Optimal Incentives to Abandon Investments

Igor Vaysman

INSEAD, Accounting & Control, 77305, Fontainebleau CEDEX, France

Phone (US): 678-999-2625; Email: igor.vaysman@insead.edu

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Abstract

This paper formalizes two facts: (i) firms can abandon previously-funded projects, and (ii) managers have private information relevant for the abandonment decision. I show that, because of the abandonment option, it can be optimal to pay managers shut-down bonuses. This counter-intuitive finding is the consequence of managers losing the opportunity to manage abandoned projects, to learn new information, and to receive optimal informational rents. The key implication for executive compensation is that it can be efficient to pay bonuses to "failing" executives. This can mute, and even reverse, the expected positive relationship between optimal executive pay and the firm's performance. I also show that giving golden parachutes to executives of an acquisition target can be efficient, even following the target's poor performance. Finally, I show that regulatory intervention to preclude or restrict "pay-for-failure" limits the ability of firms to downsize, prolonging industry recessions and impeding reallocation of assets toward their most productive use.

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1. Introduction

For the owners of a firm, assuring that managers identify and select appropriate investments is critical. This fact is recognized by practitioners and academics, and a large literature studies the incentives for managers to fund suitable projects. Most projects evolve over time; managers should re-evaluate them as they learn new information. Abandoning or scaling down a project, if the new information warrants this, is vital for maximizing the value of the firm. But convincing managers to abandon investments is complicated: managers have superior information about the projects they control; they can affect project cash flows; and they may be reluctant to scale back the assets under their control. Providing incentives for managers to efficiently manage contraction is the focus of this paper.

Efficient decisions to scale back or abandon projects midstream are of great importance to firms and industries. For the firm, the abandonment and scale-back options, if properly exercised, increase the value of any investment (see Dixit and Pindyck, 1994 and Trigeorgis, 1999). For industries with excess capacity, downsizing delays deepen recessions and eventually lead to "right-sizing" through costly changes in corporate ownership (Jensen, 1993). Further, shutting down investments is an integral component of the "creative destruction" of capitalism (Schumpeter, 1942).

But abandoning or scaling back existing investments is traumatic for the firm and its managers. Downsizing, product-market exits, segment sales, layoffs, geographical pull-backs, selling the entire firm: all usually generate negative publicity and career uncertainty for managers. Asset disposals may reduce the value of the manager's employment relationship. Also, the labor market may view the reversal of a prior investment as admission of a bad decision (though this is not a component of my analysis below). Thus, for many reasons, managers are reluctant to downsize (for evidence, see Jensen, 1993). This makes it vital to explicitly consider project-abandonment incentives when designing compensation plans.

A major incentive problem complicating proper abandonment decisions is asymmetric information. The firm's owners and boards of directors don't have access to the CEO's (and lower-level managers') information about the firm's portfolio of projects. And while there is a large and growing literature on convincing privately-informed managers to *make* appropriate investments, until recently little work has been done on providing incentives to abandon investments or downsize.[1]

Incentive implications of asset disposals are beginning to receive due attention; two recent papers consider various issues. Arya and Glover (2003) explicitly incorporate a principal's abandonment option into the analysis of optimal contracting with unobservable action by the agent. Dutta and Reichelstein (2005) study the role of accrual accounting in providing robust incentives for managers for a range of decisions, including asset disposals (section 3.3).[2]

In this paper, I consider a different question: how can the firm's owners convince a manager to efficiently dispose of assets under his control when the manager periodically learns private information about the assets' value? To do this, I consider abandonment incentives in a three-period setting. The firm's owners hire a manager to evaluate, review, and operate investment projects. In the first period, the manager is

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[1] Research on optimally selecting investments under private information includes Antle and Eppen, 1985; Antle and Fellingham, 1990; Baldenius, 2003; Dutta, 2003; Dutta and Reichelstein, 2002 and 2005; Harris et al., 1982; Rajan and Reichelstein, 2004; and many others.

[2] Pfeiffer and Schneider (2005) investigate incentive issues that arise with sequential investment and growth options.

better informed than the owners about the value of a potential project. If the project is funded, in the second period the manager learns new information relevant for reviewing and possibly abandoning the project. Unless the project is abandoned, the manager learns new information and operates the project in the third period.

The most important insight of my analysis is the necessity of counter-intuitive incentives in the form of abandonment bonuses. Abandoning investments has negative consequences for the manager; thus, the owners must pay to convince him to make the hard decision to abandon (or to reveal private information that triggers abandonment).

The abandonment bonus is not a consequence of empire benefits (non-pecuniary benefits of control), which are not a part of the basic model. It is also not sub-optimal rent extraction by the managers (for the sub-optimal rent extraction view, see Bebchuk and Fried, 2003, 2005). Fundamentally, the bonus is the consequence of *efficient* contracts: if the project continues, the manager will learn new private information and earn future compensation above his market wage (this excess compensation is the manager's informational rent standard in optimal contracts for privately-informed managers). The owners, correctly anticipating this, can reduce the manager's pay at the time of project review by the expected value of his future excess compensation, if and only if the project continues. Abandoning the project means no future rents for the manager and no ability to reduce his project-review-stage pay.

Abandonment bonuses have numerous implications for managerial and executive compensation. First, explicitly incorporating abandonment incentives into managerial contracts is required to counteract the reluctance of managers to dispose of assets under their control.

Second, abandonment bonuses may have to be paid to “failing” executives, whether failure is defined in terms of accounting income or financial returns. Accounting write-downs and special charges frequently accompany shut-downs and sales of underperforming assets. And if abandonment reveals bad news relative to market expectations, the firm’s market price declines. This failure takes place at the same time as optimal abandonment executive bonuses are paid, complicating the standard “pay-for-performance” and relative-performance-evaluation relationships. This has major implications for empirical studies examining these relationships and for the “pay-without-performance” literature (see sections 6.1 and 6.2 for detailed discussion).

Third, the analysis provides a novel argument for the optimality of golden parachutes (the payments and other benefits granted to departing CEOs of acquired firms). Selling the firm is an ultimate form of abandonment for the CEO of a target firm; golden parachutes provide incentives for these CEOs to make the merger decision. There are two novel predictions from my analysis: (i) golden parachutes are optimal only in a subset of firms; and (ii) golden-parachute payments can follow either success or failure (see section 6.3 for details).

Fourth, the analysis suggests that long-running regulatory attempts to curb executive pay and to strengthen the relation between pay and performance can have significant unintended consequences. Restricting or precluding “pay-for-failure” will limit the abilities of the owners to use contractual incentives for optimal downsizing, abandonment, and asset sales. The effects can range from delayed industry-level recessions from persistent excess capacity to more general economy-wide barriers to the reallocation of assets toward their most productive use.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 solves the firm's owners' value-maximization problem. Section 4 discusses the implications for optimal managerial compensation and documents the existence of optimal abandonment bonuses. I discuss extensions to the analysis in section 5 and implications in section 6. Section 7 concludes.

2. The model

The firm consists of the headquarters (HQ) and an investment-center manager. HQ, who represents the firm's risk-neutral owners, contracts with the manager. The firm has an investment opportunity that requires a cash outflow at the *evaluation* stage (i.e., at time $t = 0$). If funded, the project will generate cash flows during two *operating* periods. In the first operating period, the firm will have an opportunity to review and shut down the project and sell off any project assets at some exogenously-determined market price (normalized to zero). I will refer to this first operating period as the *review* stage.

The investment-center manager has a wealth of local knowledge relevant for evaluating the project; if the project is funded, the manager learns new information in each operating period. At least some of the manager's relevant knowledge is private.[3] The standard technique for representing informational asymmetry in firms is to condense all of the manager's private knowledge relevant for evaluating the project at $t = 0$ into a single private-information variable θ_0. If the firm funds the project, in the review period $(t = 1)$ the manager will learn θ_1: new private information relevant for operating and

[3] Some examples of relevant local information are: the manager's knowledge of markets, selling channels, customers, competitors' products and prices, suppliers, product-design and engineering tradeoffs, and alternative uses of constrained resources.

possibly shutting down the project. Unless the project is shut down, the manager will learn new private information θ_2 in the second operating period $t = 2$.

The set of possible realizations of the manager's private information at time $t \in \{0,1,2\}$ is an interval $\Theta_t = \left[\underline{\theta}_t, \overline{\theta}_t\right]$, with higher realizations of private information representing "good news" for the firm. To contract with the manager, HQ relies on its knowledge of the distribution function $F_t(\theta_t)$ of the manager's time-*t* private-information random variable. As is standard in analyses of contracting and organizational design with private information, assume that $F_t(\theta_t)$ has a continuous density function $f_t(\theta_t)$, and that the inverse-hazard-rate rate $\left[\left(1-F_t(\theta_t)\right)/ f_t(\theta_t)\right]$ is decreasing for all θ_t (these conditions hold for the uniform, normal, chi-squared, exponential and most other standard continuous distribution functions). The distributions of θ_0, θ_1, and θ_2 are independent.

