Market Pressure, Control Rights, and Innovation*

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Abstract

We study an environment in which: (1) a firm's insiders have superior information about the expected value of the firm's ongoing R&D activities; (2) the firm faces market pressure to sell its operating assets but the sale would disrupt these R&D activities; and (3) insiders are biased against selling the firm's assets. Given this second-best environment, using tools of mechanism design we derive the allocation of control rights that maximizes the external shareholders' payoff.

We show that the optimal allocation of control depends on the underlying features of the firm's R&D environment. In particular, we demonstrate that if the firm's R&D activity is innovative, in the sense that it is high-risk/high return and it generates high information asymmetry between insiders and external shareholders, then control rights should be assigned to insiders. Conversely, if the firm's R&D activity is routine, then control rights over the sale decision should be retained by the shareholders.

Our analysis also indicates that the optimal mechanism prescribes seemingly suboptimal features of corporate governance that resemble poison pills, golden parachutes, and managerial entrenchment. Given the market pressure faced by insiders, these features are necessary to induce insiders to carry out innovative projects.

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1 Introduction

A recurring theme in corporate governance is that good governance and greater transparency are two sides of the same coin. The argument for such a viewpoint is that greater disclosure of a firm's financial activities allows outsiders to better assess the firm's future cash flows thereby enabling them to exercise greater market pressure on the firm's insiders. The greater the market pressure insiders face, the more likely they would act in the best interests of the shareholders. Such an argument seems quite compelling for environments in which direct disclosure of insider information is credible. However, for certain environments, direct disclosure of information to outsiders is inherently non–trivial. In this paper, we study such an environment in which: (1) a firm's insiders have superior information about the expected value of the firm's long term activities but such information cannot be credibly disclosed; (2) the firm faces market pressure to sell its operating assets but the sale would disrupt the firm's long term activities; and (3) insiders are biased against selling the firm's assets. Given this second-best environment, we derive the allocation of control rights between insiders and external shareholders over the sale decision that maximizes the external shareholders' payoffs.

We model a firm that is engaged in a long term R&D project. The tasks associated with the project are ill–defined and, over time, the firm's insiders privately learn the likelihood that the project would eventually be successful. Before the project matures, the firm faces market pressure to sell its assets in the form of a takeover offer. If the firm is sold, its operating assets are transferred to the buyer at a gain and the project is disrupted. If the firm is retained, the project is allowed to mature. Furthermore, insiders' incentives are not perfectly aligned with those of the firm's shareholders. In particular, insiders derive non–pecuniary private benefits from engaging in the R&D project. In order to enjoy these private benefits, insiders may therefore wish to hold on to the firm to the detriment of the external shareholders.

We take as given the environment of a firm with the frictions described above. The shareholders' objective is to target the insiders' superior information through appropriate transfers that induce the latter to make an informed sale decision. Given this second–best environment, we solve for the optimal contract that maximizes the shareholders' payoffs. We analyze how such an optimal contract can be implemented in practice. In particular, we derive conditions that determine how control rights over the sale decision should be allocated between insiders and external shareholders. We then relate those conditions to the underlying features of the firm's environment.

In designing the optimal contract, shareholders weigh the costs and benefits of assigning control rights to insiders over the sale decision. Assigning control rights is costly because, in order to induce biased insiders to act on their superior information, they must earn information rents. Assigning control rights, however, may benefit the shareholders because the sale decision is better informed. Therefore, when the *ex ante* value of insiders' private information about the R&D project is large relative to costly information rents, shareholders should assign control rights to the insiders. Otherwise, shareholders' should retain all control rights.

The upshot of our analysis is that the optimal allocation of control rights over the sale decision depends on the *nature* of the firm's R&D project. More precisely, we show that if the firm's R&D project is *innovative*, in the specific sense that: (1) it is high-risk/high return, *and* (2) it generates high information asymmetry between insiders and external shareholders, then control rights over the sale decision should be assigned to insiders. Conversely, if the firm's R&D project is *routine* in the sense that shareholders are essentially equally informed about its value as insiders, then control rights over the sale decision should be retained by the shareholders.

A by–product of our analysis is that assigning control rights to insiders entails seemingly sub-optimal features of corporate governance that resemble poison pills, golden parachutes, and insider entrenchment. We show that these insider protection devices are natural consequences of an optimal contract in a second–best world. More importantly, we demonstrate that these devices are necessary to induce insiders to carry out innovative projects despite market pressure to sell the firm. When insiders have control rights over the sale decision, they may not sell the firm even though, given *outsiders' information*, selling would seem to be the efficient decision. In that sense, we show that the optimal contract has the flavor of a poison pill: for innovative activities, it protects insiders from the market pressure to sell the firm even though shareholders may get arbitrarily large gains from selling the firm. Excessive transfer payments that are akin to golden parachutes may also be optimal because insiders are biased in favor of retaining the firm. Therefore, in order to induce insiders to sell the firm, we show that the optimal contract must compensate them for their bias via an excessive transfer. Finally, the insider entrenchment feature arises as follows: in order to maximize shareholders' payoffs, the optimal contract must transfer rents to insiders. However, under certain circumstances, it may be so costly to induce insiders to sell the firm that the optimal contract allows insiders to inefficiently hold on to the firm even though their information should lead them to sell the firm.

Our paper contributes to the accounting literature that investigates the incentives of firms to engage in R&D activities. Kanodia et al (2004) model an environment in which insiders and shareholders incentives are perfectly aligned and insiders can credibly disclose information to outsiders. However, even though direct disclosure of the firm's R&D investment is verifiable, it is inherently noisy. They show that, from a real effects perspective, measuring and disclosing investments in R&D is not unambiguously desirable. The forces in our environment are different. We investigate an environment where direct disclosure of the profitability of an R&D activity to outsiders is not feasible and insiders' incentives may not be aligned with those of shareholders. In such an environment, we show that market pressure alone may not provide sufficient incentives for the firm's insiders to maximize shareholder value. We derive the features of an optimal contract that induces informed insiders to engage in innovation. To the best of our knowledge, we are the first study to explicitly show that, for innovative R&D activities, control rights over the takeover decision should be allocated to the insiders while for routine R&D activities, control rights should reside with shareholders.

Our paper is also related to several strands of the literature. First, we contribute to the literature that investigates how market pressure affects the incentives of informed insiders to engage in long term activities. Using a signaling model, Stein (1988) investigates how takeover pressure may disrupt a firm's long term activity by inducing insiders to act myopically. Bebchuk and Stole (1993) also use a signaling model to demonstrate how short term market pressure induces a firm's insiders to overinvest in a long run activity if the firm investment level is observable but their superior information is not. Our methodology differs significantly from these two studies. Using the tools of mechanism design, we study a two-dimensional screening problem in which insiders hold private information about the firm's long-term value as well as their own bias. This allows us to solve for the general optimal contract that maximizes the shareholders payoffs. Furthermore, we derive the features of the optimal screening mechanism that provides incentives for insiders to carry out the innovative project.

Second, our paper is related to a burgeoning literature that investigates the incentives of firms to engage in innovation. Aghion and Tirole (1994) investigate the optimal allocation of control rights that motivates innovation in an incomplete contracting setting. Zwiebel (1995) studies how asymmetric information about managerial ability may affect the likelihood of innovation. Manso (2007) develops a theory of innovation in a moral hazard setting. Sapra et al (2009) theoretically and empirically investigate how external and internal features of corporate governance interact to affect incentives to engage in innovation in an environment in which there is imperfect and symmetric information between insiders and outsiders. In our information asymmetric environment, we do not assume that the R&D project is innovative or routine. Rather, using an optimal screening mechanism, we uncover a link between the nature of the firm's underlying R&D activity and the optimal allocation of control rights. We show that, in order to maximize shareholder value, control rights should be allocated to insiders if and only if the project is innovative.

Finally, our paper is related to a large literature that investigates the desirability of insider protection devices. The perspective taken in that literature is that, in a second–best environment, such devices may be optimal because they benefit the shareholders by making it harder for outsiders to take over the firm. For example, Shleifer and Vishny (1986) and Harris and Raviv (1988) argue that takeover defenses increase the bargaining power of the board vis-a-vis a raider by allowing them to extract a raider's surplus. Similarly, Stein (1988) shows that takeover protection devices reduce the likelihood that a raider may wish to purchase a firm, lowering the takeover pressure on insiders who, otherwise, engage in wasteful signaling. Our study differs from this literature in an important way. A common thread among these studies is that takeover devices affect the behavior of *outsiders* such as raiders. In this paper, we take the behavior of outsiders as given by assuming that the selling price of the firm is exogenous. This allows us to understand how the optimal contract affects the behavior of *informed insiders*. In particular, we show that the optimal contract has protection devices that resemble poison pills, golden parachutes, and insider entrenchment. More importantly, given the market pressure faced by insiders, we pinpoint how these devices induce insiders to carry out an innovative project by acting on their private information.

In section 2, we discuss the major ingredients of our model. In Section 3, we show how the optimal screening mechanism between informed insiders and shareholders can be simplified to a mechanism that has desirable incentive and implementation properties. Using this mechanism, we derive the optimal allocation of control rights between insiders and outsiders and show how it has desirable implementation properties. In Section 4, we show how the expected value of the agent's private information plays a key role in determining the nature of the R&D project and the optimal allocation of control rights. Section 5 demonstrates how protection devices such as poison pills, golden parachutes and insider entrenchment are natural features of the optimal contract. Section 6 concludes. The Appendix contains the major proofs.

2 The Model

There are two risk-neutral players: a principal and an agent. The principal represents the outside owners of a firm while the agent represents the CEO or the CEO-controlled board of the firm. There are two dates indexed by 1 and 2. For simplicity, we assume there is no discounting across these dates. At date 1, the firm is endowed with two assets: an operating asset and an R&D project. The R&D project matures at date 2 and delivers a return r. For simplicity, we assume r takes one of two values representing either success or failure. If the project succeeds, it is worth R. Otherwise, it fails and is worth 0. From the standpoint of date 1, the value of r is uncertain. The operating asset is worth v which is non-random at date 1.

At date 1, the firm may be sold to a potential buyer. However, selling the firm disrupts the R&D project making it non-transferable. Therefore, only the operating asset is transferred to the buyer at a price of $v + s$ where s represents the synergy that the buyer could generate from utilizing the operating asset.[1] If the firm is retained, the R&D project matures and the firm's assets are worth $v + r$ at date 2. Furthermore, in the event that the firm is not sold, the agent earns a non-pecuniary benefit b which represents a bias against selling the firm. We assume that b lies in an interval $[0, B]$ where B is an exogenous positive parameter.

