Information Acquisition and Corporate Debt Illiquidity*

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ABSTRACT

Models based on asymmetric information predict that debt is least sensitive to private information and cannot explain the illiquidity of corporate debt in secondary markets. We analyze security design with moral hazard and offer a new explanation. First, the optimal compensation contract creates incentives for the manager to engage in risk-shifting, making her interests congruent with those of shareholders. Second, because debtholders are negatively affected by risky investments, they have an incentive to acquire information and discipline the manager. Debtholders' information acquisition solves the moral hazard problem, but makes debt less liquid than equity. Debt illiquidity covaries with credit risk.

It is well known that secondary debt markets are often characterized by a lack of liquidity and that debt liquidity tends to dry up when firms are close to default (Edwards, Harris, and Piwowar (2007), and Bao, Pan, and Wang (2011)). Debt illiquidity also appears to be priced in the data as structural models have difficulty explaining the credit spreads for corporate bonds (Huang and Huang (2012)). Yet, from the standpoint of economic theory it is unclear why corporate debt is illiquid. After all, models based on asymmetric information commonly predict that debt should be more liquid than equity because it is less sensitive to private information (see, e.g., Boot and Thakor (1993), Dang, Gorton, and Holmstrom (2011), Hennessy (2012) and Yang (2014)).[1] In this paper, we aim to explain this puzzle by analyzing the incentives of different claim holders to acquire costly information. The central result that emerges is that, in order to create optimal corporate governance, debt claim has to be more information-rich than junior claims; as such, it is subject to a greater degree of adverse selection.

To study the information acquisition incentives, we set up the optimal security design problem. The objective of a firm is to maximize firm value by selling a portfolio of external securities and designing the optimal compensation for the firm's manager. There is double-sided moral hazard associated with the problem. First, the manager's unobserved effort affects the quality of a risky project in which the manager can later decide to invest. Second, a critical element of the model is that outside investors can acquire costly private information about the quality of the project and block the manager from making investment. The design of managerial compensation and external securities is directed at inducing sufficient information acquisition by outsiders and creating a discipline scheme that motivates high effort from the manager, thereby maximizing the ex ante firm value.

We first show that the optimal compensation contract resembles a performance-vested call option, which induces excessive risk-taking by the manager. Intuitively, because the manager is protected by limited liability, the optimal contract has to re-

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[1]Empirical evidence indicates that secondary equity markets are more liquid than debt markets (see, e.g., Edwards, Harris, and Piwowar (2007)).

ward her in the right tail of the cash flow distribution (as in Innes (1990) and Hebert (2015)); otherwise the manager would choose to exert no effort. However, because of the endogenous convexity in the payoff structure, such contract necessarily creates an incentive to engage in risk-shifting, so that the manager prefers to invest in risky projects regardless of their quality. To motivate the manager to improve the project quality ex ante and to terminate poor projects ex post, it is then essential for the outsiders to impose discipline on the manager by acquiring information and shutting down investment when the quality of the project is low.

Our central result is that the debtholder is able to implement such optimal discipline when the external securities of the firm are tranched into debt and equity. In general, because the debtholder has a concave claim on firm value, his asset would be most negatively affected by the risk-shifting investment. Compared to a shareholder, he then would be more willing to expend resources on information acquisition and to exercise tough discipline. In contrast, shareholders have a convex claim on firm value which is akin to the payoff of the managerial compensation contract; as such, they have a risk preference congruent with that of the manager and can only implement a discipline weaker than optimal.[2]

Furthermore, we demonstrate that a debt contract with proper covenants weakly dominates other financial securities in implementing the optimal managerial discipline. Intuitively, a debt security maximizes the incentive of its holder to acquire costly information and exercise control, and covenants provide the intervention rights that facilitate such control.[3] Therefore, our paper directly speaks to an important question in corporate finance: why and when debtholders should participate in a firm's corporate governance. We argue that debtholder "toughness" at the time of poor firm performance combined with a convex compensation payoff to the firm's manager creates a strong incentive for the manager to exert effort.

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[2]Shareholders are unable to commit to the implementation of the optimal discipline because of the possibility of ex post renegotiation with the firm's manager.

[3]Covenants are value-creating in our setting despite an opportunity to renegotiate claims ex post.

