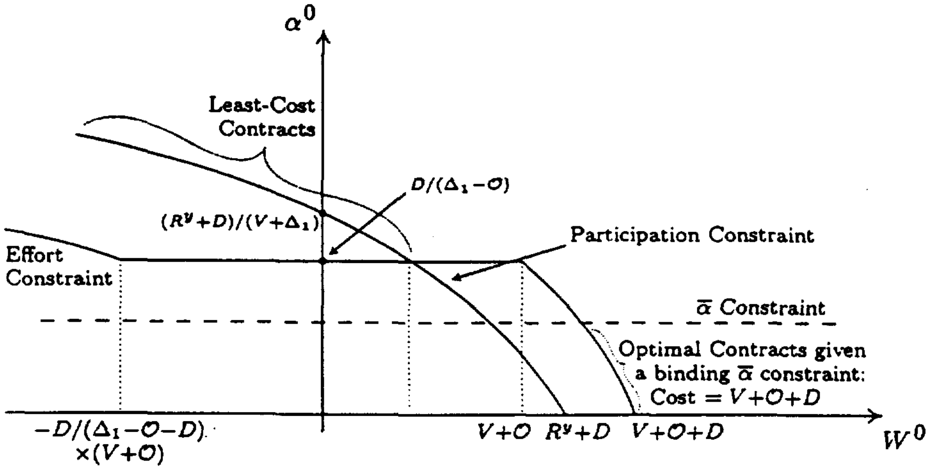

Figure 4(b) $R^y < V + \mathcal{O} < \frac{\Delta_1-\mathcal{O}}{D} R^y$

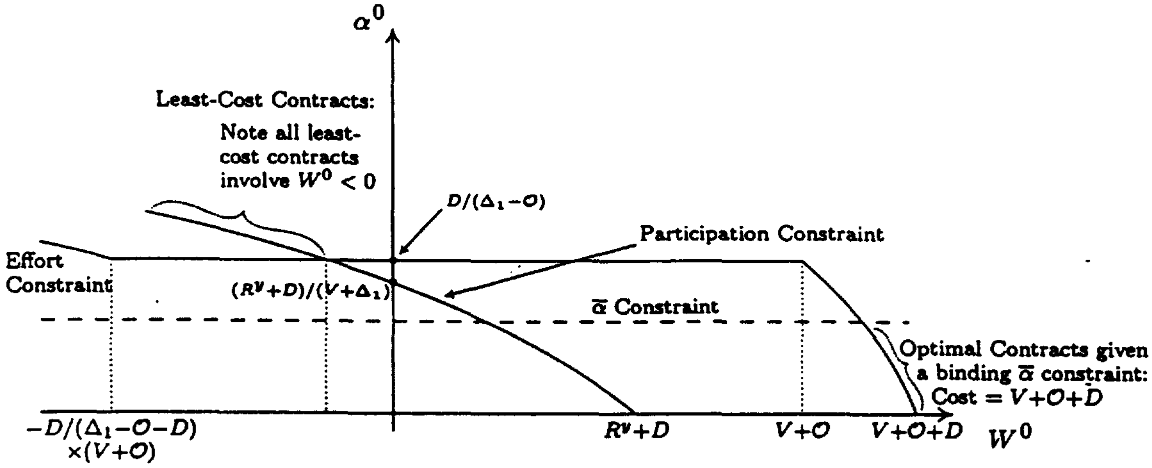

Figure 4(c) $\frac{\Delta_1-\mathcal{O}}{D} R^y < V \div \mathcal{O}$

Figure 4. Time 0 short-term compensation contracts, $\{\alpha^0, W^0\}$, given a long-lived project and vesting at time 1. α^0 is the equity share promised the initial manager hired at time 0. W^0 is the wage promised the manager hired at time 0 with the wage due at time 1. $\mathcal{O} := \max[0, \Delta_2 - C^1(SL)]$ is the value of the replacement option and $C^1(SL)$ is the cost of hiring a replacement manager at time 1.