When the firm funds the project, the manager makes numerous decisions affecting the firm's cash flows from the project; this happens both at the project-evaluation stage and, unless the firm exits, in each operating period. Many of the manager's decisions are potential sources of conflict with HQ. Two examples of such decisions are: (i) the manager supplies personally-costly unobservable effort, which reduces the cash flows required to fund the project and enhances cash inflows from operations; and (ii) the manager values managerial perquisites, or "organizational slack," and slack is costly to the firm (see Harris, Kriebel and Raviv, 1982; Antle and Eppen, 1985; and Rajan and Reichelstein, 2004, for further discussion and examples).

It is standard to convert incentive problems with unobservable managerial decisions and private information into economically equivalent pure-private-information representations by eliminating the decision variable (Demski and Sappington, 1984 and Guesnerie and Laffont, 1984 document the equivalence of the two representations). The decision variables can be eliminated because both private information and unobservable actions are of interest to the HQ only as they affect the *observable* cash flows, $c_t \in \mathbb{R}$, for $t \in \{0,1,2\}$. Every period $t \in \{0,1,2\}$, the analysis of the project can then be conducted on the observable project cash flows c_t and the change in the manager's period-*t* utility $\left[x_t + V_t\left(c_t,\theta_t\right)\right]$, where x_t is the manager's incremental financial compensation and the function $V_t\left(c_t,\theta_t\right)$ captures either the manager's incremental utility from slack or disutility of effort. As is standard, assume $V_t\left(c_t,\theta_t\right)$ is twice differentiable, with a well-defined strictly positive cross-partial derivative (this is the single-crossing property used in studies of contracting with private information; see Fudenberg and Tirole, 1991, page 259). For the "slack" interpretation maintained for the majority of the paper, $V_t\left(c_t,\theta_t\right) \geq 0$, with $\frac{\partial}{\partial \theta_t} V_t\left(c_t,\theta_t\right) > 0$ and $\frac{\partial}{\partial c_t} V_t\left(c_t,\theta_t\right) < 0$, for $t \in \{0,1,2\}$.[4]

[4] For example, suppose the period-0 cash flow is $c_0 = \left[\bar{c}_0 + \theta_0 - s_0\right]$, where $\bar{c}_0$ is known to all parties; θ_0 is the manager's private information; and $s_0 \geq 0$ is the period-0 slack. If the manager's utility from consuming slack is a strictly increasing function $\bar{V}\left(s_0\right)$, the analysis is converted into the pure-private-information setting by treating c_0 as the manager's decision variable, with the manager's utility-from-slack-consumption function $V_0\left(c_0,\theta_0\right) \equiv \bar{V}\left(\bar{c}_0 + \theta_0 - c_0\right)$. Note that the conditions on the partial derivatives are correct: holding θ_0 constant, increasing c_0 is equivalent to reducing slack (and thus the utility from slack); holding c_0 constant, $\frac{\partial}{\partial \theta_t} V_t\left(c_t,\theta_t\right) > 0$ is simply the "higher private information is good news" convention. Also note that, with the "unobservable-effort" interpretation, $V_t\left(c_t,\theta_t\right) \leq 0$. See section 5.1 for discussion of the effort interpretation.

The manager can quit at any time, enter the labor market, and earn some minimum reservation utility, normalized to zero. To convince the manager to stay with the firm, the present value of his expected incremental utility from the project must then be non-negative each period $t \in \{0,1,2\}$.[5]

The firm's opportunity cost of capital relevant for evaluating the project is r_f; the manager discounts future utility at the rate r_m, with $r_m \geq r_f$.[6] The corresponding discount factors are then $\gamma_f = (1+r_f)^{-1}$ and $\gamma_m = (1+r_m)^{-1}$.

To rule out circumstances with trivial decisions (such as "never fund a project" or "always shut down at the review stage regardless of private information"), I focus on situations where:[7]

1. Both funding and not funding the project at $t = 0$ can be optimal, depending on the manager's period-0 private information;
2. Both continuation and shut-down at review stage can be optimal, depending on the manager's period-1 private information; and
3. The final operating period is non-trivial: expected period-2 project value is strictly positive.

The Revelation Principle allows the firm to determine the upper bound on the project's value using a system of managerial reports and report-contingent compensation

[5] This presumes that, without the investment project, the manager earns exactly his reservation utility from "normal" employment with the firm. Higher utility from "normal" employment does not change the results.
[6] All of the analysis below applies when the manager and the firm have equal discount rates. I allow the manager's discount rate to exceed the firm's to allow for the exogenous possibility that the manager is separated from the firm and, thus, from future rents (because of the firm's bankruptcy, the manager's mortality, or any other reason).
[7] For a formal statement of these "non-triviality" conditions, see the paragraph following Proposition 2 on page 14.

contracts (see the first paragraph of Section 3 below); the sequence of events is in Figure 1 below.

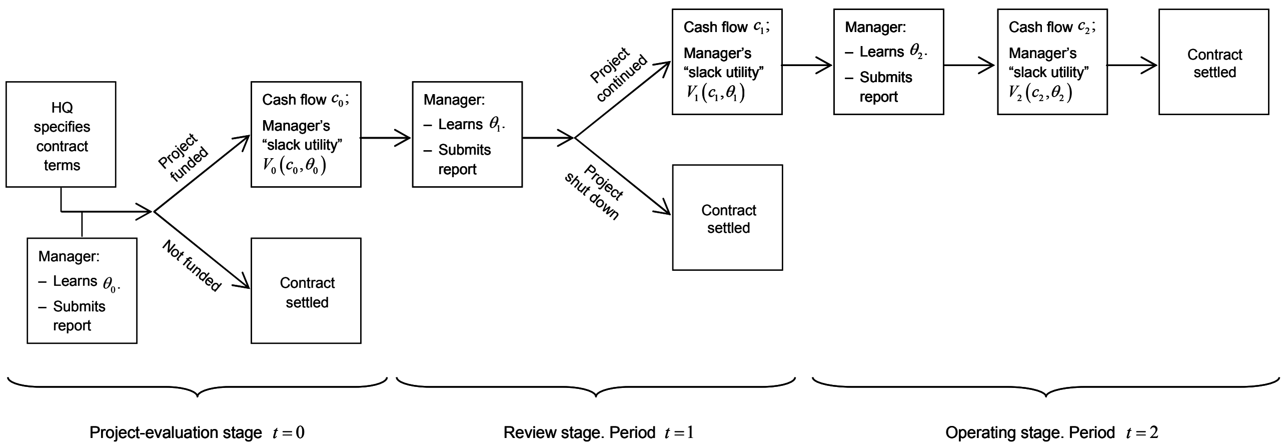

Figure 1. The sequence of events: contracting, private information, managerial reports, and project funding, exit, and operating decisions.

It is convenient to define a term to refer to an investment proceeding along the upper path in the timeline in Figure 1: one that is funded in period 0 and continued in period 1; for the remainder of the paper, the term *live project* will refer to such investment.

3. Optimal contracts

Optimal managerial compensation is shaped by efficient funding, shut-down, and operating decisions. When the manager has private information relevant at the evaluation stage and privately learns new information in each operating period, efficient decisions depend on the manager's private information. The Revelation Principle implies that it is optimal for HQ to provide the manager with incentives to report local private information truthfully and to use the manager's reports to make the project decisions, using the timeline of Figure 1 (for a textbook treatment of the Revelation Principle, see Fudenberg and Tirole, 1991, pages 253-257).[8] Formally, at the outset HQ proposes to the manager a contract covering the project's evaluation and operating stages; the contract includes the following provisions:

At $t = 0$. At the project-evaluation stage, the manager must furnish HQ with a report $m_0 \in \Theta_0$ about his local information. Based on the manager's report, the contract specifies: (i) the *funding decision* – the probability $p_0(m_0) \in [0,1]$ that the firm funds the project; (ii) the initial cash flow $c_0(m_0)$ of a funded project (negative if the project involves a cash outflow); and (iii) the payment to the manager $x_0(m_0)$. If the project is funded, it proceeds to the review stage.

At $t = 1$. For a project funded at the evaluation stage $t = 0$, the manager must furnish HQ with a report $m_1 \in \Theta_1$ about the new period-1 local information. As functions of this report, the contract specifies: (i) the *shut-down decision* – the probability $p_1(m_1) \in [0,1]$ that the firm allows the project to continue to period 2 (so the probability that the project is shut down equals $[1 - p_1(m_1)]$); (ii) the period-1 operating cash flow $c_1(m_1)$ that the manager must deliver if the project is not shut down; and (iii) the payment to the manager $x_1(m_1)$.[9] If the project is not shut down, it proceeds to the next (and last) operating period.

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[8] Following most of the literature on contracting with private information, the analysis below posits that HQ asks the manager to provide a report about his private information. Alternatively, HQ can ask the manager to provide (i) a capital budget, with an estimate of the project's NPV, or (ii) an estimated rate of return from the project. The capital-budget, the estimated-rate-of-return , and the report-about-private-information interpretations are informationally equivalent; and all the results are identical.

[9] In general, the shut-down rule and the period-1 and period-2 cash flows and payments can depend on the entire prior history of the manager's reports. In the proof of Propositions 1 and 2, I show that the decisions and payments in periods 1 and 2 only depend on whether the project is funded and continued, and not on the entire reporting history. Also, each period the manager's reporting strategy depends on the prior reporting history only to the extent the past history influences the funding and continuation decisions.