The important implication of the optimal security design under moral hazard is that the debtholder should actively seek new information and discipline the firm's manager, while the equity holders have no incentive to do so and remain passive. The result that a debt contract induces more information acquisition than an equity contract differs from conclusions in the existing literature.

In the literature on optimal security design under asymmetric information, a debt contract is optimal because it has the least informational content (e.g., DeMarzo and Duffie (1999)), or because it deters the undesirable acquisition of information, which creates information asymmetry (see, e.g., Dang, Gorton, and Holmstrom (2011), Yang (2014), Farhi and Tirole (2014), and Hennessy (2012)). When the information asymmetry that decreases the liquidity of an asset is the key modeled friction, a debt contract is designed to suppress information acquisition.[4] In our model, the debt contract is optimal for the opposite reason. Because we model the non-contractible managerial agency problem, information acquisition is essential for effectively disciplining the manager and increasing firm value. A debt security is optimal in this setting because it motivates information acquisition, thereby improving the firm's corporate governance.

Based on the implementation of managerial discipline by debtholders, we discuss the implications of information acquisition for secondary market liquidity. As in Maug (1998), there is a tradeoff between liquidity and monitoring in the model. To implement optimal managerial discipline, the debtholder has to selectively acquire information and monitor the manager. However, if ex post the debtholder could sell off his debt in a liquid secondary market, then the monitoring incentive would vanish and the implementation would fail. Therefore, the secondary market illiquidity of debt is essential for the stability of outside monitoring.

We find that corporate debt is illiquid precisely because it induces information acquisition, while equity is perfectly liquid. In general, the debtholder's decision to procure private information has two effects. First, if the information acquisition leads

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[4]A decrease in liquidity will result in the loss of a trading surplus between seller and buyer, either in a primary market (Dang, Gorton, and Holmstrom (2011)) or in a secondary market (Hennessy (2012)).

to restricting managerial over-investment, it increases the value of the firm (corporate governance effect). Second, the acquired information creates information asymmetry between the debtholder and the uninformed secondary market (information asymmetry effect), which results in lower debt liquidity. We show that in the cross-section of firms, secondary market debt illiquidity is correlated with the firm's credit risk because the debtholder has a greater incentive to collect information at the onset of the firm's financial distress. This result is consistent with empirical evidence documented by Bao, Pan, and Wang (2011), who find a strong link between bond illiquidity and bond prices. Furthermore, debt liquidity tends to vary with the overall state of the economy and is procyclical, which is also supported by the data (see, e.g., Dick-Nielsen, Feldhutter, and Lando (2012)).

The theory developed in this paper shows that the information asymmetry effect is the force that prevents the debtholder from liquidating his debt in the secondary market, thereby preserving his monitoring incentive. This result has important policy implications. For the sake of better corporate governance, the illiquidity of corporate debt should be encouraged by allowing the acquired information to be kept private. This recommendation goes against the recent Securities and Exchange Commission's (SEC's) regulation that requires the issuer of securities backed by corporate debt to disclose asset-level information.[5] We argue that regulation aimed at eliminating information asymmetry between debtholders and the uninformed market (e.g., through more or better information disclosure) can allow debtholders to sell their assets without spending resources to uncover wasteful managerial investment and will undo the optimal managerial discipline. Therefore, while such regulation is likely to improve debt liquidity,[6] it may have a negative effect on the value of corporate debt.

The rest of the paper is organized as follows. The next section reviews the rele-

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[5]See Asset-Backed Securities Disclosure and Registration, Securities and Exchange Commission, Release Nos. 33-9638; 34-72982; File No. S7-08-10.

[6]Several studies document that enhanced transparency of the bond market leads to lower transaction costs and higher bond liquidity (Edwards, Harris, and Piwowar (2007) and Bessembinder, Maxwell, and Venkataraman (2006)), which is consistent with the predictions of our model.

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vant literature. Section II describes the setup of the model. Section III derives the optimal managerial discipline and implements it with a capital structure. Section IV demonstrates the optimality of debt in disciplining the manager. Section V analyzes the relation between information acquisition and securitization of corporate debt and discusses implications for debt liquidity. The last section concludes.