At date 1, there are two sources of information asymmetry between the principal and the agent. First, the agent privately learns the probability that the R&D project will succeed if the firm is not sold. We denote this probability by $\theta \in [0, 1]$. Second, the agent also privately learns the amount of his non–pecuniary benefit b. We refer to the pair (θ, b) as the agent's *type* which we denote by ω. Note that this type ω belongs to the space $\Omega \equiv [0, 1] \times [0, B]$.

The variables θ and b are distributed according to a joint density $h(\theta, b)$ defined over the type space Ω with marginal densities $f(\theta)$ and $g(b)$, respectively. Note that the joint density function $h(.)$ allows for θ and b to be positively (negatively) correlated so that an agent who knows that the expected value of the R&D project is high (low) may also be very biased in holding on to the firm. Let $\theta_0 \equiv \int_0^1 \theta f(\theta) d\theta$ denote the unconditional expected probability of success of the R&D project from the principal's perspective at date 1. Note that the characteristics of the R&D project are summarized by the density h together with its potential return R. Let $\mathcal{P} \equiv \langle R, h \rangle$ denote this pair

[1] We assume that the selling price is exogenous. For instance, the operating asset could be sold in competitive market consisting of a large number of buyers who create synergies s from utilizing the asset.

of characteristics. Henceforth, we refer to the firm's project as $\mathcal{P}$.

At date 1, before learning the realization of r, the principal must decide whether or not to sell the firm. In order to make an informed decision, the principal designs a direct revelation mechanism $\mathcal{M}$, to elicit the agent's private information ω. Such a mechanism calls for the agent to report his type ω given the project $\mathcal{P}$ and synergy s. We denote the agent's report by $\widetilde{\omega} \in \Omega$. Conditional on the agent's report $\widetilde{\omega}$, the project $\mathcal{P}$, and the synergy s, the mechanism determines: (a) a sale decision $\rho \in \{0, 1\}$, where $\rho = 0$ denotes that the firm is retained, and $\rho = 1$ denotes that the firm is sold, (b) provided the firm is sold, a monetary transfer t from the principal to the agent at date 1, and (c) provided the firm is retained, a transfer $m(r)$ from the principal to the agent once the R&D project matures at $t = 2$. This payment m may depend on r, the terminal value of the project.[2]

For future reference, it will be useful to divide the type space Ω according to the sale decision rule $\rho(\cdot)$ followed by the principal. For any given parameters $\mathcal{P}$ and s, the type space Ω can be split into a retention region Ω_0, consisting of all types ω such that $\rho = 0$ and a sale region Ω_1, consisting of all types ω such that $\rho = 1$.

We assume that the agent has limited liability so that all transfers from the principal to the agent are non–negative. This limited liability assumption precludes the straightforward contract that prescribes the principal to sell the firm to the agent.

Formally, the mechanism $\mathcal{M}$ is a mapping from the agent's report $\widetilde{\omega}$, project $\mathcal{P}$ and synergy s to: (1) a sale decision ρ, (2) conditional on $\rho = 1$, a transfer t at date 1, and (3) conditional on $\rho = 0$, a transfer $m(r)$ at date 2 (which, in turn, can depend on the realization of r). Formally,

$$\mathcal{M} : (\widetilde{\omega}, \mathcal{P}, s) \to [\rho, t, m(r)].$$

From the revelation principle, we know that the principal can restrict, without loss, to direct-revelation mechanisms of the above form. Of course, such mechanisms are an abstraction with no direct empirical counterpart. In addition, they require the implicit assumption that the principal is capable of committing to a specific course of action following the agent's report. However, in section 3 below, we show how the optimal mechanism can be implemented using a simple contract with realistic features.

[2]In principle, regardless of the sale decision, the agent could receive transfers at both dates 1 and 2. If the firm is sold, the R&D project is disrupted so that the transfers to the agent cannot depend on its value r. Given that the agent is risk neutral, it is therefore, without loss, to shift all the transfers to date 1. Similarly, if the firm is retained, the agent could receive a transfer at date 1. Because of the agent's risk neutrality and a zero discount rate, shifting the total transfers to date 2 if the firm is retained is also without loss.

Given the mechanism $\mathcal{M}$, we describe the payoffs of the principal and the agent. If the firm is sold, the principal receives $v + s$ for the operating asset but she transfers t to the agent. If the firm is retained, the principal's assets are worth $v + r$ but the principal transfers $m(r)$ to the agent who also earns his private benefit b.

Given s, r, and b, and the outcome $\mathcal{M}(\widetilde{\omega}, \mathcal{P}, s) = [\rho, t, m(r)]$ of the mechanism, the principal's payoff is

$$V \equiv \rho\,[s - t] + (1 - \rho)\,[r - m(r)] + v, \tag{1}$$

while the agent's payoff is

$$U \equiv \rho t + (1 - \rho)\,[m(r) + b] \tag{2}$$

where, for notational convenience, we have suppressed the dependence of the outcomes ρ, t, and $m(r)$ of the mechanism on the triple $(\widetilde{\omega}, \mathcal{P}, s)$.

Note that, regardless of the sale decision ρ, the principal always receives the payoff v from the operating asset. However, whether the principal receives the synergy s from selling the asset at date 1 or the return r of the project at date 2 depends on the sale decision ρ. Given that v is realized regardless of whether the firm is retained or sold, for expositional clarity, we will henceforth normalize the selling price $v + s$ of the firm to s.

Given the above payoffs, we next characterize the optimal screening mechanism that the principal chooses.

3 Mechanism Design Problem

In designing the mechanism $\mathcal{M}$, the principal maximizes the expected value of V described in (1) subject to: (i) incentive compatibility constraints for the agent that induce truthful reporting, and (ii) the limited liability constraints mentioned above. Formally, given selling price s and project $\mathcal{P}$, the principal chooses the mechanism $\mathcal{M}$ to maximize:

$$E_{(\omega,r)}V \tag{3}$$

subject to:

$$E_r(U|\omega) \geq E_r(U|\widetilde{\omega}) \text{ for all types } \omega \text{ and reports } \widetilde{\omega} \tag{4}$$

and

$$t(\widetilde{\omega}) \geq 0 \text{ for } \widetilde{\omega} \in \Omega_1, \text{ or} \tag{5}$$
$$m(\widetilde{\omega}) \geq 0 \text{ for } \widetilde{\omega} \in \Omega_0.$$

Note that the principal's payoff described in (1) depends on (1) the agent's report $\widetilde{\omega}$ that affects the transfers t and $m(r)$ paid to the agent, and (2) the return r when the firm is retained. However, when designing the optimal mechanism, the principal does not know the agent's type ω or the return r. Therefore, the expectation described in (3) is taken over the random variables (ω, r). When the agent of type ω chooses his report $\widetilde{\omega}$, the return r is the only source of uncertainty in his payoff described in (2). In choosing his report, the agent calculates his expected payoffs described in (4) over the random variable r. The incentive compatibility constraints described in (4) ensure that an agent whose true type is ω has no incentives to misreport his type $\widetilde{\omega}$ where $\widetilde{\omega} \neq \omega$. The limited liability constraints described in (5) ensure that, regardless of the sale decision, all transfers from the principal to the agent are non–negative.

Before analyzing the optimal mechanism, we first consider a hypothetical environment where the principal directly observes the agent's type ω. In this full information environment, the principal maximizes her payoffs by retaining the firm if $s < \theta R$ and selling the firm otherwise.

Figure 1 illustrates the full information (FI) benchmark given the selling price s. The region Ω_0^{FI} depicts agents of type ω such that $\frac{s}{R} < \theta$. Similarly, the region Ω_1^{FI} depicts agents of type ω such that $\frac{s}{R} > \theta$.

From the principal's perspective, the full information regions Ω_0^{FI} and Ω_1^{FI} represent ideal retention and sale regions, respectively. These regions fully screen the agents along the profitability dimension θ so that the selling price s can be evaluated *solely* in terms of the profitability parameter θ of the project but not in terms of the agent's private benefit b. When the agent's type ω is unobservable, in order to induce him to act on his private information about the profitability θ, the principal must transfer information rents to the agent. However, as we will see below, fully screening the agents along θ for any level of b may be very costly so that the full information retention and sale regions may not be achieved. Therefore, in designing the optimal mechanism, the principal necessarily trades off full screening along the θ dimension against costly transfers to the agent.

We now return to the original screening mechanism $\mathcal{M}$ described above in which truth telling is potentially costly for the principal. The first main result of the paper is to demonstrate that the

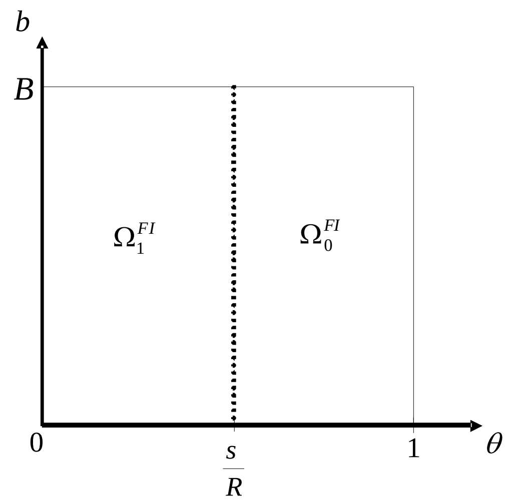

Figure 1: Full information (FI) benchmark given the selling price s. Ω_0^{FI} represents ideal retention region while Ω_1^{FI} represents ideal sale region.

direct revelation mechanism described above simplifies to a contract that has desirable implementation features. Specifically, we show that the principal can focus, without loss, on *maximal incentive* mechanisms.

Definition 1 *A mechanism $\mathcal{M}$ is called a* ***maximal incentive*** *mechanism if there exist non-negative constants τ and α such that:*
*(**a**) $t(\omega) = \tau$ for every $\omega \in \Omega_1$, and*
*(**b**) $m(\omega, r) = \alpha \cdot r$ for all r, and every $\omega \in \Omega_0$.*

Notice that under a maximal incentive mechanism, the transfer payment τ (if the agent's report prescribes a sale) and the equity stake α (if the agent's report rejects the sale) are constants and therefore do not depend *directly* on the agent's report. The transfers made to the agent depend on his report only *indirectly* through the effect of the report on the decision to retain or sell the firm.[3] As we discuss below, this particular feature of the maximal incentive contract not only has desirable incentive properties that allow for efficient screening of the agents but it also allows for practical implementation of the optimal mechanism using a simple contract with realistic features.

[3]This feature of the maximal incentive mechanism shares the same fundamental feature of a Groves mechanism in which given an announcement, say θ_{-i} of agents $j \neq i$, agent $i's$ transfer depends on his announced type only through the effect of his announcement on the choice of a project [see Groves (1973)].