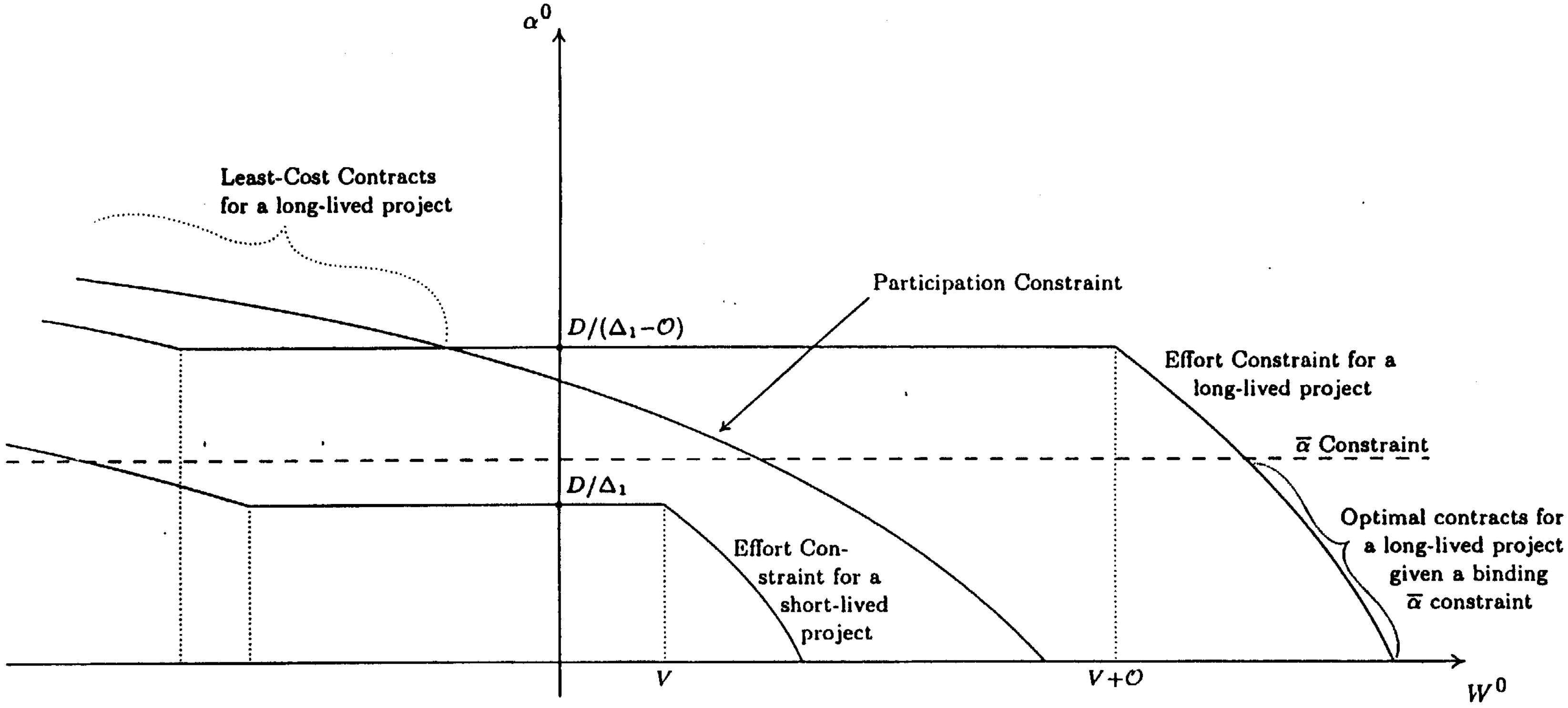

Figure 5. Illustration of the difference in the effort constraints when a manager is hired under a short-term contract to manage a short- versus long-lived project. For the long-lived project $\mathcal{O} > 0$. The $\overline{\alpha}$ constraint is binding (not binding) at time 0 if the project is long-lived (short-lived). $\mathcal{O} := \max[0, \Delta_2 - C^1(SL)]$ is the value of the replacement option, and $C^1(SL)$ is the cost of hiring the replacement manager at time 1.