At $t = 2$. For a project that reaches the final operating period, the manager must furnish HQ with a report $m_2 \in \Theta_2$ about the new local information. As functions of this report, the contract specifies: (i) the period-2 operating cash flow $c_2(m_2)$ that the manager must deliver; and (ii) the payment to the manager $x_2(m_2)$.

When determining the optimal funding, shut-down, and operating decisions, HQ can restrict its attention to contracts that, during the life of the project (i) provide the manager incentives to reveal each period's private information truthfully, and (ii) convince the manager to remain with the firm for the project's duration. HQ's project-value-maximization problem is then: maximize the present value of expected project cash flows (net of managerial compensation), subject to truthful-reporting and continued-employment constraints. Using $U_t(m_t,\theta_t)$ to represent the change in the manager's utility from reporting m_t when private information is θ_t in period $t \in \{0,1,2\}$, HQ's problem is[10]

$$\max_{\substack{p_0(\cdot),p_1(\cdot)\\ c_t(\cdot),x_t(\cdot)\text{ for }t\in\{0,1,2\}}} \Big\{ E_{\Theta_0}\left[p_0(\theta_0)c_0(\theta_0)-x_0(\theta_0)\right] + \gamma_f E_{\Theta_0}E_{\Theta_1}\left[p_0(\theta_0)\big(p_1(\theta_1)c_1(\theta_1)-x_1(\theta_1)\big)\right] + \gamma_f^2 E_{\Theta_0}E_{\Theta_1}E_{\Theta_2}\left[p_0(\theta_0)p_1(\theta_1)\big(c_2(\theta_2)-x_2(\theta_2)\big)\right]\Big\}, \tag{1}$$

subject to, for each $t \in \{0,1,2\}$:

$$U_t(\theta_t,\theta_t) \geq U_t(m_t,\theta_t) \text{ for all } m_t,\theta_t \in \Theta_t; \tag{2}$$

$$U_t(\theta_t,\theta_t) \geq 0 \text{ for all } \theta_t \in \Theta_t. \tag{3}$$

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[10] $E_S[\cdot]$ is the expectations operator over the set S. Note that the manager's utility in periods 0 and 1 includes the future-period consequences of current-period reports.

To guarantee that the manager reports private information truthfully (captured in constraints (2)) and remains with the firm (constraints (3)), HQ must pay a compensation premium every period $t \in \{0,1,2\}$, whenever the project cash flows $c_t(\cdot)$ are non-zero. This premium – the manager's *informational rent* – is necessary to guarantee that the manager reports private information truthfully. It is standard, following Myerson (1981), to define a function, called *virtual costs*, that incorporates the effect of informational rent in managerial compensation on the HQ's maximization objective in (1). The optimal cash flows of a live project can then be computed using virtual costs – when the manager's period-*t* private information is θ_t, the firm's relevant costs to attain project cash flows c_t are the virtual costs $h_t(c_t, \theta_t)$ documented in Proposition 1.[11]

Proposition 1. *The optimal cash flows of a live project satisfy, each period* $t \in \{0,1,2\}$:

$$c_t^*(\theta_t) \equiv \arg\max_c \left[c - h_t(c, \theta_t) \right], \tag{4}$$

where

$$h_0(c_0, \theta_0) \equiv \frac{1-F_0(\theta_0)}{f_0(\theta_0)} \frac{\partial}{\partial \theta_0} V_0(c_0, \theta_0) - V_0(c_0, \theta_0), \text{ and} \tag{5}$$

$$h_t(c_t, \theta_t) \equiv \frac{1-F_t(\theta_t)}{f_t(\theta_t)} \frac{\partial}{\partial \theta_t} V_t(c_t, \theta_t) \left(1 - \frac{\gamma_m}{\gamma_f} \right) - V_t(c_t, \theta_t) \text{ for } t \in \{1,2\}. \tag{6}$$

Proof. See Appendix for all proofs.

Using the cash flows from Proposition 1, the optimal project-funding and continuation decisions $p_0^*(\theta_0)$ and $p_1^*(\theta_1)$ can be represented using standard present-

[11] Recall that the term *live project* refers to an investment funded at time 0 and continued at time 1. If a project is not funded, all cash flows are, of course, equal to zero; if a project is shut down in period 1, cash flows in periods 1 and 2 are zero. Note that period-0 virtual costs $\left[h_0(c_0, \theta_0) \right]$ in (5) are of the form standard in analyses of contracting with private information. Virtual costs in periods 1 and 2 in (6) differ from the standard one: they include an adjustment capturing the firm's ability to reduce the manager's compensation in periods 0 and 1 by the expected future informational rents; see footnote 14 for details.

value techniques, as follows. Beginning at the right-hand-side of the timeline, if the project reaches the final operating period, HQ instructs the manager to deliver cash flows $c_2^*(\theta_2)$ defined by (4) when the manager reports that private information is θ_2 (recall that the manager's informational rent, which guarantees truthful reporting, is captured in the virtual cost of delivering these cash flows).

At the review stage $t=1$, the firm can either shut down the project or continue operating it. $NPV_1^*(\theta_1)$ – the change in the firm's value from continuing the project when the manager reports that private information is θ_1 – equals the sum of: (i) the optimal period-1 cash flows less their virtual cost, and (ii) the expected period-2 cash flows scaled by the firm's discount factor:

$$NPV_1^*(\theta_1) \equiv \left[c_1^*(\theta_1) - h_1\left(c_1^*(\theta_1), \theta_1\right)\right] + \gamma_f E_{\Theta_2}\left[c_2^*(\theta_2) - h_2\left(c_2^*(\theta_2), \theta_2\right)\right]. \tag{7}$$

At the project-evaluation period $t=0$, when the manager reports that private information is θ_0, the consequences for the firm of funding the project include the optimal period-0 cash flows less their virtual cost plus the discounted expected value of the project in period 1 (given by $\max\left\{0, NPV_1^*(\theta_1)\right\}$). Proposition 2 documents the optimal funding and shut-down decisions.

Proposition 2. *The optimal period-1 continuation decision is*

$$p_1^*(\theta_1) = \begin{cases} 1 & \textit{if} \quad NPV_1^*(\theta_1) \geq 0; \\ 0 & \textit{otherwise.} \end{cases} \tag{8}$$

With

$$NPV_0^*(\theta_0) \equiv \left[c_0^*(\theta_0) - h_0\left(c_0^*(\theta_0), \theta_0\right) + \gamma_f E_{\Theta_1}\left[p_1^*(\theta_1) NPV_1^*(\theta_1)\right]\right], \tag{9}$$

the optimal period-0 funding decision is

$$p_0^*(\theta_0) = \begin{cases} 1 & \text{if} \quad NPV_0^*(\theta_0) \geq 0; \\ 0 & \text{otherwise.} \end{cases} \tag{10}$$

The assumption on page 8 that the project funding and continuation decisions are not trivial can now be formalized as $NPV_0^*(\underline{\theta}_0) < 0$, $NPV_0^*(\overline{\theta}_0) > 0$, $NPV_1^*(\underline{\theta}_1) < 0$, $NPV_1^*(\overline{\theta}_1) > 0$. The optimal funding and shut-down decisions can be equivalently represented by intuitively appealing cut-off rules of the following form: (i) fund the project if and only if the manager's period-0 report is better than some threshold value; (ii) shut down the project if and only if the manager's review-stage report is worse than some threshold value.

Corollary 1. *The optimal period-1 continuation decision is equivalent to*

$$p_1^*(\theta_1) = \begin{cases} 1 & \text{if} \quad \theta_1 \geq \theta_1^*; \\ 0 & \text{otherwise,} \end{cases} \tag{11}$$

with the threshold value $\theta_1^* \in (\underline{\theta}_1, \overline{\theta}_1)$ *defined by* $NPV_1^*(\theta_1^*) = 0.$

The optimal period-0 funding decision is equivalent to

$$p_0^*(\theta_0) = \begin{cases} 1 & \text{if} \quad \theta_0 \geq \theta_0^*; \\ 0 & \text{otherwise,} \end{cases} \tag{12}$$

with the threshold value $\theta_0^* \in (\underline{\theta}_0, \overline{\theta}_0)$ *defined by* $NPV_0^*(\theta_0^*) = 0.$

4. Implications for optimal managerial compensation

The abandonment option has major consequences for the optimal managerial compensation; the exact effects are largely determined by the truthful-reporting and continued-employment constraints in (2) and (3). Consider these constraints, beginning at the right-hand-side of the timeline in Figure 1.