Proposition 1 *Without loss, the principal can restrict to maximal incentive mechanisms.*

The intuition behind Proposition 1 is as follows. If the firm is sold, the R&D project is disrupted and therefore not only does the agent not earn the private benefit b but the agent's knowledge of the expected profitability θ of the project also becomes irrelevant. Conditional on selling the firm, the agent's type ω cannot therefore directly affect his payoff at date 1 so that any transfer payment at date 1 cannot be used to screen across types. This fact directly implies that any incentive compatible mechanism must prescribe the same transfer τ across all types if the firm is sold. We will show later that the transfer payment τ resembles a golden parachute because it is excessive.

Conditional on retaining the firm, the agent's private benefit b cannot be used to screen across types because the agent experiences this private benefit *regardless* of what the mechanism prescribes. The mechanism, however, can screen across types θ by making the transfer contingent on the project's success. In fact, given that the principal's goal is to provide incentives for the high θ types to retain the firm while simultaneously deterring the low θ types from doing so, the most efficient way of achieving this goal is to reward an agent who decides to retain the firm only if this R&D project succeeds. The maximal incentive mechanism precisely achieves the latter goal by rewarding any agent with a *constant* equity stake α that puts *all* the weight on the firm's terminal value r so that the agent is rewarded only if the project succeeds.

Furthermore, the fact that the transfers α and τ depend on the agent's report $\widetilde{\omega}$ only *through* the effect of the report on the sale decision, in turn, implies that the contract can be implemented by simply allocating *control rights* over the sale decision between the agent and the principal. In particular, such a contract would only need to specify a state–contingent allocation of control rights over the sale decision that, in turn, will determine whether the agent receives α or τ. Notice that all that we need to implement such a contract is that: (i) the court system is capable of transferring control rights over the sale decision between principal and agent (i.e., between external shareholders and the board of directors), and (ii) the court is capable of enforcing monetary transfers from principal to agent. We next investigate the allocation of control rights between the principal and the agent.

3.1 Control Rights and Delegation

Consider a mechanism that grants the *agent* control rights over whether the firm should be retained or sold. We refer to such a mechanism as a *delegation mechanism*. In a delegation mechanism, the sale decision depends on the agent's report so that the decision $\rho(\widetilde{\omega})$ is non-constant over the agent's report $\widetilde{\omega}$. Next, consider an alternative mechanism which, instead, prescribes that the *principal* has the decision rights over whether the firm should be retained or sold. We refer to such a mechanism as a *non-delegation mechanism*. In a non-delegation mechanism, because the principal always ignores the agent's report, the decision $\rho(\widetilde{\omega})$ is always a constant over $\widetilde{\omega}$.

If the principal retains the control rights over the sale decision, the agent's information is ignored so that no transfers are made to the agent in a non-delegation mechanism. If the principal gives control rights to the agent, the latter must be induced to act on his information about θ. In other words, the agent must earn informational rents in a delegation mechanism. To see why, note that in a delegation mechanism, given that the decision $\rho(\omega)$ depends on the agent's report ω, there exists a pair of types ω_1, ω_2 such that type ω_1 prescribes sale and $\rho(\omega_1) = 1$ and type ω_2 prescribes retention so that $\rho(\omega_2) = 0$. If no transfers are made to either of these agents, then type $\omega = \omega_1$ would receive a strictly higher payoff when choosing the report $\widetilde{\omega} = \omega_2$ (namely, a payoff of at least b) than when choosing the truthful report $\widetilde{\omega} = \omega_1$ (namely, a payoff equal to zero). Therefore, if no transfers are made to the agents, the delegation mechanism cannot be incentive compatible.

Each mechanism specifies an allocation of control rights over the sale decision together with monetary transfers defined as follows:

- *In a delegation mechanism (a) assign all control rights over the sale decision to the agent, (b) transfer τ to the agent if he sells the firm, and (c) grant an equity stake α in the firm to the agent if he holds on to the firm.*

- *In a non-delegation mechanism (a) do not assign control rights over the sale decision to the agent, and (b) do not make any transfers to the agent so that $\alpha = \tau = 0$.*

Assigning control rights to the agent is costly because, in order to induce the agent to act on his private information, the principal has to make positive transfers α and τ to the biased agent. However, the benefit of assigning control rights to the agent is that his private information θ about the profitability of the project can be very valuable. Therefore, in determining whether control rights should be delegated to the agent, the delegation mechanism must trade off the *expected value of the agent's information* against the *costly transfers* that the principal must make to the agent in order to induce the latter to act on his private information.

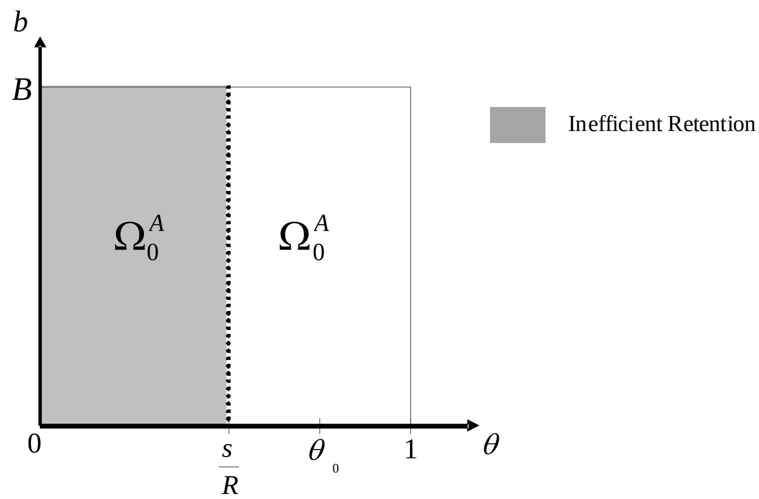

Figure 2: Non Delegation Mechanism with Selling Price $s < \theta_0 R$. Ω_0^A denotes the retention region.

To better understand how the principal makes the above trade–off, it is useful to analyze the following scenarios:

Scenario A: Suppose the principal designs a non-delegation mechanism. The benefit of such a mechanism is that no transfers to the agent are necessary and therefore $\alpha_A = \tau_A = 0$. But the drawback is that the principal must base her sale decision exclusively on her prior belief θ_0, rather than the agent's revised belief θ. In particular, if $s > \theta_0 R$, the principal sells the firm, and if $s < \theta_0 R$, the principal retains the firm. Note that, in such a mechanism, the agents are pooled along the profitability dimension θ. Therefore, this non-screening mechanism can be very inefficient.

Figure 2 illustrates a non-delegation mechanism under scenario A for the case where $s < \theta_0 R$. In this case, regardless of the agent's type, the principal does not sell the firm so that the retention region Ω_0^A overs the whole type space. Therefore $\Omega_0^A = \Omega \equiv [0, 1] \times [0, B]$. In order to gauge the magnitude of the inefficiency from not delegating, let's compare the non-delegation mechanism illustrated in Figure 2 with the full information benchmark illustrated in Figure 1. The shaded area in Figure 2 illustrates the inefficient retention region as a result of non-delegation: any type $\omega = (\theta, b)$ in the shaded area inefficiently retains the firm even though, regardless of b, $s > \theta R$.

Scenario *B:* Suppose instead, in order to exploit the agent's information, the principal designs a delegation mechanism that screens the agents *only* along the private benefit dimension b. Such a screening may be accomplished via a transfer payment $\tau_B > 0$ to the agent if he sells the firm

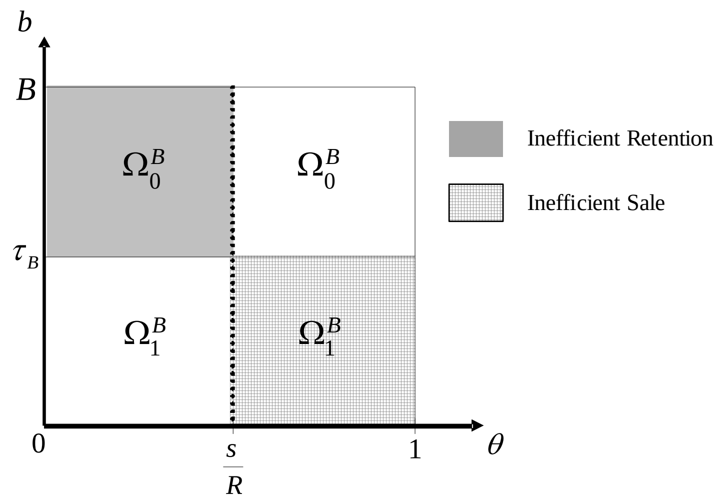

Figure 3: Delegation Mechanism with $\alpha_B = 0, \tau_B > 0$. Ω_0^B denotes the retention region while Ω_1^B denotes the sale region.

and via a zero equity stake otherwise, i.e., $\alpha_B = 0$. Clearly, under such a mechanism, for *any* θ, all agents of types $\omega = (\theta, b)$ such that $\tau_B > b$ will sell the firm while, all agents of types ω such that $\tau_B < b$ will retain the firm. Figure 3 depicts the retention and sale regions denoted by Ω_0^B and Ω_1^B, respectively. The shaded areas in Figure 3 illustrate the inefficient retention and sale regions for such a mechanism.

The non-delegation mechanism described in scenario A is inefficient because it completely ignores the agent's information so that the principal does not screen the agent along either the θ or the b dimension. Of course, from the principal's perspective, the benefit of such a mechanism is that no transfers are necessary because $\alpha_A = \tau_A = 0$. The delegation mechanism described in scenario B induces the agent to only use his information about b but not his information about θ. Therefore, despite the costly transfer τ_B to the agent, this mechanism is also inefficient because the agent is not induced to act on his information about θ. Therefore, in any delegation mechanism, regardless of the magnitude of τ_B, in order to induce the agent to act on his information about θ, the agent must be granted incentives to use his information about θ via a positive equity stake α in the firm. Scenario C explores such a delegation mechanism.

Scenario C: Suppose the principal designs a delegation mechanism with transfers $\tau_C > 0$ and $\alpha_C > 0$. If an agent of type $\omega = (\theta, b)$ sells the firm, he receives τ_C. Otherwise, he receives an equity stake α_C so that his expected payoff is $\alpha_C \cdot \theta R + b$. Therefore all agents of type ω such that

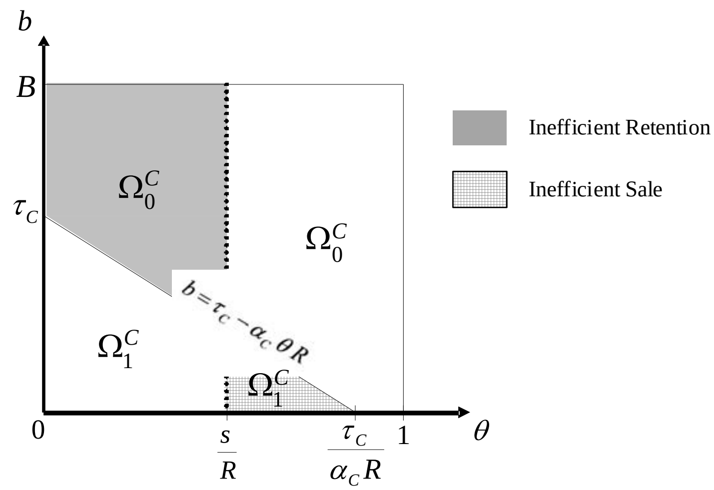

Figure 4: Delegation Mechanism with $\alpha_C > 0$ and $\tau_C > 0$. Ω_0^C denotes the retention region while Ω_1^C denotes the sale region.