I. Literature Review

Debt illiquidity in our model is the result of asymmetric information between the debtholder who collects information and other investors who are not interested in information acquisition. Our paper is thus most closely related to the large literature on security design under asymmetric information. An important insight from this literature is that, because "ignorance is bliss," the design of securities should focus on suppressing information. Debt is optimal because it is information-insensitive and it has greater liquidity than junior claims.[7] While this intuition is helpful in explaining the liquidity of debt contracts in financial intermediation (e.g., Gorton and Pennacchi (1990) and Dang, Gorton, and Holmstrom (2011)), it does not suit well the corporate setting because equity markets are generally more liquid than corporate debt markets. For example, Boot and Thakor (1993) argue that a privately informed issuer of firm securities should split cash flow into debt and equity claims because information-sensitive equity will motivate information production by sophisticated investors and maximize issuing prices. In their model, debt is information-insensitive and is traded without any frictions by uninformed investors. In a similar setting, but with an uninformed issuer, Hennessy (2012) establishes that value of the firm is maximized by offering a liquid senior debt tranche that suppresses informed trading and an illiquid junior tranche. In our setting, debt claim is information-sensitive, while junior claims, such as equity, are not. This is because the debtholder is motivated to acquire information that can

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[7]One exception to this literature is Fulghieri, Garcia, and Hackbarth (2015), who argue that the sensitivity of a security to information in general depends on the "location" of asymmetric information.

be used to stop managerial risk-shifting.[8] Another major difference from the existing security-design literature is in the social value of information. In our model, the conclusion that "ignorance is bliss" is no longer valid because the acquisition of substantive information (as compared with socially wasteful information in Dang, Gorton, and Holmstrom (2011) and Yang (2014)) increases aggregate cash flow by mitigating the managerial moral hazard problem.

Our explanation of debt illiquidity is distinct from that in search-based models, such as those of Duffie, Garleanu, and Pedersen (2007), Feldhutter (2012) and He and Milbradt (2014), where illiquidity arises from the costly search for a counter-party. It also differs from the mechanism of Hennessy and Zechner (2011), who model debt liquidity in a trading game between large and small debtholders. When buying debt from small debtholders, the large debtholder can confound them by not revealing whether he would offer debt relief to the firm, which may result in an illiquid equilibrium. As in our model, He and Milbradt (2014) and Hennessy and Zechner (2011) generate a positive correlation between default probability and debt illiquidity, but they offer no comparison between liquidity of equity and debt under the same trading mechanism. In our model, illiquidity of debt is a result of the debtholder's information acquisition and is necessary for optimal corporate governance, while equity is always liquid because shareholders are not interested in information acquisition. Therefore, we focus on how frictions inside a firm (moral hazard) affect liquidity of securities in the external market, rather than on how external market imperfections affect firm decisions, as He and Milbradt (2014) and Hennessy and Zechner (2011) do.

The corporate governance theory developed here is related to the moral hazard models of Innes (1990) and Hebert (2015). As we consider both effort provision and risk-shifting, our study is more similar to that of Hebert (2015). He shows that when the manager can flexibly change the cash flow distribution, the optimal security con-

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[8]In our model, the information to be acquired does not have to be directly related to the risk of final cash flow. Instead, any signal that is informative about managerial effort can be used for discipline, and is optimally acquired by a debtholder.

tract is a debt contract. Unlike Hebert (2015), we use a very simple setting with binary effort and risk choices, which suffices to show that the manager engages in risk-shifting under the optimal contract. The key security design problem from which we derive the optimality of debt is, however, very different from Innes (1990) and Hebert (2015). In our model, it is possible to acquire a costly signal at an interim date that is informative about the effort level of the manager. The questions we ask are who should acquire this information and when, and how it affects the managerial incentives. In particular, we show that the external financing contract derived by Innes (1990) and Hebert (2015) should be further tranched into a senior debt claim and a junior claim, such as equity, because tranching motivates information acquisition and improves contracting efficiency. As such, our model could also be considered a theory of capital structure.

The paper belongs to a large literature on contract design that analyzes the allocation of decision rights (see, e.g., Aghion and Bolton (1992), Dewatripont and Tirole (1994), Berglof and von Thadden (1994), and Guembel and White (2014)). Unlike Aghion and Bolton (1992) and Berglof and von Thadden (1994), we model a two-dimensional moral hazard problem. The optimal contract in the model has to provide sufficient incentive for the manager to exert effort and also to induce efficient information acquisition and monitoring by outside investors. Furthermore, we consider how information acquisition affects the liquidity of securities in the secondary market, which in turn affects the renegotiation outcomes and efficacy of ex post monitoring.