In the final operating period $t = 2,$ standard analysis of private-information problems applies. With any report-contingent payments $x_2(\cdot)$ and optimal cash flows $c_2^*(\cdot),$ the change in the manager's utility from reporting m_2 when private information is θ_2 equals

$$U_2(m_2,\theta_2) = x_2(m_2) + V_2\left(c_2^*(m_2)\theta_2\right). \tag{13}$$

HQ must convince the manager to report truthfully and to remain with the firm. To do this, HQ sets the manager's financial compensation so that $\bar{U}_2(\theta_2)$ – the change in utility of the manager with private information $\theta_2 \in \Theta_2$ who truthfully reports this – satisfies[12]

$$\bar{U}_2(\theta_2) \equiv U_2(\theta_2,\theta_2) = \left[\int_{\underline{\theta}_2}^{\theta_2} \frac{\partial}{\partial\theta_2} V_2\left(c_2^*(s),s\right)ds\right] \geq 0 \text{ for all } \theta_2 \in \Theta_2. \tag{14}$$

The expression in (14) is the manager's period-2 informational rent; it exceeds zero with strictly positive probability. The manager's *expected* utility of managing the project in period 2 is then strictly positive; taking expected value of (14) and using a standard integration-by-parts technique,

$$E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right] = E_{\Theta_2}\left[\frac{1-F_2(\theta_2)}{f_2(\theta_2)} \frac{\partial}{\partial\theta_2} V_2\left(c_2^*(\theta_2),\theta_2\right)\right] > 0. \tag{15}$$

The manager's positive expected utility from managing in period 2 significantly affects optimal managerial-compensation contracts in prior periods – in particular, it complicates HQ's ability to elicit a truthful report from the manager at the project-review

[12] To see why this convinces the manager to report private information truthfully, note that (13) and (14) imply that $U_2(m_2,\theta_2) = \left[\int_{\underline{\theta}_2}^{m_2} \frac{\partial}{\partial\theta_2} V_2\left(c_2^*(s),s\right)ds - V_2\left(c_2^*(m_2),m_2\right) + V_2\left(c_2^*(m_2),\theta_2\right)\right]$, and that $\partial U_2(m_2,\theta_2)/\partial m_2 = 0$ at the truthful report $m_2 = \theta_2$. See the proof of Proposition 1 for details.

stage $t=1$ if the manager's private information indicates that the project should be shut down. The change in the manager's utility from reporting m_1 when private information is θ_1 incorporates the period-2 expected utility, adjusted by the manager's present value factor γ_m and the probability $p_1^*(m_1)$ of the project continuing to period 2:

$$U_1(m_1,\theta_1) = x_1(m_1) + p_1^*(m_1)V_1(c_1^*(m_1),\theta_1) + p_1^*(m_1)\gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]. \tag{16}$$

Now, whenever the manager's review-stage information indicates that the project should be shut down, reporting this to HQ has rather negative consequences for the manager: there will be no slack to enjoy in period 1 and no chance to earn future informational rents $E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]$ from operating the project in period 2. To convince the manager to reveal information that triggers the shut-down of the project, HQ must thus somehow persuade him to forgo the slack and the expected informational rents. To accomplish this, HQ's best option is to offer the manager a counter-intuitive incentive: a bonus for reporting bad news.

The size of the optimal bonus can be determined from Corollary 1 and the truthful-reporting and continued-employment constraints (2) and (3). To satisfy the two constraints at the time of the project's review, HQ must set the manager's financial compensation $x_1(\cdot)$ so the utility of the manager with private information $\theta_1 \in \Theta_1$ who truthfully reports this equals[13]

$$\bar{U}_1(\theta_1) \equiv U_1(\theta_1,\theta_1) = \left[\int_{\underline{\theta}_1}^{\theta_1} p_1^*(s)\frac{\partial}{\partial\theta_1}V_1(c_1^*(s),s)\,ds\right] \geq 0 \text{ for all } \theta_1 \in \Theta_1. \tag{17}$$

[13] As in footnote 12, this guarantees that $\partial U_1(m_1,\theta_1)/\partial m_1 = 0$ at the truthful report $m_1 = \theta_1$.

Using (16) and (17), the investment project's impact on the manager's financial compensation satisfies, for all $\theta_1 \in \Theta_1$,[14]

$$x_1^*(\theta_1) = \int_{\underline{\theta}_1}^{\theta_1} p_1^*(s) \frac{\partial}{\partial \theta_1} V_1(c_1^*(s), s)\, ds - p_1^*(\theta_1)\left[V_1(c_1^*(\theta_1), \theta_1) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]\right]. \quad (18)$$

From Corollary 1, it is optimal to shut down the project if and only if the manager's private information is worse than the threshold value θ_1^*. The change in financial compensation for a manager who reports that the project should be continued is then

$$x_1^*(\theta_1) = \int_{\theta_1^*}^{\theta_1} \frac{\partial}{\partial \theta_1} V_1(c_1^*(s), s)\, ds - \left[V_1(c_1^*(\theta_1), \theta_1) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]\right]. \quad (19)$$

Continuing the project allows HQ to reduce the manager's review-stage financial compensation by the value of review-stage slack $V_1(c_1^*(\theta_1), \theta_1)$ and discounted expected period-2 informational rents $\gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]$. But shutting down the project precludes this reduction in the manager's pay. Thus, managerial compensation following shut-down exceeds compensation following project continuation for at least a subset of continued projects.

Proposition 3. *For any $\theta_1 \in \left[\theta_1^*, \bar{\theta}_1\right]$ (project is continued) and any $\theta_1' \in \left[\underline{\theta}_1, \theta_1^*\right)$ (project is shut down), the difference between shut-down compensation and continuation compensation is*

[14] The firm's ability to write multi-period contracts and to reduce the manager's compensation in period 1 by $\left[p_1^*(\theta_1)\gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]\right]$ – discounted expected period-2 informational rents – has important consequences for HQ's contract-design problem. In particular, this reduces the firm's period-2 virtual costs by the $(1-\gamma_m/\gamma_f)$ factor in equation (6). Similarly, the manager's compensation in period 0 can be reduced by discounted expected informational rents in periods 1 and 2, reducing the firm's period-1 virtual costs. Note that when the manager's and the firm's discount factors are close, the virtual costs defined by equation (6) are close to the personal costs $\left[b_t(c_t)v_t(\theta_t)\right]$, and the optimal period-1 and period-2 cash flows are close to the first-best ones.

$$x_1^*(\theta_1') - x_1^*(\theta_1) = V_1\left(c_1^*(\theta_1),\theta_1\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right] - \int_{\theta_1^*}^{\theta_1} \frac{\partial}{\partial \theta_1} V_1\left(c_1^*(s),s\right) ds. \qquad (20)$$

For a non-empty interval $\left[\theta_1^*,\hat{\theta}_1\right] \subseteq \left[\theta_1^*,\bar{\theta}_1\right]$, *the difference in* (20) *is strictly positive – if* $\theta_1 \in \left[\theta_1^*,\hat{\theta}_1\right]$ *and* $\theta_1' \in \left[\underline{\theta}_1,\theta_1^*\right)$, *then* $x_1^*(\theta_1') > x_1^*(\theta_1)$.

From (20), it is possible that abandoning the project triggers strictly higher managerial compensation compared with *any* continued project (i.e., for all $\theta_1 \in \Theta_1$). This happens if the manager's period-2 expected informational rents and utility for slack are high enough.

5. Extensions

The basic model can be extended in various directions. It is straightforward to extend the analysis to incorporate asymmetric information about the market price of the project assets at shut-down. In the basic model, the disposal price of the project assets at review stage is some exogenously-determined market price (normalized to zero). If, instead, the manager has private information relevant for determining the disposal price and can affect the final price by some unobservable actions, the implications for optimal compensation are identical to those documented by Proposition 3: abandoning the project triggers strictly higher managerial compensation compared with some, and possibly all, continued projects. Three further extensions deserve attention: analysis with "unobservable-effort" interpretation of the incentive problem; multiple review and operating periods; and single-period contracts.

5.1. Unobservable effort

With the slack interpretation, the manager derives non-financial benefits of leisure or perquisites consumption from managing the project (and it is optimal to allow the manager to do this). For a continued project, HQ can then reduce the manager's financial compensation in (19) by $V_1\left(c_1^*\left(\theta_1\right),\theta_1\right)$ to reflect this. Proposition 3's unambiguous result, where shut-down compensation exceeds continuation compensation for a range of private-information values, is possible because the slack utility $V_1\left(c_1^*\left(\theta_1\right),\theta_1\right)$ and the discounted period-2 expected informational rents $\gamma_m E_{\Theta_2}\left[\bar{U}_2\left(\theta_2\right)\right]$ in equation (20) are both strictly positive.

Instead of slack consumption, the central incentive problem may be the need to convince the manager to provide personally-costly unobservable effort that is valued by the firm. In this case, the analysis preceding Proposition 3 is identical, but the conclusions on pay differences are generally less straightforward. For the "unobservable-effort" interpretation, the function $V_t\left(c_t,\theta_t\right)\leq 0$ captures the manager's disutility from effort in period $t\in\left\{0,1,2\right\}$, and all of the analysis of sections 3 and 4 applies.[15] The difference in shut-down pay and continuation pay is still given by equation (20), but, with $V_1\left(c_1^*\left(\theta_1\right),\theta_1\right)$ negative, there is no clear conclusion that this difference is positive for a range of private-information values.

The manager has to expend effort if and only if the project continues. HQ has to compensate the manager for the effort if and only if the project continues. In particular,

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[15] The partial derivatives are the same as with the slack interpretation: $\frac{\partial}{\partial\theta_t}V_t\left(c_t,\theta_t\right)>0$ and $\frac{\partial}{\partial c_t}V_t\left(c_t,\theta_t\right)<0$.

when the manager reports that private information is at the threshold value θ_1^*, the change in the manager's pay equals

$$x_1^*\left(\theta_1^*\right) = -\left[V_1\left(c_1^*\left(\theta_1^*\right),\theta_1^*\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2\left(\theta_2\right)\right]\right]. \tag{21}$$

The change in pay from reporting $\theta_1' \in \left[\underline{\theta}_1, \theta_1^*\right)$ (leading to a shut-down) is greater than $x_1^*\left(\theta_1^*\right)$ if and only if the discounted period-2 expected informational rents $\gamma_m E_{\Theta_2}\left[\bar{U}_2\left(\theta_2\right)\right]$ are strictly greater than the review-period disutility of effort $\left[-V_1\left(c_1^*\left(\theta_1^*\right),\theta_1^*\right)\right]$. When this is the case, the rest of Proposition 3 applies: shut-down pay exceeds continuation pay for a range of private-information values.