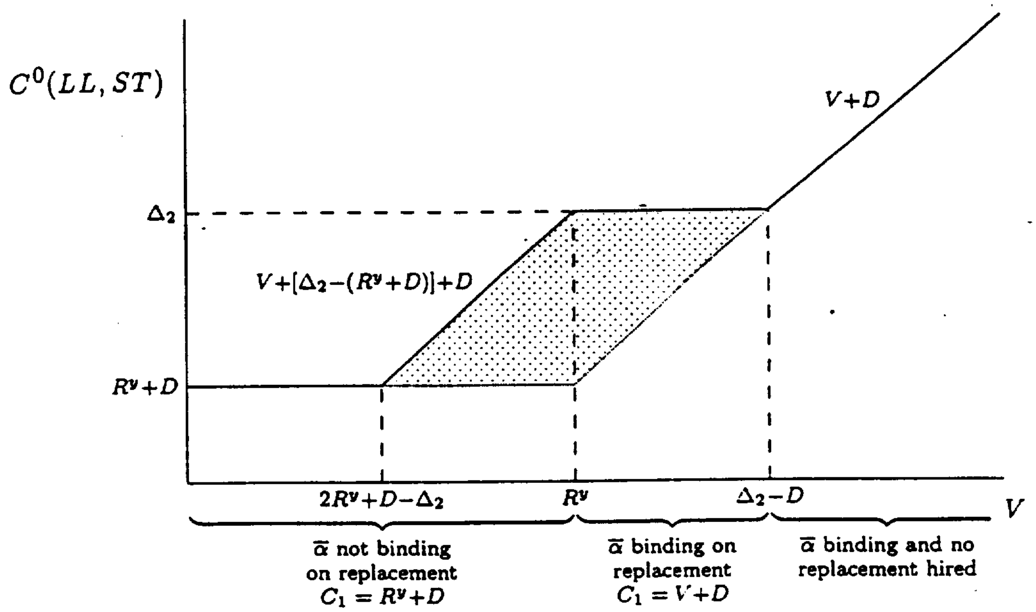

Figure 6(a). $\overline{\alpha}$ such that $\overline{\alpha} < \frac{D}{\Delta_1} < \min\left[\frac{D}{\Delta_2}, \frac{D}{\Delta_1-[\Delta_2-(R^y+D)]}\right]$.

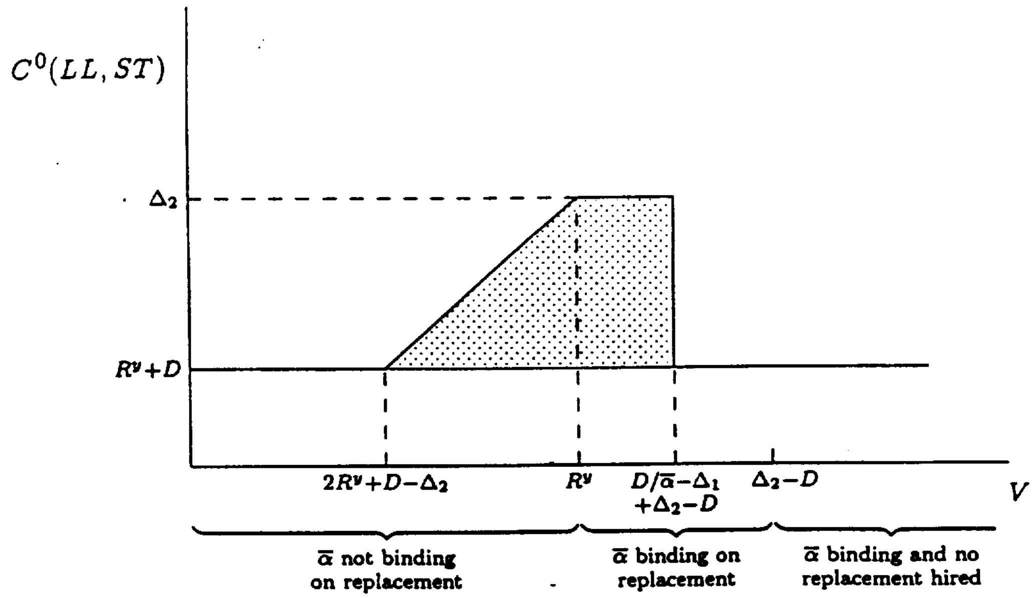

Figure 6(b). $\overline{\alpha}$ such that $\frac{D}{\Delta_1} < \overline{\alpha} < \min\left[\frac{D}{\Delta_2}, \frac{D}{\Delta_1-[\Delta_2-(R^y+D)]}\right]$.