$\alpha_C \cdot \theta R + b > \tau_C$ will retain the firm while all agents of type ω such that $\alpha_C \cdot \theta R + b < \tau_C$ will sell the firm. Agents of type ω such that $\alpha_C \cdot \theta R + b = \tau_C$ are indifferent between selling or retaining the firm. Figure 4 illustrates the retention and sale regions for such a mechanism denoted, respectively, by Ω_0^C and Ω_1^C.

Again, using Figure 1 as an efficiency benchmark, the shaded areas in Figure 4 capture the inefficient sale and retention regions. The negatively sloped line that divides these two regions, i.e., $b = \tau_C - \alpha_C \cdot \theta R$ represents types ω who are indifferent between retaining or selling the firm. The magnitude of the slope of the indifference condition is therefore $\alpha_C \cdot R$. It follows that, in order to approach the full information benchmark, the slope $\alpha_C \cdot R$ of the indifference condition and therefore α_C must increase (so that the indifference condition tilts clockwise). This fact, in turn, implies that the slope of the indifference condition must approach infinity! But, this is clearly infeasible given that the equity stake α_C cannot exceed one.

The preceding analysis illustrates the dilemma that the principal faces in designing the optimal mechanism. Ignoring the agent's superior information by designing a non-delegation mechanism as described in *scenario A* leads to a suboptimal sale decision even though the principal makes no costly transfers. However, *scenarios B and C* indicate that inducing the agent to act fully on his information about θ is prohibitively costly from the principal's perspective because, regardless of the positive transfer τ, an infinitely large equity stake α is necessary.

The principal resolves the dilemma by seeking the following compromise: in choosing a delegation mechanism, the principal trades off the information rents paid to the agent against the cost of making an inefficient decision represented by inefficient retention and sale regions. Therefore, in any delegation mechanism, the principal has to tolerate some regions of inefficiencies such that some agents inefficiently retain the firm (i.e., agents of type ω such that $s > \theta R$ but $\alpha \cdot \theta R + b > \tau$) while other agents inefficiently sell the firm (i.e., agents of type ω such that $s < \theta R$ but $\tau > \alpha \cdot \theta R + b$). In section 5 below, we show how such inefficient retention and inefficient sale regions are necessary features of a delegation mechanism. In particular, we explain how the region of inefficient retention entails *entrenchment* while the region of inefficient sale results in *golden parachute* payments.

In resolving the preceding trade–off between maximizing efficiency versus minimizing rent transfers, the potential value of the agent's private information plays a crucial role. We next investigate how, in designing the optimal mechanism, the principal assesses the value of the agent's private information.

4 Value of Agent's Private Information

Let $\mathcal{P} \equiv \langle R, h \rangle$ denote the underlying characteristics of the firm's R&D project. Note that the R&D project is fully summarized by the return R and the density $h(\theta, b)$. We henceforth refer to the pair $\mathcal{P}$ as a project. Recall that from the principal's perspective, the expected value of the R&D project is given by $\theta_0 R$ and this information is common knowledge to both principal and agent. However, between dates 0 and date 1, the agent updates his beliefs about the project to θR, resulting in an information asymmetry between the agent and the principal. The value of such information asymmetry is given by $|\theta R - \theta_0 R|$.

Therefore, when the principal is designing the mechanism, the expected value of the information asymmetry about the return of project $\mathcal{P}$ is:

$$\int_0^1 |\theta R - \theta_0 R| f(\theta) d\theta \tag{6}$$

Definition 2 *We refer to the expected value of the agent's information advantage given by (6) as the "Mean Absolute Revision", $\Phi(\mathcal{P})$, of project $\mathcal{P}$.*

It is useful to compare projects $\mathcal{P}$ that differ along the mean absolute revision dimension, i.e., along $\Phi(\mathcal{P})$, while holding their *ex ante* expected value $r_0 \equiv \theta_0 R$ constant. The next two remarks describe the properties of $\Phi(\mathcal{P})$ across projects $\mathcal{P}$ that have a constant expected value r_0.

Remark 1 *Fix* $r_0 > 0$. *The range of values that* $\Phi(\mathcal{P})$ *can take across projects* $\mathcal{P}$ *such that* $\theta_0 R = r_0$ *is given by the interval* $[0, 2r_0)$.

Proof of Remark 1. Using (6):

$$\begin{aligned}\Phi(\mathcal{P}) &\equiv \int_0^1 |\theta R - r_0| f(\theta) d\theta \text{ which can be rewritten as:} \\ &= \int_{\theta_0}^1 (\theta R - r_0) f(\theta) d\theta + \int_0^{\theta_0} (r_0 - \theta R) f(\theta) d\theta \text{ which simplifies to:} \\ &= 2\int_0^{\theta_0} (r_0 - \theta R) f(\theta) d\theta \text{ because } \int_0^{\theta_0} (r_0 - \theta R) f(\theta) d\theta + \int_{\theta_0}^1 (r_0 - \theta R) f(\theta) d\theta = 0\end{aligned}$$

The expression $2\int_0^{\theta_0}(r_0 - \theta R) f(\theta) d\theta$ achieves a minimum value of 0 when $\theta = \theta_0$ and a least upper bound equal to $2r_0$ (because $2\int_0^{\theta_0}(r_0 - \theta R) f(\theta) d\theta \le 2r_0 \int_0^{\theta_0} f(\theta) d\theta < 2r_0$, and is continuous in $\mathcal{P}$ (which implies that the range of $\Phi(\mathcal{P})$ is an interval). It remains to be shown that this least upper bound $2r_0$ cannot be achieved by any project. To see why this is the case, notice that $\Phi(\mathcal{P}) = 2r_0$ would require that $\theta_0 = 1$ and $R\int_0^1 \theta f(\theta) d\theta = \theta_0 R = 0$. But this would imply that the *ex ante* value of the project is zero, which is impossible under the identity $r_0 \equiv \theta_0 R$, and the fact that $r_0 > 0$. ■

Remark 2 *As* $\Phi(\mathcal{P})$ *approaches its upper bound of* $2r_0$, *the following conditions must hold:*

$$(a) \int_{\theta_0}^1 f(\theta) d\theta \to 0$$

$$(b) \int_0^{\theta_0} \theta R f(\theta) d\theta \to 0 \textit{ and } \int_{\theta_0}^1 \theta R f(\theta) d\theta \to r_0 \textit{ and therefore } R \to \infty, \theta_0 \to 0.$$

Condition (a) of Remark 2 implies that as $\Phi(\mathcal{P})$ for a project $\mathcal{P}$ increases, the density of $f(\theta)$ shifts to the left so that less weight is placed on relatively large values of θ. Condition (b) implies as $\Phi(\mathcal{P})$ increases, most of the expected value of the project is derived from relatively large values of θ (i.e., $\int_{\theta_0}^1 \theta R f(\theta) d\theta \to r_0$ while $\int_0^{\theta_0} \theta R f(\theta) d\theta \to 0$). Taken together, these conditions imply that as $\Phi(\mathcal{P})$ approaches its upper bound of $2r_0$, the return R from the project must grow to infinity and therefore the prior probability of success of the project must approach 0.

In the next section, we will discuss how the conditions described in remark 2 (resulting from projects with large values of $\Phi(\mathcal{P})$) have fundamental features that are usually associated with innovative projects. Before doing so, we will first examine how the control rights over the sale decision of a firm engaged in project $\mathcal{P}$ depends on the magnitude of its mean absolute revision, $\Phi(\mathcal{P})$.

4.1 Nature of Project and Optimal Control Rights

Theorem 1 *There exists a constant $\Phi^* < 2r_0$ such that, for all projects $\mathcal{P}$ such that $\Phi(\mathcal{P}) \geq \Phi^*$, the optimal mechanism is a delegation mechanism.*
In words, for projects with high values of mean absolute revision, control rights over the sale decision should be assigned to the agent .

In order to understand Theorem 1, it is useful to investigate how the costs and benefits of screening the agent vary with the mean absolute revision of the project. The benefits of assigning control rights to the agent is that it enables the principal to take advantage of the agent's superior information about θ. Anticipating this, the more important the expected value of the agent's information advantage is, i.e., the larger $\Phi(\mathcal{P})$ is, the more attractive assigning control rights to the agent becomes. To be sure, such benefits must be weighed against the costly transfers α and τ that must be made to the agent in order to induce him to act on his superior information. Recall that the maximal incentive mechanism rewards an agent who retains the firm via an equity stake α by putting all the weight on the terminal return r of the project. But as $\Phi(\mathcal{P})$ increases, we know from Remark 2 that most of the expected value of the project is derived from large values of θ (i.e., $\int_{\theta_0}^{1} \theta R f(\theta) d\theta \to r_0$ as $\Phi(\mathcal{P}) \to 2r_0$). Therefore, from the principal's perspective, it becomes cheaper to provide sharper incentives to induce a high θ type to retain the firm while simultaneously deterring a low θ type from doing so. In other words, the transfers α and τ can be reduced. Thus, as $\Phi(\mathcal{P})$ grows, not only does the value of the agent's information increase so that the benefits of assigning control rights to the agent increase, but the costs of screening the agent also go down. Above a certain threshold Φ^*, the benefit of delegating swamps the cost of delegating so that it is optimal for the principal to assign control rights to the agent.

The preceding result depended crucially on the requirement that projects $\mathcal{P}$ should have large values of $\Phi(\mathcal{P})$. Consequently, in the next step in our analysis, we examine the characteristics of such projects. We demonstrate that projects with high values of mean absolute revision $\Phi(\mathcal{P})$ are innovative in the sense that they: (a) are *high-risk/high return*, and (b) generate high information asymmetry between insiders and outsiders.

To understand why projects $\mathcal{P}$ acquire these two preceding properties as $\Phi(\mathcal{P})$ increases, recall from remark 2 that as $\Phi(\mathcal{P})$ approaches its upper bound of $2r_0$, the following conditions must hold:

(i) $R \to \infty$ and $\theta_0 \to 0$.

In words, for those projects whose mean absolute revisions approach their upper bound, such projects become high-risk/high return projects in the sense that they must not only have a large potential return R but they must also have a low *ex ante* probability of success θ_0. In particular, as $\Phi(\mathcal{P})$ approaches its upper bound $2r_0$, the return R must grow to infinity while the *ex ante* probability of success θ_0 converges to zero.