In a related paper, Guembel and White (2014) also show that a debtholder can be active in disciplining the manager. We generalize their corporate governance results in several ways. First, we do not assume managerial private benefits associated with risk-shifting, and we design external securities and managerial compensation in a general contract space with continuous states. The risk-shifting incentive therefore arises endogenously in our model and is driven by the managerial compensation that is optimally designed to induce high effort.[9] Second, we show that if securities (including manage-

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[9]As a result, external intervention through information acquisition is necessary for optimal corporate governance even if the manager does not have any private benefits of risk-shifting.

rial compensation) are designed in a general contract space, the optimal discipline that maximizes ex ante firm value is always "tougher" than the discipline that maximizes ex post value. Thus, a debtholder is always the optimal information producer in our model, whereas it can sometimes be an equity holder in the model of Guembel and White (2014). We show that "soft" discipline imposed by the equity holder is always inferior because it is less efficient at inducing managerial effort than a properly designed compensation contract. The uniform optimality of debt in information acquisition is important for explaining the illiquidity of debt relative to that of equity. Third, we model the ex post trading game between a debtholder and a shareholder and show why the possibility of trading does not eliminate the debtholder's incentive to acquire information and discipline the manager.

The idea of the debtholder's monitoring also builds on work by Rajan and Winton (1995), who analyze how various contract features affect the incentives of creditors to monitor. We contribute to this line of work by endogenizing the security design problem and showing that a debtholder is a better candidate for monitoring than a shareholder. Our model also shares some features with models of optimal contract design by Garleanu and Zwiebel (2009) and Dessein (2005), but focuses on a non-contractible agency problem rather than on the asymmetric information between the manager and investors. For example, in Garleanu and Zwiebel (2009) covenants appear optimal because high-quality borrowers want to relinquish control to investors to credibly signal the congruence of their preferences. In contrast, there are no signaling considerations in our model, but there is moral hazard. The optimal contract features covenants because they endow creditors with the right to block undesirable investment and provide an incentive for the manager to improve the quality of the firm' projects.

The prediction of our model that debtholders can discipline a manager by selective enforcement of debt covenants is broadly consistent with empirical evidence provided by Chen and Wei (1993), Feldhutter, Hotchkiss, and Karakas (2015), and Roberts and Sufi (2009). It also corroborates findings by Chava and Roberts (2008), who show

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that covenant violations result in greater declines in capital investment in firms with more severe agency problems. Finally, the empirical result in Nini, Smith, and Sufi (2009) that covenant enforcement is associated with higher subsequent stock returns is difficult to reconcile in a traditional framework with debt-equity conflicts, but is perfectly consistent with our model. The debtholder's decision to intervene increases equity value because it blocks wasteful managerial investment when the firm's prospects are poor.

II. Model Setup

A. Managerial Moral Hazard and Investment

The managerial moral hazard problem is modeled after Dewatripont and Tirole (1994). The model has three dates, and the discount rate is set to zero. At $t = 0$ the firm's manager exerts an unobservable level of effort $e \in \{\underline{e}, \overline{e}\}$ to set up a potential project. Managerial effort improves the quality of the project. We assume that a high level of effort is efficient, but it costs the manager a disutility K; a low level of effort has no cost to the manager.[10] An imperfect signal of project quality $u \in [0, 1]$ is observed by the manager and outside investors at $t = 1$; this signal has density $\overline{h}(u)$ for $e = \overline{e}$ and $\underline{h}(u)$ for $e = \underline{e}$. As is standard in the literature, we assume that densities $\overline{h}(u)$ and $\underline{h}(u)$ satisfy the monotone likelihood ratio property (MLRP), i.e., ratio $\overline{h}(u)/\underline{h}(u)$ increases in signal u.

The manager can choose to make investment, I, in the project at $t = 1$. Making investment is costless to the manager because funds come out of the corporate budget. Investment is non-contractible; i.e., it is impossible to design a contract that would pay the manager based on her investment decision. The final cash flow y generated by the firm at $t = 2$ depends both on the investment decision and on project quality.