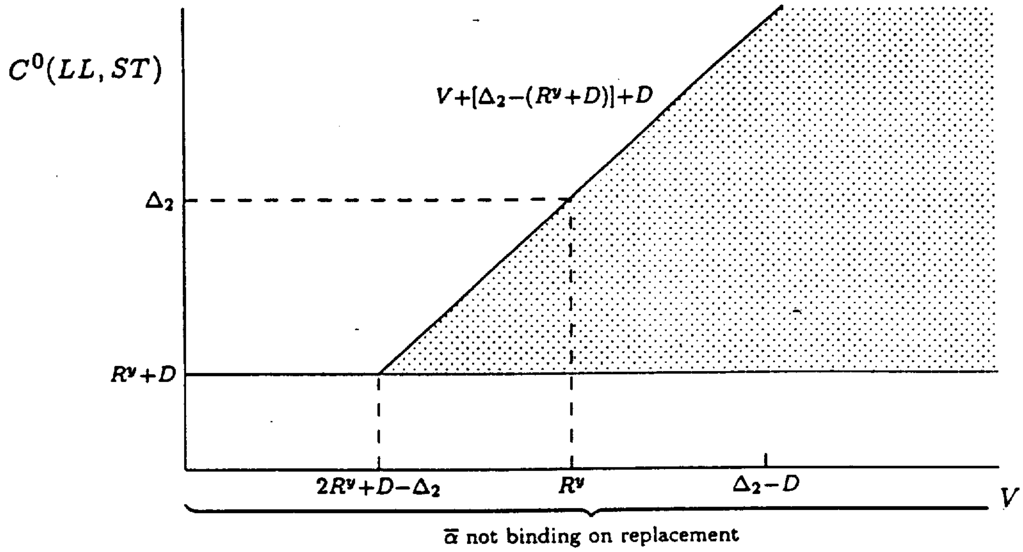

Figure 6(ci). $\overline{\alpha}$ such that $\frac{D}{\Delta_1} < \frac{D}{\Delta_2} < \overline{\alpha} < \frac{D}{\Delta_1 - [\Delta_2 - (R^y + D)]}$.

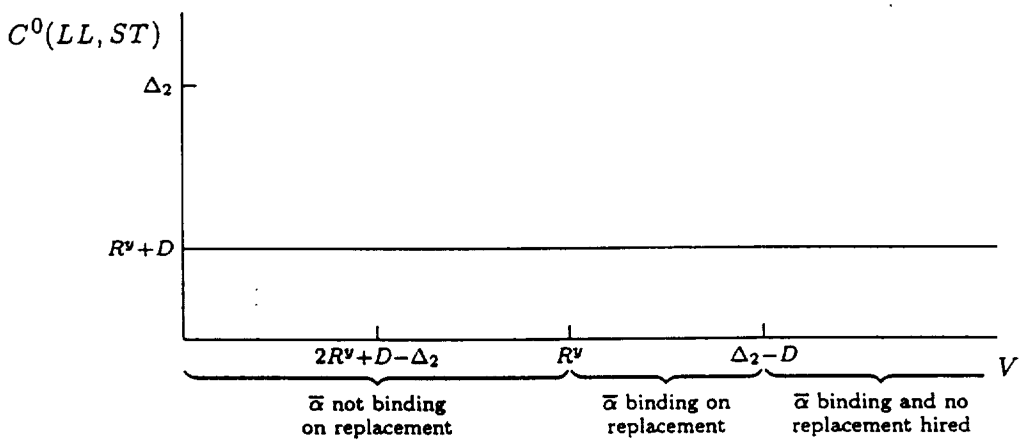

Figure 6(cii). $\overline{\alpha}$ such that $\frac{D}{\Delta_1} < \frac{D}{\Delta_1 - [\Delta_2 - (R^y + D)]} < \overline{\alpha} < \frac{D}{\Delta_2}$.

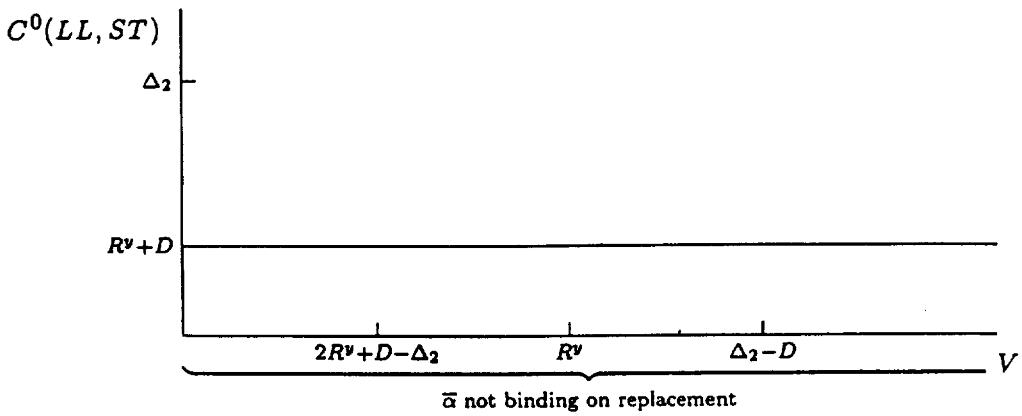

Figure 6(d). $\overline{\alpha}$ such that $\frac{D}{\Delta_1} < \max\left[\frac{D}{\Delta_2}, \frac{D}{\Delta_1 - [\Delta_2 - (R^y + D)]}\right] < \overline{\alpha}$.