5.2. Multiple review and operating periods

It is straightforward to extend the analysis to include additional operating and review periods. While intuitively one might expect that longer-lived projects generate higher managerial rents and require higher shut-down bonuses, this in fact is not the case. To see this, extend the basic slack model to include *T* operating periods, with the manager learning new independently-distributed private information $\theta_t \in \left[\underline{\theta}_t, \bar{\theta}_t\right]$ each period $t \in \left\{0,1,\ldots,T\right\}$, and with the project reviewed and possibly shut down in the first operating period. If the project gets to the final operating period, the manager earns informational rents

$$\bar{U}_T\left(\theta_T\right) = \left[\int_{\underline{\theta}_T}^{\theta_T} \frac{\partial}{\partial\theta_T} V_T\left(c_T^*\left(s\right),s\right)ds\right] \geq 0 \text{ for all } \theta_T \in \Theta_T, \tag{22}$$

with $\bar{U}_T(\theta_T) > 0$ for some $\theta_T \in \Theta_T$. In period *T-1*, the manager's optimal compensation is reduced by the expected period-*T* informational rents (discounted at the manager's discount rate)

$$x_{T-1}^*(\theta_{T-1}) = \int_{\underline{\theta}_{T-1}}^{\theta_{T-1}} \frac{\partial}{\partial \theta_{T-1}} V_{T-1}\left(c_{T-1}^*(s), s\right) ds - V_{T-1}\left(c_{T-1}^*(\theta_{T-1}), \theta_{T-1}\right) - \gamma_m E_{\Theta_T}\left[\bar{U}_T(\theta_T)\right]. \quad (23)$$

At *T-1,* the manager's present value of utility from managing the project in the final *two periods* thus equals

$$\bar{U}_{T-1}(\theta_{T-1}) = \left[\int_{\underline{\theta}_{T-1}}^{\theta_{T-1}} \frac{\partial}{\partial \theta_{T-1}} V_{T-1}\left(c_{T-1}^*(s), s\right) ds\right] \geq 0 \text{ for all } \theta_{T-1} \in \left[\underline{\theta}_{T-1}, \bar{\theta}_{T-1}\right]. \quad (24)$$

In period *T-2*, the manager's optimal compensation is reduced by the expected present value of $\bar{U}_{T-1}(\theta_{T-1})$ from (24). Compensation and the manager's present value of utility from managing the project in the final three periods are of the same form as in (23) and (24). More generally, every period $t \in \{2, \ldots, T\}$, the manager's present value of utility from managing the project in periods *t* through *T* equals just the period-*t* informational rents, because HQ reduces the manager's current compensation by the present value of the expected informational rents in periods (*t*+1) through *T*:

$$\bar{U}_t(\theta_t) = \left[\int_{\underline{\theta}_t}^{\theta_t} \frac{\partial}{\partial \theta_t} V_t\left(c_t^*(s), s\right) ds\right] \geq 0 \text{ for all } \theta_t \in \left[\underline{\theta}_t, \bar{\theta}_t\right]. \quad (25)$$

Consequently, at the period-1 review stage, the project's impact on the manager's financial compensation satisfies, for all $\theta_1 \in \Theta_1$,

$$x_1^*(\theta_1) = \int_{\underline{\theta}_1}^{\theta_1} p_1^*(s) \frac{\partial}{\partial \theta_1} V_1\left(c_1^*(s), s\right) ds - p_1^*(\theta_1)\left[V_1\left(c_1^*(\theta_1), \theta_1\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right]\right]. \quad (26)$$

The difference between abandonment pay and continuation pay is thus the same as in Proposition 3: to convince the manager to reveal information that triggers shut-down, HQ must compensate the manager for the loss of period-1 slack and only the period-2 informational rents; informational rents in periods 3 through *T* do not affect the review-stage compensation.

5.3. Single-period contracts

In the basic model, HQ commits to a three-period contract. The key result of the analysis – the requirement for higher shut-down pay than continuation pay – holds even if HQ is only able to sign single-period contracts. The results of Proposition 1 and 2 likewise continue to hold, with a single adjustment: the period-1 and period-2 virtual costs in (6) no longer include the $\left(1-\gamma_m/\gamma_f\right)$ adjustment; instead, the virtual costs change to

$$h_t\left(c_t,\theta_t\right) \equiv \frac{1-F_t\left(\theta_t\right)}{f_t\left(\theta_t\right)} \frac{\partial}{\partial \theta_t} V_t\left(c_t,\theta_t\right) - V_t\left(c_t,\theta_t\right) \text{ for } t \in \{1,2\}.$$

Not surprisingly, if HQ can only commit to single-period contracts, the value of the project decreases as optimal cash flows $c_1^*\left(\theta_1\right)$ and $c_2^*\left(\theta_2\right)$ are further away from first-best. Consequently, each period, the manager's informational rent is lower than in the three-period-contract case. Because of this, the difference between shut-down pay and continuation pay in (20), while still generally positive, is lower as well.

6. Implications and discussion

The most important implication of the analysis is also the most obvious. If privately-informed managers are not given abandonment incentives, they will be unwilling to downsize, to exit unprofitable product and geographical markets, to shut down unsuccessful projects, to sell assets more valuable outside the firm than inside. Managers of acquisition targets will fight proposed acquisitions. The "difficulty of exit", the delays in downsizing, and the corresponding "… substantial cost of real resources to society" documented by Jensen (1993, page 847) are all conceivably the consequences of managerial-compensation systems without shut-down bonuses.

To efficiently manage contraction as well as growth, managerial incentives must thus include optimal shut-down bonuses. Restricting or precluding "pay-for-failure" – an objective of long-running regulatory intervention – can limit the ability of firms to optimally downsize, abandon underperforming markets, and sell assets. The unintended consequences can be significant, ranging from delayed industry-level recessions from persistent excess capacity to more general economy-wide barriers to the reallocation of assets toward their most productive use.

Below, I discuss additional implications of this analysis for research on executive compensation.

6.1. Pay and performance

The necessary incentive link between pay and performance is suggested by the seminal analyses of agency problems by Mirrlees (1976), Holmström (1979), and Grossman and Hart (1983). Using executive-compensation data in the U.S., numerous studies have examined, and drawn different conclusions about, the sensitivity between pay and performance of top executives (see reviews by Becht et al., 2003; Bushman and Smith, 2001; Murphy, 1999; and Prendergast, 1999).

In the late 1980s and early 1990s, Baker et al. (1988) and Jensen and Murphy (1990) argued that the pay-performance sensitivity was too low (though see Bushman and

Smith, 2001, pages 244-25, and Prendergast, 1999, page 19, for reviews of conceptual and econometric problems with these conclusions). Hall and Liebman (1998) document that, by the mid 1990s, average pay-performance sensitivities imposed significant risk on executives (though Perry and Zenner, 2001, argue that at least a part of the increase in incentive-based compensation was the consequence of Internal Revenue Code Section 162(m), limiting tax deductibility of non-performance-based executive pay to one million dollars). There is no consensus among academics (see the competing arguments and the references in Bebchuk and Fried, 2005 and Core et al., 2005) or practitioners (see the opposing views in "Have They NO Shame?" cover story in *Fortune* by Useem et al., 2003, and in the *Business Week* article by Lavelle and Arndt, 2004).

Although the link between pay and performance is grounded in motivating unobservable effort, and my analysis is focused on managerial private information, the necessity of shut-down incentives has an important, counter-intuitive, implication for compensation. Optimal abandonment of a project generally implies "bad-news" resolution of uncertainty, because prior to the abandonment, there was positive probability of project continuation. The price of a publicly-traded firm can thus decline when investors learn of the project abandonment. But the manager's optimal compensation following abandonment can exceed compensation following continuation.

Conversely, the "good news" of project continuation triggers a stock price increase. But the optimal managerial compensation is reduced by the manager's utility from optimal slack and from future informational rent. Thus, optimal abandonment incentives, if important, can mute, and even reverse, the standard expectation of a positive relationship between observed pay and performance.[16]

6.2. Relative performance evaluations

Efficient abandonment bonuses at the time of poor performance have consequences for the literature on relative performance evaluations (RPEs). A key implication of the analysis in Baiman and Demski (1980), Diamond and Verrechia (1982), and Holmström (1982) is the optimality of RPEs, where the performance of a peer group is used to filter out common risk from compensation packages. There is a large literature on RPEs (for reviews, see Becht et al., 2003; Bushman and Smith, 2001; Core et al., 2003; Lambert, 2001; Murphy, 1999; and Prendergast, 1999). The evidence for the use of RPEs is puzzlingly weak at best, though several recent studies enlarge the basic agency model to include competitive considerations and point out conceptual or empirical problems with the earlier works.[17]

To include the implications of optimal shut-down incentives into RPE analysis requires extending the basic model to incorporate risk aversion, other firms, and performance-measure shocks. While these extensions are beyond the scope of this paper, I expect the key conclusion to hold: convincing a manager to reveal private information leading to abandonment of a project requires paying him a bonus. Suppose a public firm has in place a compensation plan including RPEs that optimally exposes the manager to idiosyncratic risk by filtering out common risk. Consider the consequences of optimal abandonment incentives in this compensation plan. When the manager's firm-specific

[16] Asset abandonment and downsizing frequently trigger accounting write-downs and special charges. Thus, increased pay can follow poor *accounting* performance as well.