We make two assumptions regarding the firm's investment technology. First, in-

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[10]In equilibrium, the value created from high effort is greater than the cost of the effort. Therefore, we limit attention to contracts that induce high effort $\overline{e}$.

vestment increases the risk of the final cash flow. Specifically, suppose cash flow y has a cumulative distribution function $F_I(.|u)$ and a probability density function $f_I(.|u)$ if the manager makes an investment. If no investment is made, cash flow is drawn from a different distribution, with a cumulative distribution function $F(.|u)$ and a probability density function $f(.|u)$. Without loss of generality, denote the common support of $F_I(.|u)$ and $F(.|u)$ as $[0, \overline{Y}]$.

Assumption 1. *For any signal u, there exists a threshold $\hat{y}(u)$ such that*

$$F(y|u) < F_I(y|u) \text{ for } 0 < y < \hat{y}(u), \tag{1}$$

$$F(y|u) > F_I(y|u) \text{ for } \hat{y}(u) \le y < \overline{Y}. \tag{2}$$

This assumption indicates that distribution F_I has fatter tails than distribution F, which means it is a riskier distribution from the perspective of an outside investor. We show in Section III.B that because the optimal managerial compensation is convex, the manager always prefers distribution F_I over F. Thus the manager has an incentive to engage in risk-shifting in the model and may take decisions that do not necessarily maximize firm value.[11] As we will see later, the outside intervention is made necessary by the risk-shifting preferences of the manager. We refer to such outside intervention as "corporate governance" throughout the paper.

Second, we assume that the value of investment increases with the signal of project quality. This implies in particular that investors find it optimal to allow the manager to invest when the project quality is high.

Assumption 2. *A higher signal u indicates better prospects for the project, i.e.,*

$$\frac{\partial[F_I(y|u) - F(y|u)]}{\partial u} < 0 \text{ for all } y \text{ and } u. \tag{3}$$

Both the manager and outside investors are assumed to be risk-neutral, which allows us to abstract away from the risk-sharing motives of security design and to focus instead on moral hazard.

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[11]Hellwig (2007) and Hebert (2015) also show that a manager engages in excessive risk-taking under the optimally designed managerial compensation when she can choose both the effort level and the risk profile of the project.

B. Information Acquisition and Intervention

Investors holding the firm's claims may be interested in shutting down investment when project quality is low. We assume investors can only do so if they acquire verifiable information and have proper rights to intervene. Specifically, outsiders can decide whether to seek costly information, w, as well as how precise this information needs to be, p. The new information is assumed to be binary: $w \in \{0, 1\}$. If $w = 1$, the outside investors successfully verify signal u and can block undesirable investment. If $w = 0$, the investors observe pure noise, and we assume they cannot intervene because signal u alone does not present sufficient legal evidence that can be taken to a court of law. Precision p is the probability of $w = 1$, and it can be interpreted as the aggressiveness of outside investors in pursuing information. While higher precision p gives outside investors more opportunities to intervene, they also have to pay a higher cost, which we model as a linear function

$$c(p) = ap \text{ for } p \in [0, \bar{p}], \tag{4}$$

where a is the marginal cost of information, and $\bar{p} < 1$ is the upper limit for precision.[12]

We assume that all outsiders have the same costly information acquisition device available to them. The legal rights to intervene could be structured as a covenant written on noisy signal u, such that the claim holder can initiate an action based on a certain level of u, but the covenant can only be enforced when information is verifiable in court, i.e., when $w = 1$. Whether to acquire information, which precision to choose, and whether to intervene are all decisions of the claim holder.[13]

Essentially, what we want to capture by modeling the information acquisition in this way, is that a successful outside intervention is not always possible or can be prohibitively costly and value-destroying. Only after acquiring information the outsiders

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[12]The assumption that increasing precision beyond $\bar{p}$ is prohibitively costly can be motivated by the fact that the acquired information can never be perfect.

[13]This means, in particular, that the claim holder is free to waive any restrictive contract terms. Furthermore, the aggressiveness of a claim holder in pursuing some written contract terms is the claim holder's own decision. In practice, waivers and renegotiation of covenants are common (Roberts and Sufi (2009)).

learn whether their intervention will be successful or not.[14] The manager also does not know ex ante whether there will be an outside intervention (does not know w) and learns about it only when his investment is blocked (or not) by outsiders.

The timing of the model is summarized below.

Period 1	**Period 2**	**Period 3**
Manager exerts effort $e \in \{\underline{e}, \overline{e}\}$	$\rightarrow$ Investors observe signal u and decide whether to acquire w with precision p.	$\rightarrow$ Manager is restricted or makes investment, depending on w.	$\rightarrow$ Compensation is paid to the manager, cash flow y is distributed to investors.