(ii) $\int_0^{\theta_0} \theta R f(\theta) d\theta \to 0$ and $\int_{\theta_0}^1 \theta R f(\theta) d\theta \to r_0$.
Recall that at date 1, there is information asymmetry between the principal and the agent: the principal knows θ_0 while the agent knows θ. Condition (ii) tells us how the *value* of the agent's superior information changes as $\Phi(\mathcal{P})$ increases. In particular, a large $\Phi(\mathcal{P})$ implies that most of the expected value of the project is derived from high rather than low values of θ. (i.e., $\int_{\theta_0}^1 \theta R f(\theta) d\theta \to r_0$). Therefore, as $\Phi(\mathcal{P})$ increases, the degree of information asymmetry between the principal and agent increases in the sense that the agent privately knows that retaining the firm would be beneficial because most of the project's expected value is being derived from high rather than low values of θ.

Summarizing, when conditions (i) and (ii) are met, even though the likelihood of the project succeeding is low on average, the principal recognizes that the agent has extremely valuable information that the project could generate a high payoff. Under those circumstances, Theorem 1 states that the uninformed principal should let the informed agent decide whether or not to sell the firm by assigning control rights to him.

Given the above result, it is natural to also analyze the converse case, i.e., who should have control rights over projects with low values of $\Phi(\mathcal{P})$? Before doing so, we first derive the properties of such projects.

Remark 3 *As $\Phi(\mathcal{P}) \to 0$, for any small $\varepsilon > 0$, the following conditions must hold:*

$$(a) \int_{\theta_0-\varepsilon}^{\theta_0+\varepsilon} f(\theta) d\theta \;\to\; 1 \text{ while both } \int_0^{\theta_0-\varepsilon} f(\theta) d\theta \text{ and } \int_{\theta_0+\varepsilon}^1 f(\theta) d\theta \to 0$$

$$(b) \int_{\theta_0-\varepsilon}^{\theta_0+\varepsilon} \theta R f(\theta) d\theta \;\to\; r_0 \text{ while both } \int_0^{\theta_0-\varepsilon} \theta R f(\theta) d\theta \text{ and } \int_{\theta_0+\varepsilon}^1 \theta R f(\theta) d\theta \to 0$$

Condition (a) of Remark 3 indicates that as the mean absolute revision $\Phi(\mathcal{P})$ becomes small, the likelihood that θ is close to θ_0 is very high. Condition (b) indicates that for projects with low values of $\Phi(\mathcal{P})$, most of the value of the project is derived from values of θ that are close to θ_0. Taken together, both conditions imply that as $\Phi(\mathcal{P})$ becomes small, not only does the agent's information advantage over the principal disappear, but the value of that information also dissipates. In practice, this means that outsiders are essentially equally informed about the value of the project as insiders, a feature that one typically associates with routine rather than innovative projects.

Theorem 2 demonstrates that, for such a class of projects, control rights should not be assigned to insiders.

Theorem 2 *There exists a constant $\Phi^{**} > 0$ such that, for all projects $\mathcal{P}$ with $\Phi(\mathcal{P}) \leq \Phi^{**}$, the optimal mechanism prescribes no delegation. In words, for projects with low values of mean absolute revision, control rights should not be assigned to the insider for all routine projects*

In order to understand the preceding result, once again, it is useful to investigate how the costs and benefits of screening the agent behave as for projects with low values of $\Phi(\mathcal{P})$. The expected value of the agent's information advantage is very low and approaches zero as $\Phi(\mathcal{P})$ is relatively low. Furthermore, as $\Phi(\mathcal{P})$ decreases, the costs of screening the agent are bounded away from zero. Consequently, it becomes optimal for the principal to retain all control rights over the offer.

5 Poison Pills, Golden Parachutes, and Entrenchment

We will now discuss how the optimal mechanism in our environment has attributes that are akin to anti–takeover features of corporate governance such as poison pills, golden parachutes, and entrenchment. In particular, we will explain how such attributes arise endogenously as optimal contracting devices in our second–best environment.

The main implication of Theorem 1 is that, for innovative projects, control rights over the sale decision should be delegated to insiders. Assigning control rights to insiders, in turn, implies that they may hold on to the firm even though, based on outsiders' information, the firm should be sold. This occurs because outsiders evaluate the selling price of the firm against the *ex ante* value of the firm so that outsiders would view any offer s that exceeds r_0 as attractive. Furthermore, the fact that Theorem 1 holds for any value of s, implies that insiders may reject seemingly attractive offers with large and arbitrarily increasing premia (i.e., $s >> r_0$). In that sense, the optimal mechanism has the flavor of a poison pill: for innovative projects, it protects the insiders by enabling them to reject arbitrarily high offers that may seem suboptimal based on the outsiders' information. Conversely, the optimal mechanism prescribes no poison pills for routine projects: the uninformed outsiders

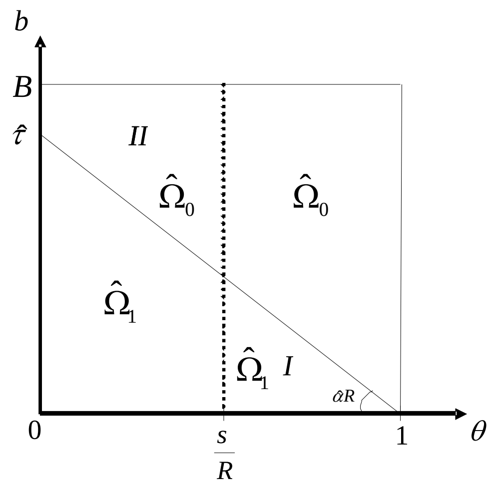

Figure 5: Delegation Mechanism with transfers $\widehat{\alpha} > 0$ and $\widehat{\tau} > 0$. The retention and sale regions are denoted by $\widehat{\Omega}_0$ and $\widehat{\Omega}_1$, respectively. Regions I and II capture inefficient sale and retention regions respectively.

retain all control rights over the sale decision so that from their perspective, any attractive offer such that $s > r_0$ is always accepted.

The optimal mechanism also entails features such as golden parachute payments and insider entrenchment. To understand this, consider a delegation mechanism with transfers $\widehat{\tau} > 0$ and $\widehat{\alpha} > 0$ illustrated in Figure 5 below.

The retention and sale regions for such a mechanism are denoted by $\widehat{\Omega}_0$ and $\widehat{\Omega}_1$, respectively. The negatively sloped line that divides these two regions is satisfied by types $\omega = (\theta, b)$ such that $b = \widehat{\tau} - \widehat{\alpha} \cdot \theta R$. Recall that the slope of the indifference line (given by $-\widehat{\alpha} \cdot R$) must be negative because the equity stake $\widehat{\alpha}$ that the agent receives in the firm is positive and cannot exceed 1. Therefore, the delegation mechanism may result in two types of inefficiencies captured by regions I and II in Figure 5. Region I depicts agents of type ω who inefficiently sell the firm (because their information should lead them to retain to firm, i.e., $s < \theta R$) and receive a transfer payment $\widehat{\tau} > \widehat{\alpha} \cdot \theta R + b$. But, for any type ω in region I, the fact that $s < \theta R$ and $b \geq 0$, together imply that $\widehat{\tau} > \widehat{\alpha} \cdot s$. Therefore, the transfer payment $\widehat{\tau}$ to insiders resembles a golden parachute in the sense that conditional on selling the firm, they receive a transfer payment that exceeds the *value* of their equity stake $\widehat{\alpha} \cdot s$ (i.e., the value of the equity stake evaluated at the offer s) in the firm.

Region II of Figure 5 also depicts agents of types ω who retain the firm even though $s > \theta R$. This feature of our optimal contract has the flavor of insider entrenchment because from the shareholders' perspective, insiders inefficiently hold on to the firm even though their information should lead them to sell the firm.

The next result demonstrates that *any* delegation mechanism necessarily entails anti-takeover features such as golden parachute payments and insider entrenchment.

Proposition 2 *For a given offer s, consider a delegation mechanism with transfers $\widehat{\tau}$ and $\widehat{\alpha}$. Then (a) $\widehat{\tau} > \widehat{\alpha} \cdot s$. In words, the transfer payment to the agent resembles a golden parachute because it exceeds the value of his stake in the firm. (b) There exist types $\omega \equiv (\theta, b)$ such that $s > \theta R$ and $\widehat{\tau} < \widehat{\alpha} \cdot \theta R + b$. In words, insiders hold on to the firm even though their information*

To understand why "golden parachute" payments are optimal, note that the agent is inherently biased in favor of retaining the firm due to the private benefit b that he extracts from the completion of the R&D project. In order to compensate the agent for this bias and induce the agent to accept an offer, the delegation mechanism makes a transfer payment $\widehat{\tau}$ that exceeds the value of the equity stake $\widehat{\alpha}$ evaluated at the offer s so that $\widehat{\tau} > \widehat{\alpha} \cdot s$. Given that it is optimal for the principal to delegate control rights only for innovative projects, the preceding result, in turn, implies that golden parachute payments go hand in hand with innovative projects but not with routine projects.

The intuition behind the insider entrenchment result is as follows. In choosing a delegation mechanism, the principal trades off the information rents paid to the agent against the cost of making an inefficient decision. The preceding result states that, in any delegation mechanism, the transfer payment τ that is needed to induce some agents to sell the firm may be so large that the principal finds it beneficial to allow such agents to retain the firm even though the decision is inefficient (i.e., agents of type ω such that $s > \theta R$ but $\alpha \cdot \theta R + b > \tau$).

The above result highlights an important role for insider protection devices that has not received much attention in the prior literature. To be sure, there is an important and large literature on the optimality of insider protection devices. However, the perspective taken in that literature is that anti-takeover devices affect the behavior of raiders in a way that is beneficial to shareholders. For example, Stein (1988) has shown that takeover protection reduces the likelihood that a raider may wish to purchase the firm and this, in turn, reduces pressure on management to engage in wasteful signaling. Alternatively, Shleifer and Vishny (1986) and Harris and Raviv (1988) have shown that poison pills may be used directly to extract a higher price from the raider by increasing the bargaining power of the board. Thus, in the prior literature, the key role of anti-takeover devices is to affect the behavior of *outsiders* such potential raiders by making it harder for them to take over the firm. Our study differs from the prior literature in an important way. We have assumed that the selling price of the firm is exogenously given. In doing so, we have, from the outset, assumed that all bargaining power resides in the hands of insiders rather than the raider. As a result, in our environment, *by assumption*, protection devices cannot play the role of bargaining devices. This assumption has, however, allowed us to understand how anti-takeover devices affect the behavior of *insiders* rather than *outsiders*. In doing so, we have uncovered an *information revelation* role for anti-takeover devices. In particular, we demonstrate that, in a second-best environment, given the market pressure faced by insiders, these devices are necessary so that insiders may act on their superior information in carrying out innovative projects.