Figure 6. Cost of an optimal time 0 short-term contract given a long-lived project, $C^0(LL, ST)$.

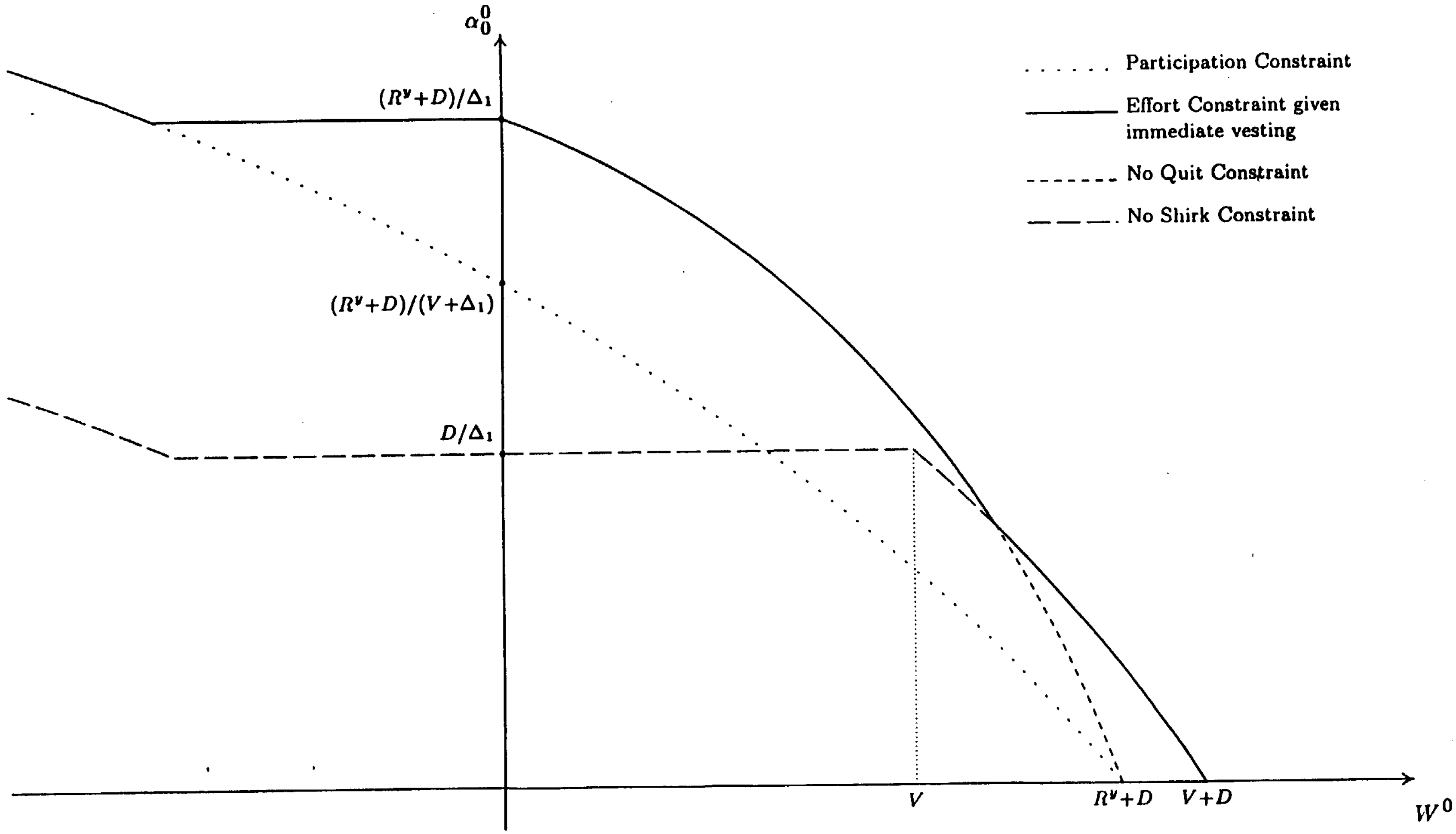

Figure A1. **Example of constraints on the optimal compensation problem given a short-lived project and vesting in the equity component of the package at time 0 (Immediate Vesting).** The example depicts a setting with $V < \frac{\Delta_1}{\Delta_1 - D} R^y$.