[17] Foe examples, see Aggarwal and Samwick (1999), Core et al. (2003), DeFond and Park (1999), Dye, (1992), Garvey and Milbourn (2003), and Ou-Yang (2005). Albuquerque (2006) finds evidence of RPEs using a peer group of similar-sized firms in the same industry.

private information that optimally triggers abandonment is "bad news" relative to the market expectations, the price of the firm's equity declines. At the same time, the manager receives bonus pay from abandonment. Pay and performance move in opposite direction; thus, the ability to detect RPEs from observed compensation and performance is reduced.

6.3. Selling the firm: golden parachutes

Considerable controversy surrounds golden parachutes: the payments and other benefits granted to departing CEOs of acquired firms. Golden parachutes are common and significant; in a recent study, Hartzell et al. (2004) document that sixty-nine percent of CEOs in their sample had explicit golden-parachute arrangements; they found the average total gain for target CEOs in the range of $8 million to $12 million. Bebchuk and Fried (2003) argue that the practice is a problem (in a normative sense) – a method of rent extraction by executives.

Popular press, politicians, and activist investors view golden parachutes with suspicion, even when the acquisition creates significant shareholder value. Gilette's CEO James Kitts received departure compensation valued in the $165-$180 million range following the sale of Gillette to Procter & Gamble in 2005. Even though the acquisition created billions of dollars in value for Gillette shareholders, Kitts' deal caused major outrage, leading U.S. Representative Barney Frank to introduce legislation (Protection Against Executive Compensation Abuse Act) that aims to significantly limit the ability of boards to set executive pay. And certainly there is a strong feeling that executives should not receive takeover payouts following poor performance. Concerned about AT&T's CEO's $55 million payout following the merger with SBC Communications, California

Public Employees' Retirement System, an activist pension fund, attempted to push through shareholder proposals explicitly limiting golden parachutes. A senior investment officer at CalPERS summarizes the fund's view: "We're not anti-pay. We're anti-pay for failure" (Thornton et al., 2005).

Several theoretical studies have documented the potential value-enhancing effects of golden parachutes (Harris, 1990; Knoeber, 1986; and Lambert and Larcker, 1985), and Lambert and Larcker (1985) document the empirical evidence of positive market reaction to the adoptions of this executive-compensation tool. But none of these papers offer the asymmetric-information explanation for the extra compensation paid to executives of target firms. My analysis of managers privately informed about asset-disposal opportunities in section 4 implies that *optimal* compensation contracts for CEOs can comprise golden parachutes.

With the target firm's CEO privately informed about the internal value of the firm assets or about the attainable market price, selling the firm and departing has negative consequences (see Hartzell et al., 2004 for evidence of high turnover rates for target CEOs, even those who are initially retained). The CEO loses current utility from slack and expected future wages. Both are likely significant. Sizeable abandonment bonuses – golden parachutes – can then be required to convince the target's CEO to make the abandonment decision if (and only if) he or she departs.[18]

My analysis has two novel predictions. First, from Proposition 3 and section 5.1, golden parachutes are not universally optimal. Firms where the central incentive problem is the need to convince the CEO to provide personally-costly unobservable effort are less

[18] The "abandonment bonus *if and only if* the CEO departs" argument is consistent with the evidence in Hartzell et al. (2004) that CEOs who are *retained* by the acquirer receive on average $5 million less in cash compensation from takeovers.

likely to employ them. Second, golden-parachute payments can be efficient following both success and failure. As in the discussion of section 6.1 on pay for performance, selling the firm can be a consequence of new bad news. Thus, abandonment bonuses can follow poor financial performance preceding a takeover.

Interestingly, at least one CEO has used the above reasoning to justify his own bonus. James Rogers of Cinergy justified his $23 million parachute following acquisition by Duke Energy: "To keep management ahead of the game [and] to get ultimate shareholder value, you want a management team that's *economically indifferent* to whether or not they will have a job when the deal is done." (Thornton et al., 2005, emphasis added).

7. Conclusion

Two facts provide the basis for this study. Firms can abandon previously-funded projects, and managers have private information relevant for the abandonment decision. This study explicitly incorporates these facts and shows that optimal contracts may require firms to pay managers shut-down bonuses. This counter-intuitive finding has numerous implications for contract design and for the burgeoning literature on executive compensation, particularly for analyses of the relationship between pay and performance and for studies of golden parachutes.

The results are derived in a complete contracting setting and do not depend on managers enjoying non-pecuniary benefits from controlling the project ("empire benefits"). Instead, the analysis relies on the manager consuming some optimal level of slack or providing personally-costly effort. My conjecture is that empire benefits can be easily incorporated into the analysis, along the lines of Baldenius (2003), and that empire benefits would increase the required abandonment bonuses.

Two interesting extensions to the analysis should be explored. First, a manager's outside opportunities can be affected by the abandonment decision, changing his reservation utility (for an analysis of contracting incorporating reservation-utility changes, see Oyer, 2004). Second, when the manager has private information about the value of a project, the outside market price for the project assets likely reflects the manager's decision to sell. While not straightforward, these extensions can enhance our understanding of the implications of abandonment opportunities for optimal contracting.

Appendix: Proofs

Propositions 1 and 2.

The proof incorporates the possibility that each period, the manager's reporting strategy and HQ's decisions can depend on the entire prior history of the HQ-manager interactions relating to the investment project. The definitions of the manager's incremental utilities U_t and all of the HQ's contracting instruments are thus different from the body of the paper – here, they are defined as follows.

First, define $\boldsymbol{\Theta}_0 \equiv \Theta_0; \boldsymbol{\Theta}_1 \equiv \Theta_0 \times \Theta_1; \boldsymbol{\Theta}_2 \equiv \Theta_0 \times \Theta_1 \times \Theta_2$. Also, for notational convenience, define $\boldsymbol{\Theta}_{-1} \equiv \varnothing; \boldsymbol{\Theta}_3 \equiv \varnothing$. The vector of the manager's private-information realizations through period t is $\boldsymbol{\theta_t} \in \boldsymbol{\Theta_t}$. Imposing the direct-revelation consequence of the revelation principle, the vector of the manager's reports through period t is likewise an element of $\boldsymbol{\Theta_t}$.

HQ's contracting instruments are $p_0 : \boldsymbol{\Theta}_0 \to [0,1]$; $p_1 : \boldsymbol{\Theta}_1 \to [0,1]$; and $c_t : \boldsymbol{\Theta_t} \to \mathbb{R}; x_t : \boldsymbol{\Theta_t} \to \mathbb{R}$ for $t \in \{0,1,2\}$. The manager's period-*t* pure reporting strategy is $\boldsymbol{m_t} : \boldsymbol{\Theta_t} \to \Theta_t$ for $t \in \{0,1,2\}$ (if the project is not funded or shut down, reporting is not an issue).[19] The strategy depends on prior-period reports and the current-period private information (it is easy to see that the strategy is independent of prior-period private information, except through the manager's reports).

Consider the manager's generic 3-period reporting strategy $\boldsymbol{m} = \{\boldsymbol{m}_1, \boldsymbol{m}_2, \boldsymbol{m}_3\}$. Given specific contracting instruments, $U_t(\boldsymbol{m}, \theta_t)$ represents the change in the manager's utility from reporting m_t given prior reports $\boldsymbol{m_{t-1}}$, current private information θ_t, and the

[19] It is standard in the mechanism-design literature to focus on pure reporting strategies.

expected effects of future reports $\boldsymbol{m}_{t+1}$ (using for completeness the notation $\boldsymbol{m}_{-1} \equiv \varnothing, \boldsymbol{m}_3 \equiv \varnothing$). Specifically,

$$U_2\left(\boldsymbol{m},\theta_2\right)=x_2\left(\boldsymbol{m_2}\right)+V_2\left(c_2\left(\boldsymbol{m_2}\right),\theta_2\right); \tag{27}$$

$$U_1\left(\boldsymbol{m},\theta_1\right)=x_1\left(\boldsymbol{m_1}\right)+p_1\left(\boldsymbol{m_1}\right)\left[V_1\left(c_1\left(\boldsymbol{m_1}\right),\theta_1\right)+\gamma_m E_{\Theta_2}\left[U_2\left(\boldsymbol{m},\theta_2\right)\right]\right]; \tag{28}$$

$$U_0\left(\boldsymbol{m},\theta_0\right)=x_0\left(\boldsymbol{m_0}\right)+p_0\left(\boldsymbol{m_0}\right)\left[V_0\left(c_0\left(\boldsymbol{m_0}\right),\theta_0\right)+\gamma_m E_{\Theta_1}\left[U_1\left(\boldsymbol{m},\theta_1\right)\right]\right]. \tag{29}$$