6 Conclusion

We have investigated an environment in which informed and biased insiders face market pressure to sell a firm. Given this environment, we derive the optimal contract that maximizes the shareholders' payoffs. We show that the optimal allocation of control rights over the sale decision depends on the nature of the long term project: control rights should be allocated to insiders for innovative projects but not for routine projects. Our analysis also indicates that the optimal mechanism prescribes seemingly suboptimal features of corporate governance that resemble poison pills, golden parachutes, and managerial entrenchment. Given the market pressure faced by insiders, we show that these features are necessary to induce insiders to carry out innovative projects.

In the paper, we have assumed that insiders cannot credibly disclose their private information to shareholders. It is, of course, possible that some of the private information of insiders could be verifiable and thus could be credibly disclosed to outsiders. In such an environment, the market price of the firm may alleviate the information asymmetry between insiders and outsiders so that the information rents transferred to the insiders must be lower. In future work, it would be interesting to investigate how the market price of the firm interacts with the optimal contract to affect insiders' incentives to engage in R&D activities. This interaction would depend on the information efficiency of the market price and therefore on the accounting measurement regime in place.

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7 Appendix: Proofs

Proof of Remark 2. From the proof of Remark 1, $\mathcal{R}(\mathcal{P}) = 2\int_0^{\theta_0}(r_0-\theta R)f(\theta)d\theta = 2r_0\int_0^{\theta_0} f(\theta)d\theta - 2\int_0^{\theta_0}\theta R f(\theta)d\theta$. Therefore as $\mathcal{R}(\mathcal{P}) \to 2r_0$, $\int_0^{\theta_0} f(\theta)d\theta \to 1$ and $\int_0^{\theta_0}\theta R f(\theta)d\theta \to 0$.
Because the expected return of the project is constant at r_0, $\int_0^{\theta_0}\theta R f(\theta)d\theta \to 0$ must, in turn, imply that $\int_{\theta_0}^1 \theta R f(\theta)d\theta \to r_0$. Finally, from part (a), $\int_{\theta_0}^1 f(\theta)d\theta \to 0$ and $\int_{\theta_0}^1 \theta R f(\theta)d\theta \to r_0$ together imply that $R \to \infty$. Given a constant r_0, $R \to \infty$ implies that $\theta_0 \to 0$. ■

Before beginning with the proof of Proposition 1, we first establish some preliminary results that permit a more fluid presentation of the main proof.

Lemma 1 *For any optimal Incentive Compatible (IC) mechanism* (ρ, t, m_r)*,* $t(\theta, b)$ *is independent of* θ *and* b *for all pairs* $(\theta, b) \in \Omega_1(\mathcal{M}) = \{(\theta, b)\,|\rho(\theta, b) = 1\}$ *Let* τ *denote this payment.*

Proof. *Suppose we have an IC mechanism. Consider* $(\theta, b) \neq (\theta', b')$ *such that both belong to* $\Omega_1(\mathcal{M})$*. By IC, and given that* $\rho = 1$ *for both types, we have:* $t(\theta, b) \geq t(\theta', b')$ *and* $t(\theta', b') \geq t(\theta, b)$*; thus,* $t(\theta, b) = t(\theta', b') = \tau$*.* ■

Lemma 2 *Without loss of generality, for any optimal IC mechanism* (ρ, τ, m_r)*, we can focus on* $m_R(\theta, b)$ *and* $m_0(\theta, b)$ *independently of* b*. Denote them by* $m_R(\theta)$ *and* $m_0(\theta)$*.*

Proof. *Consider an optimal IC mechanism. From IC we know that:*

$$\theta m_R(\theta, b) + (1-\theta)\, m_0(\theta, b) \geq \theta m_R\left(\theta, b'\right) + (1-\theta)\, m_0\left(\theta, b'\right)$$

Suppose that $m_R(\theta, b) \neq m_R(\theta, b')$ *and* $m_0(\theta, b) \neq m_0(\theta, b')$*. If the inequality holds strictly, then agent* (θ, b') *will mimic* (θ, b)*, which implies a contradiction with our IC assumption. Therefore, the inequality above must hold with equality. In this case, the principal can choose* $m_r(\theta) = m_r(\theta, b)$ *for some* b*, which leaves the agents' decisions and the principal's expected payoff unaltered.* ■

Remark 4 *For any optimal incentive compatible mechanism, we have* $\tau \leq s$ *where* s *is the selling price of the firm.*

Proof. *To show this, consider an optimal IC mechanism* $\mathcal{M}_1 = (\rho, \tau, m_r)$*, such that* $\tau > s$*. The principal's expected payoff is*

$$\int_0^1 \left(\rho(\theta, b)(s-\tau) + (1-\rho(\theta, b))\, E\left[r - m_r(\theta)\,|\theta\right]\right) f(\theta)d\theta \quad \textit{which is equivalent to}$$

$$\int_{\Omega_1(\mathcal{M}_1)} \left(\rho(\theta, b)(s-\tau)\right) f(\theta)d\theta + \int_{\Omega_0(\mathcal{M}_1)} \left((1-\rho(\theta, b))\, E\left[r - m_r(\theta)\,|\theta\right]\right) f(\theta)d\theta$$

Now consider the alternative IC mechanism $\mathcal{M}_2 = \left(\rho', s, m_r'\right)$, *with* $m_r'(\theta, b) = m_r(\theta, b)\ \forall\ \omega \in \Omega_0(\mathcal{M}_1)$

$$\int_0^1 \left(\left(1-\rho'(\theta,b)\right) E\left[r - m_r'(\theta)\,|\theta\right]\right) f(\theta)d\theta$$

or

$$\int_{\Omega_0(\mathcal{M}_2)} \left(\left(1-\rho'(\theta,b)\right) E\left[r - m_r'(\theta)\,|\theta\right]\right) f(\theta)d\theta$$

Note that $\Omega_0(\mathcal{M}_1) \subseteq \Omega_0(\mathcal{M}_2)$ $(\rho(\theta,b) \geq \rho'(\theta,b)$ *for any* $(\theta,b))$, *because of the lower cost of selling. Additionally* $E[r - m_r(\theta)\,|\theta] > 0$ *for every* $\theta > 0$. *Given* $\tau > s$, *we found an alternative mechanism with a higher expected value for the principal, which contradicts the assumption that the original mechanism was optimal.* ■

Proof of Proposition 1. We will now prove Proposition 1 by proving a series of claims below.

Definition 3 *Let function* $\beta(\theta)$ *be such that for all types* $\omega = (\theta, b)$ *such that* $b \geq \beta(\theta)$ *the principal keeps the project and sells for all types* ω *such that* $b < \beta(\theta)$.

$$\beta(\theta) = \begin{cases} B & if\ \tau > E[m_r(\theta) \mid \theta] + B, \\ \tau - E[m_r(\theta) \mid \theta] & if\ E[m_r(\theta) \mid \theta] + B \leq \tau \leq E[m_r(\theta) \mid \theta], \\ 0 & if\ \tau < E[m_r(\theta) \mid \theta] \end{cases} \tag{7}$$

Claim 1 *For any optimal IC mechanism* $\beta(\theta)$ *is continuous in* θ.

Proof. *From the definition of* $\beta(\theta)$ *it suffices to show that* $\tau - E[m_r(\theta)\,|\theta]$ *is continuous in* θ. *IC implies:*

$$\theta m_R(\theta) + (1-\theta)\, m_0(\theta) \geq \theta \lim_{\theta' \to \theta^+} m_R(\theta') + (1-\theta) \lim_{\theta' \to \theta^+} m_0(\theta')$$

and

$$\begin{aligned} \lim_{\theta' \to \theta^+} \left(\theta' m_R(\theta') + (1-\theta')\, m_0(\theta')\right) &\geq \lim_{\theta' \to \theta^+} \theta' m_R(\theta) + \left(1 - \lim_{\theta' \to \theta^+} \theta'\right) m_0(\theta) \\ \theta \lim_{\theta' \to \theta^+} m_R(\theta') + (1-\theta) \lim_{\theta' \to \theta^+} m_0(\theta') &\geq \theta m_R(\theta) + (1-\theta)\, m_0(\theta) \end{aligned}$$

therefore:

$$E[m_r(\theta) \mid \theta] \geq \theta \lim_{\theta' \to \theta^+} m_R(\theta') + (1-\theta) \lim_{\theta' \to \theta^+} m_0(\theta') \geq E[m_r(\theta) \mid \theta]$$

The exact same argument applies for the left limit:

$$E\left[m_r(\theta)\mid\theta\right]\geq\theta\lim_{\theta'\to\theta^-}m_R\left(\theta'\right)+(1-\theta)\lim_{\theta'\to\theta^-}m_0\left(\theta'\right)\geq E\left[m_r(\theta)\mid\theta\right]$$

Thus:

$$\theta\lim_{\theta'\to\theta^+}m_R\left(\theta'\right)+(1-\theta)\lim_{\theta'\to\theta^+}m_0\left(\theta'\right)=\theta\lim_{\theta'\to\theta^-}m_R\left(\theta'\right)+(1-\theta)\lim_{\theta'\to\theta^-}m_0\left(\theta'\right)$$

Therefore the function $E\left[m_r(\theta)\,|\theta\right]$ is continuous which completes the proof of the claim because $\tau-E\left[m_r(\theta)\,|\theta\right]$ is also continuous. ■

Claim 2 *There exists a $\widehat{\theta}\in[0,1]$ such that $s=E[r\mid\widehat{\theta}]+\beta(\widehat{\theta})$.*

Proof. *We showed above that $\beta(\theta)$ is continuous as is $E[r\mid\theta]$. To show that $\hat{\theta}$ exists we need to find $\theta_1\neq\theta_2$, such that $E[r\mid\theta_1]+\beta(\theta_1)\geq s\geq E[r\mid\theta_2]+\beta(\theta_2)$ which enables us to apply the intermediate value theorem. Take $\theta_1=0$ and $\theta_2=1$, we have $E\left[r\mid 0\right]+\beta(0)=\beta(0)$, and $E[r\mid 1]+\beta(1)=R+\beta(1)$. On one hand, through inspection of (1) we know that, $\beta(0)\leq\tau$, we also know that $\tau\leq s$, thus, $E\left[r\mid 0\right]+\beta(0)=\beta(0)\leq s$. On the other hand $R>s$ and $\beta\left(\theta\right)\geq 0$ for any θ, therefore $E[r\mid 1]+\beta(1)>s$. Thus, the intermediate value theorem applies.* ■