C. Admissible Securities

Our goal is to design managerial compensation and external financial securities sold to outsiders that jointly implement the optimal corporate governance and maximize firm value. Both external financial securities and managerial compensation are considered to be *normal* securities written on the final cash flow y. We adopt the same definition of normal securities as Nachman and Noe (1994).

Assumption 3. *Both external financial securities and managerial compensation are normal securities. A security is "normal" if it has a continuous payoff $s(y)$ that satisfies the following conditions:*

(a) payoff is contingent only on the cash flow y;

(b) payoff satisfies the limited liability condition

$$0 \leq s(y) \leq y; \tag{5}$$

(c) payoff is weakly increasing in y, i.e., $s'(y) \geq 0$; and

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[14]In this sense, an uninformed intervention by outsiders would never be optimal as it can result in a large value loss. For example, Burkart, Gromb, and Panunzi (1997) assume that an uninformed party can accidentally choose a project with an infinitely negative net present value.

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(d) payoff is not increasing faster than cash flow, i.e., $s'(y) \leq 1$.

The first condition implies, in particular, that the payoff function cannot depend on the investment decision of the manager or the actions of outside investors. The second condition states that the payoff of the normal security is a fraction of the total firm cash flow, i.e., the security's owner has a limited liability. The third condition means the payoff should (weakly) increase with the total cash flow y. Finally, the last condition stipulates that the marginal increase in the payoff of the normal security cannot exceed the marginal increase in firm cash flow. Conditions (a)-(c) are standard assumptions made in the contracting literature. Condition (d) is necessary to prevent simple arbitrage in the model.[15] Most financial assets, such as equity securities, senior and junior debt claims, convertible bonds, and standard options, satisfy all of these conditions.

III. Governance from Debt and Optimal Capital Structure

A. Ex post Efficiency

Here we show that if the firm has a sole owner (a single shareholder), it is generally impossible to induce high effort from the manager, as long as the manager is able to renegotiate her compensation with the shareholder ex post. Thus the security design problem becomes relevant.

Assume for now that the manager's effort level is fixed, and the firm is held by a single shareholder who naturally has a right to intervene in the firm's investment policy. Suppose also the manager's compensation contract induces risk-shifting for all signals u. The shareholder optimally decides to acquire information whenever signal u falls below a certain threshold. Denote by $R(u)$ the probability that information w is acquired by the shareholder conditional on a signal u. The gathered information is valuable only

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[15]If $r'(y) > 1$ for some y, the claim holder can make arbitrage profits by investing a dollar in the firm and obtaining a payoff that is larger than a dollar.

with probability $p(u)$, i.e., when $w = 1$. After observing signal u but before additional information w is acquired, the shareholder and the manager can renegotiate the contract terms. Because there is no asymmetric information between the shareholder and the manager at this point, the outcome of their renegotiation maximizes the ex post firm value (the equity value plus the managerial compensation), i.e.,

$$\max_{R,p} [1 - R(u)] E_I[y|u] + R(u) [(1 - p(u)) E_I[y|u] + p(u) E[y|u] - c(p(u))], \quad (6)$$

which can be simplified to

$$\max_{R,p} E_I[y|u] + R(u)p(u) [E[y|u] - E_I[y|u] - a]. \quad (7)$$

Here the expectation operators $E[.|u]$ and $E_I[.|u]$ are defined for any function $g(y)$ as

$$E[g(y)|u] = \int_0^{\overline{Y}} g(y)f(y|u)dy, \quad (8)$$

$$E_I[g(y)|u] = \int_0^{\overline{Y}} g(y)f_I(y|u)dy. \quad (9)$$

The optimization problem (7) has a solution that consists of a discipline scheme, $R(u)$, and the associated information precision, $p(u)$. Formally, a *discipline scheme* $R(u)$ is a function that maps a signal u to an action space $[0, 1]$, which denotes a probability that information w is acquired by outside investors. The solution is summarized in the following proposition.