HQ's value-maximization program is then, using the revelation principle:

$$\begin{aligned}\max_{\substack{p_0(\cdot),p_1(\cdot),\\ c_t(\cdot),x_t(\cdot)\text{ for }t\in\{0,1,2\}}} \quad & \Big\{E_{\Theta_0}\left[p_0\left(\boldsymbol{\theta_0}\right)c_0\left(\boldsymbol{\theta_0}\right)-x_0\left(\boldsymbol{\theta_0}\right)\right] \\ & +\gamma_f E_{\Theta_0}E_{\Theta_1}\left[p_0\left(\boldsymbol{\theta_0}\right)\left(p_1\left(\boldsymbol{\theta_1}\right)c_1\left(\boldsymbol{\theta_1}\right)-x_1\left(\boldsymbol{\theta_1}\right)\right)\right] \\ & +\gamma_f^2 E_{\Theta_0}E_{\Theta_1}E_{\Theta_2}\left[p_0\left(\boldsymbol{\theta_0}\right)p_1\left(\boldsymbol{\theta_1}\right)\left(c_2\left(\boldsymbol{\theta_2}\right)-x_2\left(\boldsymbol{\theta_2}\right)\right)\right]\Big\},\end{aligned} \tag{30}$$

subject to, for each $t \in \{0,1,2\}$:

$$\begin{aligned}&U_t\left(\left(\boldsymbol{m}_{t\text{-}1},\theta_t,\boldsymbol{m}_{t+1}\right),\theta_t\right)\geq U_t\left(\left(\boldsymbol{m}_{t\text{-}1},m_t,\boldsymbol{m}_{t+1}\right),\theta_t\right)\\ &\qquad \text{for all } m_t,\theta_t\in\Theta_t;\boldsymbol{m}_{t\text{-}1}\in\boldsymbol{\Theta}_{t\text{-}1};\boldsymbol{m}_{t+1}\in\boldsymbol{\Theta}_{t+1};\end{aligned} \tag{31}$$

$$U_t\left(\left(\boldsymbol{m}_{t\text{-}1},\theta_t,\boldsymbol{m}_{t+1}\right),\theta_t\right)\geq 0 \text{ for all } \theta_t\in\Theta_t;\boldsymbol{m}_{t\text{-}1}\in\boldsymbol{\Theta}_{t\text{-}1};\boldsymbol{m}_{t+1}\in\boldsymbol{\Theta}_{t+1}. \tag{32}$$

The solution proceeds in three steps. First, the individual rationality (IR) constraints (32) and the local versions of the incentive-compatibility (IC) constraints (31) are used to compute the minimum payments necessary to attain local IC and IR. Second, these minimum payments are substituted into the objective in (30) to compute the principal's optimal decisions on cash flows, funding, and shut-down. Third, the equivalence of local IC and global IC is verified.

Step 1. Consider the local versions of the IC constraints (31), positing piecewise differentiability of the utility functions with respect to the manager's reports each period.

In period 2, the managers' period-0 and period-1 reports are in the past and are thus constants in the agent's period-2 utility function. Local IC then implies

$$\frac{\partial}{\partial m_2} U_2\left(\left(\boldsymbol{m}_1, m_2\right), \theta_2\right) = 0 \text{ at } m_2 = \theta_2. \tag{33}$$

Using $\bar{U}_2\left(\boldsymbol{m}_1, \theta_2\right) \equiv U_2\left(\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right)$ to represent the change in utility of the manager with private information $\theta_2 \in \Theta_2$ who truthfully reports this (using $\boldsymbol{m}_1$ constant at $t = 2$),

$$\frac{d}{d\theta_2} \bar{U}_2\left(\boldsymbol{m}_1, \theta_2\right) = \frac{\partial}{\partial \theta_2} U_2\left(\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right) = \frac{\partial}{\partial \theta_2} V_2\left(c_2\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right). \tag{34}$$

Integrating (34) and using the IR constraint (32) for a boundary condition at $t = 2$ gives

$$\bar{U}_2\left(\boldsymbol{m}_1, \theta_2\right) = \int_{\underline{\theta}_2}^{\theta_2} \frac{\partial}{\partial \theta_2} V_2\left(c_2\left(\boldsymbol{m}_1, s\right), s\right) ds. \tag{35}$$

Using (35), (27), and the definition of $\bar{U}_2\left(\boldsymbol{m}_1, \theta_2\right)$, the minimum period-2 compensation required to satisfy IR and local versions of IC constraints must equal, for any funding, abandonment, and cash-flow rules:

$$x_2\left(\boldsymbol{m}_1, \theta_2\right) = \int_{\underline{\theta}_2}^{\theta_2} \frac{\partial}{\partial \theta_2} V_2\left(c_2\left(\boldsymbol{m}_1, s\right), s\right) ds - V_2\left(c_2\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right). \tag{36}$$

Using standard integration-by-parts techniques (for example, see Fudenberg and Tirole, 1991, page 264) it is straightforward to show that, if (36) holds, then

$$E_{\Theta_2}\left[x_2\left(\boldsymbol{m}_1, \theta_2\right)\right] = E_{\Theta_2}\left[\frac{1 - F_2\left(\theta_2\right)}{f_2\left(\theta_2\right)} \frac{\partial}{\partial \theta_2} V_2\left(c_2\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right) - V_2\left(c_2\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right)\right]. \tag{37}$$

The manager's expected period-2 utility is then

$$E_{\Theta_2}\left[\bar{U}_2\left(\boldsymbol{m}_1, \theta_2\right)\right] = E_{\Theta_2}\left[\frac{1 - F_2\left(\theta_2\right)}{f_2\left(\theta_2\right)} \frac{\partial}{\partial \theta_2} V_2\left(c_2\left(\boldsymbol{m}_1, \theta_2\right), \theta_2\right)\right]. \tag{38}$$

If period-2 local IC is equivalent to period-2 global IC (this will be confirmed later), in period 1 the parties expect truthful reporting from the manager in period 2, by sequential rationality. This allows substitution of the expected period-2 utility in (38) into the right-hand side of (28). The change in the manager's utility from reporting m_1 given prior report $\boldsymbol{m_0}$ (maintaining the vector notation for consistency with the principal's program) and current private information θ_1 in (28) can then be written as

$$U_1(\boldsymbol{m},\theta_1) = x_1(\boldsymbol{m_1}) + p_1(\boldsymbol{m_1})\left[V_1\left(c_1(\boldsymbol{m_1}),\theta_1\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\boldsymbol{m_1},\theta_2)\right]\right], \tag{39}$$

as long as the manager's period-2 reporting strategy involves truth-telling; i.e., $\boldsymbol{m_2}(\theta_0,\theta_1,\theta_2) = \theta_2$ for all $(\theta_0,\theta_1,\theta_2) \in \boldsymbol{\Theta_2}$.

Use $\bar{U}_1(m_0,\theta_1) \equiv U_1\left((\boldsymbol{m_0},\theta_1,\boldsymbol{m_2}),\theta_1\right)$ to represent the change in utility of the manager with private information $\theta_1 \in \Theta_1$ who truthfully reports this and expects to report truthfully in period 2. Proceeding along the lines of period-2 analysis in (33)-(35),

$$\bar{U}_1(m_0,\theta_1) = \int_{\underline{\theta}_1}^{\theta_1} p_1(s)\frac{\partial}{\partial\theta_1}V_1\left(c_1(m_0,s),s\right)ds. \tag{40}$$

Using (39), (40), and the definition of $\bar{U}_1(m_0,\theta_1)$, the minimum period-1 compensation required to satisfy IR and local versions of IC constraints must then equal, for any funding, abandonment, and cash-flow rules:

$$\begin{aligned} x_1(m_0,\theta_1) = &\int_{\underline{\theta}_1}^{\theta_1} p_1(s)\frac{\partial}{\partial\theta_1}V_1\left(c_1(m_0,s),s\right)ds \\ &- p_1(\theta_1)\left[V_1\left(c_1(m_0,\theta_1),\theta_1\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_1,\theta_2)\right]\right]. \end{aligned} \tag{41}$$

Using integration by parts,

$$E_{\Theta_1}\left[x_1\left(m_0,\theta_1\right)\right]=E_{\Theta_1}\left[p_1\left(\theta_1\right)\left(\frac{1-F_1\left(\theta_1\right)}{f_1\left(\theta_1\right)}\frac{\partial}{\partial\theta_1}V_1\left(c_1\left(m_0,\theta_1\right),\theta_1\right)\right.\right.$$
$$\left.\left.-V_1\left(c_1\left(m_0,\theta_1\right),\theta_1\right)-\gamma_m E_{\Theta_2}\left[\bar{U}_2\left(\theta_1,\theta_2\right)\right]\right)\right], \tag{42}$$

and the manager's expected period-1 utility with truth-telling in periods 1 and 2 is

$$E_{\Theta_1}\left[\bar{U}_1\left(m_0,\theta_1\right)\right]=E_{\Theta_1}\left[p_1\left(\theta_1\right)\left(\frac{1-F_1\left(\theta_1\right)}{f_1\left(\theta_1\right)}\frac{\partial}{\partial\theta_1}V_1\left(c_1\left(m_0,\theta_1\right),\theta_1\right)\right)\right]. \tag{43}$$