Definition 4 *Let $\alpha\equiv\frac{1}{R}\sup_\theta m_R(\theta)$.. Consider a new binary contract with payments αr and $\widehat{\tau}$, where $\widehat{\tau}$ is chosen such that type $\widehat{\theta}$ is indifferent between selling and holding, namely, $\widehat{\tau}=\alpha E[r\mid\widehat{\theta}]+\beta(\widehat{\theta})$.*

Claim 3 *For all θ for which there exists a b such that $(\theta,b)\in\Omega_0\left(\mathcal{M}\right),\ \alpha E\left[r\mid\theta\right]\leq E\left[m_r(\theta).\mid\theta\right]$.*

Proof. *Consider $\theta'=\arg\sup_\theta m_R\left(\theta\right)$. By IC, we have that:*

$$\theta m_R\left(\theta\right)+(1-\theta)\,m_0\left(\theta\right)\geq\theta m_R\left(\theta'\right)+(1-\theta)\,m_0\left(\theta'\right)$$

by definition of α:

$$E\left[m_r(\theta)\mid\theta\right]\geq\theta\alpha R+(1-\theta)\,m_0\left(\theta'\right)$$

but by assumption $m_0\left(\theta'\right)\geq 0$, thus, $\alpha E\left[r\mid\theta\right]\leq E\left[m_r(\theta)\mid\theta\right]$. ■

Claim 4 *$\widehat{\tau}\leq\tau$.*

Proof. *Start with $\widehat{\tau}=\alpha E\left[r\mid\widehat{\theta}\right]+\beta(\widehat{\theta})$. Since $\beta\left(\theta\right)\leq\tau-E\left[m_r(\theta)\mid\theta\right]$, we have that:*

$$\begin{aligned}\widehat{\tau}&\leq\alpha E\left[r\mid\widehat{\theta}\right]+\tau-E\left[m_r(\theta)\mid\theta\right]\\ \widehat{\tau}&\leq\tau+\alpha E\left[r\mid\widehat{\theta}\right]-E\left[m_r(\theta)\mid\theta\right]\end{aligned}$$

but as shown above $\alpha E\left[r \mid \widehat{\theta}\right] - E\left[m_r(\theta) \mid \theta\right] \leq 0$, *thus* $\tau \geq \hat{\tau}$

Note that $s - \widehat{\tau} = (1-\alpha)E[r \mid \widehat{\theta}]$. *This follows from the definitions of* $\hat{\tau}$ *and* s *in terms of* $\hat{\theta}$. ■

Claim 5 *Under the new contract, all types* $\theta < \widehat{\theta}$ *are weakly more likely to sell relative to the original contract, and all types* $\theta > \widehat{\theta}$ *are weakly more likely to hold relative to the original contract.*

$$\tau \geq \theta m_R\left(\hat{\theta}\right) - (1-\theta)\, m_0\left(\hat{\theta}\right) + b \Longrightarrow \hat{\tau} \geq \alpha\theta R + b$$

Proof. *We proceed using:*

$$\hat{\tau} = \alpha E\left[r|\hat{\theta}\right] + \beta\left(\hat{\theta}\right)$$

By inspection of $\beta(\theta)$ *we have:*

$$\tau - E\left[m_R\left(\hat{\theta}\right)|\hat{\theta}\right] \leq \beta\left(\hat{\theta}\right)$$

therefore:

$$\hat{\tau} \geq \alpha E\left[r|\hat{\theta}\right] + \tau - E\left[m_R\left(\hat{\theta}\right)|\hat{\theta}\right]$$

Now, using our premise:

$$\tau \geq \theta m_R\left(\hat{\theta}\right) - (1-\theta)\, m_0\left(\hat{\theta}\right) + b$$

we have that

$$\hat{\tau} \geq \alpha E\left[r|\hat{\theta}\right] + E\left[m_R\left(\hat{\theta}\right)|\theta\right] + b - E\left[m_R\left(\hat{\theta}\right)|\hat{\theta}\right]$$

Rewriting we are left with:

$$\hat{\tau} \geq \alpha\theta R + b + \alpha\hat{\theta}R - \alpha\theta R - E\left[m_r\left(\hat{\theta}\right)|\hat{\theta}\right] + E\left[m_r\left(\hat{\theta}\right)|\theta\right]$$

thus we only need to show that

$$\alpha\hat{\theta}R - \alpha\theta R - E\left[m_r\left(\hat{\theta}\right)|\hat{\theta}\right] + E\left[m_r\left(\hat{\theta}\right)|\theta\right] > 0$$

Applying the expectations:

$$\alpha\hat{\theta}R - \alpha\theta R > \hat{\theta} m_R\left(\hat{\theta}\right) + \left(1-\hat{\theta}\right) m_0\left(\hat{\theta}\right) - \theta m_R\left(\hat{\theta}\right) - (1-\theta)\, m_0\left(\hat{\theta}\right)$$

and simplifying, we get:

$$\left(\hat{\theta} - \theta\right)\alpha R > \left(\hat{\theta} - \theta\right)\left(m_R\left(\hat{\theta}\right) - m_0\left(\hat{\theta}\right)\right)$$

and we know that $\alpha R > \left(m_R\left(\hat{\theta}\right) - m_0\left(\hat{\theta}\right)\right)$. ■

■

Proof of Theorem 1. Suppose, in order to obtain a contradiction, that there does not exist a project such that delegation is optimal. We show that for any series of projects $\{P_n = (R_n, h_n)\}$ such that $\lim_{n\to\infty} \Phi(P_n) = 2r_0$ there exists an N such that for $n > N$ delegation is optimal. We first present some properties of the project as $\Phi(P_n) \to 2r_0$ below. With these on hand, we present a particular delegation mechanism and show that the payoff obtained by the principal under this mechanism dominates the payoff under no delegation for all projects P_n s.t. $n > N$.

We can reexpress $\Phi(P)$ as follows:

$$\begin{aligned}\Phi(P) &= \int_0^1 |\theta R - r_0| f(\theta)\, d\theta \\ &= \int_0^{\theta_0} (r_0 - \theta R) f(\theta)\, d\theta + \int_{\theta_0}^1 (\theta R - r_0) f(\theta)\, d\theta \\ &= 2\int_0^{\theta_0} (r_0 - \theta R) f(\theta)\, d\theta \quad \in \quad [0, 2r_0)\end{aligned}$$

If $\Phi(P_n) \to 2r_0$ then:

(i) $\int_0^{\theta_{0,n}} f_n(\theta)\, d\theta \to 1$

(ii) $\int_0^{\theta_{0,n}} \theta R_n f_n(\theta)\, d\theta \to 0$

(iii)$\int_{\theta_{0,n}}^1 \theta R_n f_n(\theta)\, d\theta \to r_0$, $R_n \to 0$, and $\theta_{0,n} \to 0$

(iv) $\int_{\theta_{0n}/K}^{\theta_{0,n}} f_n(\theta)\, d(\theta) \to 0$ for $K \geq 1$

(v) $\int_{\theta_{0n}/K}^{\theta_0} \theta R f(\theta)\, d(\theta) \to 0$ for $K \geq 1$.

We start by showing (i) and (ii). Take $\Phi(P_n)/2 \to r_0$, then rewrite $\Phi(P_n)$ as:

$$r_0 \int_0^{\theta_{0,n}} f_n(\theta)\, d\theta - \int_0^{\theta_{0n}} \theta R_n f_n(\theta)\, d\theta \to r_0.$$

The first term is smaller than or equal to r_0. In the second term, θ and R are non-negative, therefore:

$$\text{i)} \int_0^{\theta_0} f_n(\theta)\, d\theta \to 1 \text{ and ii)} \int_0^{\theta_{0,n}} \theta R_n f_n(\theta)\, d\theta \to 0.$$

We now proceed to show (iii). Using

$$r_0 = \int_0^1 \theta R_n f_n(\theta)\, d\theta = \int_0^{\theta_{0,n}} \theta R_n f_n(\theta)\, d\theta + \int_{\theta_{0,n}}^1 \theta R_n f_n(\theta)\, d\theta$$

and (ii) we have $\int_{\theta_{0,n}}^1 \theta R_n f_n(\theta)\, d\theta \to r_0$. Replacing θ by 1 the following relation holds:

$$R_n \int_{\theta_0}^1 \theta f_n(\theta)\, d\theta \leq R_n \int_{\theta_0}^1 f_n(\theta)\, d\theta,$$

and therefore

$$R_n \int_{\theta_0}^{1} f_n(\theta)\, d\theta \to c \geq r_0,$$

but using (i) it must be the case that $R_n \to \infty$. Now considering that $r_0 = \theta_0 R$ is constant, it must be the case that $\theta_{0,n} \to 0$.

To address (iv), we use (ii). It is clear that $\int_{\theta_{0,n}/N}^{\theta_{0,n}} \theta R_n f_n(\theta)\, d\theta \to 0$. Replacing θ by the minimum value of its range the following inequality holds

$$\int_{\theta_0/N}^{\theta_0} \theta R f(\theta)\, d\theta \geq \int_{\theta_0/N}^{\theta_0} (\theta_0/N)\, R f(\theta)\, d\theta$$

Rewriting,

$$\int_{\theta_0/N}^{\theta_0} (\theta_0/N)\, R f(\theta)\, d\theta = (r_0/N) \int_{\theta_0/N}^{\theta_0} f(\theta)\, d\theta,$$

since r_0 and N are constants, then it must be the case that $\int_{\theta_0/N}^{\theta_0} f(\theta)\, d\theta \to 0$.

To proof (v), take $\int_{\theta_0}^{N\theta_0} \theta R f(\theta)\, d\theta$ and replace θ by the max of the integral's range. We have

$$\int_{\theta_0}^{N\theta_0} \theta R f(\theta)\, d\theta \leq \int_{\theta_0}^{N\theta_0} N\theta_0 R f(\theta)\, d\theta.$$

The right hand side of the inequality can be rewritten as $N r_0 \int_{\theta_0}^{N\theta_0} f(\theta)\, d\theta$, by i) $\int_{\theta_0}^{N\theta_0} f(\theta)\, d\theta \to 0$, thus, $\int_{\theta_0}^{N\theta_0} \theta R f(\theta)\, d\theta \to 0$. Now we compare the payoff in a mechanism with no delegation,s, against the payoff of the mechanism with delegation such that $\tau = B\left(\frac{N^2}{N^2-1}\right)$, and $\alpha = \frac{B}{r_0}\left(\frac{N}{N^2-1}\right)$, for a given large N. Under the delegation mechanism, type $\left(\frac{\theta_0}{N}, B\right)$ sells and type $(N\theta_0, 0)$ holds. Given this, we divide the types in three groups: i) certain sellers, i.e., all types (θ, b) such that. $\theta < \theta_0/N$, ii) certain holders, i.e., all those types (θ, b) s.t. $\theta > N\theta_0$, and iii) the uncertain, i.e., those types (θ, b) whose decision depends on b. From the principal's perspective, the worst case scenario would be having only the lowest $\theta' s$ in the group (θ_0/N) with high $b' s$, in this case, the payoff would be $\frac{r_0}{N} - \frac{B}{N^2-1} > 0$. Thus the gain from delegation is bounded below by:

$$\int_{0}^{\theta_0/N} (s-\tau)\, f(\theta)\, d(\theta) + \int_{N\theta_0}^{1} \theta R (1-\alpha)\, f(\theta)\, d(\theta)$$

As $\Phi(P) \to 2r_0$, this expression converges to:

$$\to (s-\tau) + r_0 (1-\alpha) = r_0 (1-\alpha) + s - \tau,$$

but as $N \to \infty$, $\alpha \to 0$, and $\tau \to B$. Therefore,

$$r_0 (1-\alpha) + s - \tau \to r_o - B + s.$$

Subtracting $max\{s, r_0\}$, we have the net payoff from delegating which is:

$$r_o - B > 0 \text{ or } s - B > 0$$

Therefore, the principal is better off delegating. ■

Proof of Theorem 2. We will prove that $\exists \ \ \Phi^* > \varepsilon \ \ s.t. \ \ \forall P$ for which $\Phi(P) \leq \Phi(\varepsilon)$ and $E[b] \geq \varepsilon$ then no delegation is optimal . We compare the payoffs for the principal from the best imaginable mechanism and a no delegation mechanism, and show that for $\Phi(P)$ close to 0, the second option dominates the first.

Before doing this we will prove that as $\Phi(P) \to 0$.then:

(i) $\Phi(P) = \int_0^1 |R\theta - R\theta_0| f(\theta) d\theta \to 0$

(ii) $\int_0^{\theta_0(1-\varepsilon)} f(\theta) d\theta \to 0$

(iii) $\int_{\theta_0(1+\varepsilon)}^1 f(\theta) d\theta \to 0$

(iv) $\int_0^1 |R\theta - R\theta_0| f(\theta) d\theta \to 0$ implies $\int_0^{\theta_0} (R\theta_0 - R\theta) f(\theta) d\theta + \int_{\theta_0}^1 (R\theta - R\theta_0) f(\theta) d\theta \to 0$. Therefore,

$$\int_0^{\theta_0(1-\varepsilon)} (R\theta_0 - R\theta) f(\theta) d\theta \to 0, \text{ and} \int_{\theta_0(1+\varepsilon)}^1 (R\theta - R\theta_0) f(\theta) d\theta \to 0.$$

Plugging the highest value of the range for each integral, we have:

$$\int_0^{\theta_0(1-\varepsilon)} \varepsilon\theta_0 R f(\theta) d\theta \to 0, \text{ and } \int_{\theta_0(1+\varepsilon)}^1 \varepsilon\theta_0 R f(\theta) d\theta \to 0,$$

or equivalently:

$$\varepsilon r_0 \int_0^{\theta_0(1-\varepsilon)} f(\theta) d\theta \to 0, \text{ and } \varepsilon r_0 \int_{\theta_0(1+\varepsilon)}^1 f(\theta) d\theta \to 0,$$

but, since r_0 and ε are constants, we have (i) and (ii).

To show (iii), use

$$\varepsilon r_0 \int_{\theta_0(1+\varepsilon)}^1 f(\theta) d\theta \to 0$$

and the result that :

$$\varepsilon r_0 \int_{\theta_0(1+\varepsilon)}^1 f(\theta) d\theta < \varepsilon r_0$$

and since ε is constant,

$$\int_0^{\theta_0(1-\varepsilon)} \theta R f(\theta) d\theta \to 0.$$

Now, use

$$\int_{\theta_0(1+\varepsilon)}^1 (R\theta - R\theta_0) f(\theta) d\theta \to 0$$

$$\int_{\theta_0(1+\varepsilon)}^{1} \varepsilon\theta_0 R f(\theta)\, d\theta \to 0$$

This implies that since $\theta \leq 1$ we can plug in θ in these two integrals, which yields:

$$\int_0^{\theta_0-\varepsilon} \theta R f(\theta)\, d\theta \to 0, \text{ and } \int_{\theta_0+\varepsilon}^{1} \theta R f(\theta)\, d\theta \to 0.$$

This, together with $\int_0^1 \theta R f(\theta)\, d\theta \to r_0$, gives:

$$\int_{\theta_0-\varepsilon}^{\theta_0+\varepsilon} \theta R f(\theta)\, d\theta \to r_0.$$

The best mechanism one could have is that to accept all types with $\theta > s/R$ and reject all others. In this case, the payoff is:

$$\int_0^{s/R} (s-\tau) f(\theta)\, d(\theta) + \int_{s/R}^{1} \theta R (1-\alpha) f(\theta)\, d(\theta)$$

$$(s-\tau)\int_0^{s/R} \left(\int_0^{\tau} bg(b)db\right) f(\theta)\, d(\theta) + \int_0^{s/R} R\theta \left(\int_{\tau}^{B} bg(b)db\right) f(\theta)\, d(\theta) + \int_{s/R}^{1} \theta R(1-\alpha) f(\theta)\, d(\theta)$$

$$\leq (s-\tau)\int_0^{s/R} \tau\ f(\theta)\, d(\theta) + \int_0^{s/R} R\theta B\ f(\theta)\, d(\theta) + \varepsilon r_0$$

$$\lim_{n\to\infty} (s-\tau)\int_0^{s/R} \tau\ f(\theta)\, d(\theta) + \int_0^{s/R} R\theta B\ f(\theta)\, d(\theta) + \varepsilon r_0$$

Assume you are better off delegating.

$$\int_0^{s/R} (s-\tau) f(\theta)\, d(\theta) + \int_{s/R}^{1} \theta R(1-\alpha) f(\theta)\, d(\theta) \geq s$$

making this amount even bigger:

$$(s-\tau)\int_0^{s/R} \left(\int_0^{\tau} bg(b)db\right) f(\theta)\, d(\theta) + \int_0^{s/R} R\theta \left(\int_{\tau}^{B} bg(b)db\right) f(\theta)\, d(\theta) + \int_{s/R}^{1} \theta R(1-\alpha) f(\theta)\, d(\theta) \geq s$$

In the limit as $n \to \infty$

$$s \lim_{n\to\infty} \int_0^{\tau} g(b)\, d(b) + r_0 \lim_{n\to\infty} \int_{\tau}^{B} g(b)\, d(b) + \varepsilon r_0 \geq s$$

$$s\int_0^{\tau} g(b)\, d(b) + r_0 \int_{\tau}^{B} g(b)\, d(b) + \varepsilon r_0 \geq s$$

$$s\int_0^{\tau} g(b)\, d(b) + r_0 \int_{\tau}^{B} g(b)\, d(b) + \varepsilon r_0 \geq s$$

but εr_0 can be made as small as we want, therefore:

$$s\left(1-\frac{b_{\min}}{B}\right)+r_0\left(\frac{b_{\min}}{B}\right)+\varepsilon r_0<s$$

■

Proof of Proposition 2. For both parts we need to consider the principal's payoff:

$$\int_0^1\left[\int_{-\infty}^{\beta(\theta)}(s-\widehat{\tau})\,f(b|\theta)\,db+\int_{\beta(\theta)}^{\infty}(1-\widehat{\alpha})\,\theta Rf(b|\theta)\,db\right]dG(\theta)$$

1.- Suppose that $\widehat{\tau}\leq\widehat{\alpha}\cdot s$. We need to show that the principal can't achieve a better delegation mechanism. Consider how would the principal's payoff vary if he decided to increase $\widehat{\alpha}$ marginally:

$$\int_0^1\left[-\int_{\beta(\theta)}^{\infty}\theta Rf(b|\theta)\,db-\theta R(s-\widehat{\tau})\,f(\beta(\theta)|\theta)+(1-\widehat{\alpha})(\theta R)^2 f(\beta(\theta)|\theta)\right]dG(\theta)$$

to analyze the sign of this derivative, we need to split the range in two sections: $\theta\geq\frac{s}{R}$ and $\theta<\frac{s}{R}$.

For the first case, we know that $\beta(\theta)<0$, and that $f(\beta(\theta)|\theta)=0$, therefore we are only left with the first term, which is obviously negative as the density, θ and R are positive.

For the second case, where $\theta<\frac{S}{R}$, the first term is smaller than or equal to zero, so we are left with the second and third terms:

$$-\theta R(s-\widehat{\tau})\,f(\beta(\theta)|\theta)+(1-\widehat{\alpha})(\theta R)^2 f(\beta(\theta)|\theta)$$
$$\theta Rf(\beta(\theta)|\theta)(-(s-\widehat{\tau})+(1-\widehat{\alpha})\,\theta R)$$

since $\theta Rf(\beta(\theta)|\theta)>0$ we only need to show that $\widehat{\tau}-s+(1-\widehat{\alpha})\,\theta R\leq 0$. We know that:

$$\widehat{\tau}-s+(1-\widehat{\alpha})\,\theta R\leq\widehat{\tau}-s+(1-\widehat{\alpha})\,S=\widehat{\tau}-\widehat{\alpha}S$$

and by assumption $\widehat{\tau}\leq\widehat{\alpha}\cdot s$, therefore:

$$\widehat{\tau}-s+(1-\widehat{\alpha})\,\theta R\leq 0$$

which completes part 1.

2.- Suppose $\widehat{\tau}>\widehat{\alpha}\cdot\theta R+b$. Again use the derivative of the principal's payoff, but now w.r.t. $\widehat{\tau}$. We get:

$$\int_0^1\left[-\int_{-\infty}^{\beta(\theta)}f(b|\theta)\,db+(s-\widehat{\tau})\,f(\beta(\theta)|\theta)-(1-\widehat{\alpha})\,\theta Rf(\beta(\theta)|\theta)\right]dG(\theta)$$

from which there are two cases depending on the value of θ: $\theta \leq \frac{S}{R}$ (*or* $\beta(\theta) \geq B$), and $\theta > \frac{S}{R}$ (*or* $\beta(\theta) < B$).

For the first, we know that $f(\beta(\theta)|\theta) = 0$ and also that $-\int_{-\infty}^{\beta(\theta)} f(b|\theta)\,db < 0$ simply because $f(b|\theta)$ has positive mass.

For the second, we have that the first term is $-\int_{-\infty}^{\beta(\theta)} f(b|\theta)\,db \leq 0$, on the other hand we have

$$f(\beta(\theta)|\theta)(s - \theta R + \widehat{\alpha}\theta R - \widehat{\tau})$$

and since $\widehat{\tau} > \widehat{\alpha} \cdot \theta R$ and $\theta > \frac{S}{R}$ this term is negative. ■