If period-1 local IC is equivalent to period-1 global IC (this will be confirmed later), in period 0 the parties expect truthful reporting from the manager in periods 1 and 2, by sequential rationality. Expected period-1 utility in (43) can then be substituted into (29):

$$U_0\left(\boldsymbol{m},\theta_0\right)=x_0\left(\boldsymbol{m_0}\right)+p_0\left(\boldsymbol{m_0}\right)\left[V_0\left(c_0\left(\boldsymbol{m_0}\right),\theta_0\right)+\gamma_m E_{\Theta_1}\left[\bar{U}_1\left(m_0,\theta_1\right)\right]\right]. \tag{44}$$

Now use $\bar{U}_0\left(\theta_0\right)\equiv U_0\left(\left(\boldsymbol{m_0},\theta_1,\theta_2\right),\theta_0\right)$ to represent the change in utility of the manager with private information $\theta_0\in\Theta_0$ who truthfully reports this and expects to report truthfully in periods 1 and 2. Proceeding along the lines of period-2 and period-1 analyses,

$$\bar{U}_0\left(\theta_0\right)=\int_{\underline{\theta}_0}^{\theta_0}p_0\left(s\right)\frac{\partial}{\partial\theta_0}V_0\left(c_0\left(s\right),s\right)ds; \tag{45}$$

$$x_0\left(\theta_0\right)=\int_{\underline{\theta}_0}^{\theta_0}p_0\left(s\right)\frac{\partial}{\partial\theta_0}V_0\left(c_0\left(s\right),s\right)ds-p_0\left(\theta_0\right)\left[V_0\left(c_0\left(\theta_0\right),\theta_0\right)+\gamma_m E_{\Theta_1}\left[\bar{U}_1\left(\theta_0,\theta_1\right)\right]\right]; \tag{46}$$

$$E_{\Theta_0}\left[x_0\left(\theta_0\right)\right]=E_{\Theta_0}\left[p_0\left(\theta_0\right)\left(\frac{1-F_0\left(\theta_0\right)}{f_0\left(\theta_0\right)}\frac{\partial}{\partial\theta_0}V_0\left(c_0\left(\theta_0\right),\theta_0\right)\right.\right.$$
$$\left.\left.-V_0\left(c_0\left(\theta_0\right),\theta_0\right)-\gamma_m E_{\Theta_1}\left[\bar{U}_1\left(\theta_0,\theta_1\right)\right]\right]. \tag{47}$$

The manager's expected period-0 utility with truth-telling in all periods is then

$$E_{\Theta_0}\left[\bar{U}_0(\theta_0)\right] = E_{\Theta_0}\left[p_0(\theta_0)\left(\frac{1-F_0(\theta_0)}{f_0(\theta_0)}\frac{\partial}{\partial\theta_0}V_0\left(c_0(\theta_0),\theta_0\right)\right)\right]. \tag{48}$$

Step 2. Substitute expected payments in (47), (42), and (37) into the objective in (30) and rearrange the objective to obtain the following maximization expression:

$$\max_{\substack{p_0(\cdot),p_1(\cdot),\\ c_t(\cdot)\text{ for }t\in\{0,1,2\}}} \left\{E_{\Theta_0}\left[p_0(\boldsymbol{\theta_0})c_0(\boldsymbol{\theta_0}) - h_0\left(c_0(\boldsymbol{\theta_0}),\theta_0\right)\right]\right.$$
$$+\gamma_f E_{\Theta_0}E_{\Theta_1}\left[p_0(\boldsymbol{\theta_0})\left(p_1(\boldsymbol{\theta_1})c_1(\boldsymbol{\theta_1}) - h_1\left(c_1(\boldsymbol{\theta_1}),\theta_1\right)\right)\right] \tag{49}$$
$$\left.+\gamma_f^2 E_{\Theta_0}E_{\Theta_1}E_{\Theta_2}\left[p_0(\boldsymbol{\theta_0})p_1(\boldsymbol{\theta_1})\left(c_2(\boldsymbol{\theta_2}) - h_2\left(c_2(\boldsymbol{\theta_2}),\theta_2\right)\right)\right]\right\},$$

where $h_t\left(c_t(\theta_t),\theta_t\right), t\in\{0,1,2\}$ are as defined in (5) and (6). Note that (49) is solved pointwise; moreover, each period's optimal cash flow $c_t^*(\boldsymbol{\theta_t})$ is independent of the manager's reports in periods other than *t* (except that the cash flow of a non-funded or abandoned project is, of course, set equal to zero). Thus, the optimal cash flows $c_t^*(\ )$ can be written as functions of θ_t only, and satisfy equation (4), completing the proof of Proposition 1 (pending Step 3 below).

Given the cash flows in (4), the optimal continuation decision is independent of the manager's report in period 0. With the definitions of $NPV_t^*(\theta_t), t\in\{0,1\}$ in (7) and (9), the optimal funding and continuation decisions that solve (49) pointwise are as given in (10) and (8), completing the proof of Proposition 2 (pending Step 3 below).

Step 3. The single-crossing property and the monotone-hazard-rate condition are sufficient to allow replacement of global IC constraints with their local counterparts, provided that, each period $t\in\{0,1,2\}$, the manager's utility $U_t\left(\boldsymbol{m}_{t-1}, m_t, \boldsymbol{m}_{t+1}, \theta_t\right)$ is piecewise continuously differentiable in m_t at the optimal decisions and payments (see Fudenberg and Tirole, 1991, pages 257-268). In period 2,

$$\begin{aligned} U_2\left(\boldsymbol{m_1}, m_2, \theta_2\right) &= x_2^*\left(m_2\right) + V_2\left(c_2^*\left(m_2\right), \theta_2\right) \\ &= \int_{\underline{\theta}_2}^{m_2} \frac{\partial}{\partial \theta_2} V_2\left(c_2^*\left(s\right), s\right) ds - V_2\left(c_2^*\left(m_2\right), m_2\right) + V_2\left(c_2^*\left(m_2\right), \theta_2\right), \end{aligned} \tag{50}$$

which is continuously differentiable in $m_2 \in \Theta_2$.

In period 1,

$$\begin{aligned} U_1\left(\boldsymbol{m}, \theta_1\right) &= x_1^*\left(m_1\right) + p_1^*\left(m_1\right)\left[V_1\left(c_1^*\left(m_1\right), \theta_1\right) + \gamma_m E_{\Theta_2}\left[\frac{1-F_2\left(\theta_2\right)}{f_2\left(\theta_2\right)} \frac{\partial}{\partial \theta_2} V_2\left(c_2^*\left(\theta_2\right), \theta_2\right)\right]\right] \\ &= \int_{\underline{\theta}_1}^{m_1} p_1^*\left(s\right) \frac{\partial}{\partial \theta_1} V_1\left(c_1^*\left(s\right), s\right) ds + p_1^*\left(m_1\right)\left[V_1\left(c_1^*\left(m_1\right), \theta_1\right) - V_1\left(c_1^*\left(m_1\right), m_1\right)\right], \end{aligned} \tag{51}$$

which is piecewise continuously differentiable in $m_1 \in \Theta_1$. In exactly the same manner as in period 1, the manager's period-0 utility is piecewise continuously differentiable in $m_0 \in \Theta_0$. This completes the proof of Propositions 1 and 2.

Corollary 1.

The project period-0 value $NPV_0^*\left(\theta_0\right)$ in (9) is strictly increasing in θ_0, and the period-1 value $NPV_1^*\left(\theta_1\right)$ in (7) is strictly increasing in θ_1. The corollary results follow immediately.

Proposition 3.

First, note that if $\theta_1' \in \left[\underline{\theta}_1, \theta_1^*\right)$ and $\theta_1'' \in \left[\underline{\theta}_1, \theta_1^*\right)$, then $x_1^*\left(\theta_1'\right) = x_1^*\left(\theta_1''\right)$. Suppose not, and $x_1^*\left(\theta_1'\right) > x_1^*\left(\theta_1''\right)$. This would violate IC constraints, as the manager with private information θ_1'' would report θ_1'.

Expression (20) follows immediately from the optimal managerial compensation in (18). Note that the right-hand side of (20) is continuous in θ_1. With

$$\begin{aligned} x_1^*(\theta_1') - x_1^*(\theta_1^*) &= V_1\left(c_1^*(\theta_1^*), \theta_1^*\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right] - \int_{\theta_1^*}^{\theta_1^*} \frac{\partial}{\partial \theta_1} V_1\left(c_1^*(s), s\right) ds \\ &= V_1\left(c_1^*(\theta_1^*), \theta_1^*\right) + \gamma_m E_{\Theta_2}\left[\bar{U}_2(\theta_2)\right] > 0, \end{aligned} \tag{52}$$

the continuity of $\left[x_1^*(\theta_1') - x_1^*(\theta_1)\right]$ in θ_1 guarantees the existence of a non-empty interval $\left[\theta_1^*, \hat{\theta}_1\right] \subseteq \left[\theta_1^*, \bar{\theta}_1\right]$, with $\left[x_1^*(\theta_1') - x_1^*(\theta_1)\right] > 0$ for all $\theta_1 \in \left[\theta_1^*, \hat{\theta}_1\right]$. This completes the proof.

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