Proposition 1. *(Ex post efficient discipline) If the firm is held by a sole owner and firm manager prefers risk-shifting, the sole owner enforces the following discipline scheme*

$$R(u) = \begin{cases} 1 & \text{if } u < \tilde{u}, \\ 0 & \text{if } u \geq \tilde{u}, \end{cases} \quad (10)$$

where $\tilde{u}$ is defined by

$$E[y|\tilde{u}] - a = E_I[y|\tilde{u}]. \quad (11)$$

That is, the sole owner acquires information w with the associated precision $p(u) = \overline{p}$ whenever signal u falls below threshold $\tilde{u}$, and he intervenes if $w = 1$.

This result means that the sole owner who observes a public signal of project quality and renegotiates with the firm manager, decides to acquire verifiable information according to rule (10). For a high signal $u > \tilde{u}$, information w is not acquired and there is no intervention. For a low signal $u < \tilde{u}$, the marginal benefit of intervention exceeds the marginal cost of information a. Thus the owner acquires information with probability one and restricts investment with probability $\bar{p}$. At the cutoff point, $\tilde{u}$, the decrease in firm value due to managerial investment is exactly equal to the marginal cost of information, making the sole owner indifferent between acquiring information and not.

Note that any discipline scheme $R(.)$ has a disciplinary effect on the manager who prefers risk-shifting because for low signals she loses the option to choose investment that may increase her compensation. We refer to the discipline defined by threshold $\tilde{u}$ as an *ex post efficient discipline*. The problem with this discipline scheme, however, is that it is solely based on the ex post firm value maximization and ignores the ex ante incentive provision for the manager. When the ex post renegotiation between the manager and the sole owner is possible, the sole owner cannot commit to any discipline scheme other than the ex post efficient scheme because all other discipline schemes will eventually be renegotiated.

The lack of an incentive provision under the ex post efficient scheme results in a lower ex ante firm value. In the next subsection, we solve for the optimal discipline and managerial compensation that jointly maximize firm value.

B. Optimal Discipline and Compensation

Both the possibility of outside intervention and managerial compensation can be a source of incentives for the manager, so they must be determined jointly. In this section, we solve for such optimal discipline and compensation that induce the manager to exert effort and maximize firm value, assuming that the discipline can be enforced by some third party (i.e., we ignore the outsiders' incentive compatibility constraint necessary for

implementation of the optimal discipline). This approach allows us to first find the most desirable discipline and then to analyze who is the best candidate for implementation. We analyze implementation in Section IV.

Throughout, we focus on the case in which the managerial cost of effort, K, is not too large compared to the value of the firm, as otherwise the agency problem would become irrelevant. If the cost of effort K were large, most of the firm's cash flows would have to be pledged as compensation to the firm's manager in order to induce her effort, which would essentially make the manager the owner of the firm and make outside monitoring unnecessary.[16]

We consider a compensation contract with payoff $s(wu, y)$ at date 2 to the firm manager. The contract can be written on all verifiable variables in the model, i.e., the final cash flow of the firm, y, and the verifiable signal, wu. We require that the contract $s(wu, y)$ is a normal security, conditional on signal wu. Note that if firm investors do not acquire any information or if they seek information but turn out to be unlucky, i.e., $w = 0$, the effective managerial compensation can only depend on cash flow y, so we denote it by $s(y)$. In contrast, if the outsiders acquire information and $w = 1$, the contract can also be a function of signal u, i.e., $s(u, y)$. Therefore, we can write the compensation payoff as follows

$$s(wu, y) = (1 - w)s(y) + ws(u, y) = s(y) - w\left[s(y) - s(u, y)\right]. \tag{12}$$

We denote the conditional expectation of the managerial compensation at date 1 by $M(u)$

$$M(u) = E_M\left[s(y)|u\right] - p\left(u\right)R(u)(E_M\left[s(y)|u\right]) - E\left[s(u, y)|u\right]). \tag{13}$$

Here $E_M\left[.|u\right]$ is the expectation given the manager's optimal investment decision.

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[16]The upper bound for K is defined by (66). Another interpretation of a relatively low K is that the firm is costly to set up and the manager needs to issue external securities to finance this initial cost. In this case, the manager should be able to pledge a majority of the firm's cash flow to external securities, so that the necessary amount of financing is obtained, as well as to commit to the high effort induced by the remaining cash flow. Without a requirement that the manager needs to raise external financing, the discipline problem is trivially solved by giving the whole firm to the manager.

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Specifically, for any function $g(y)$, the expectation operator $E_M[.|u]$ is defined as

$$E_M[g(y)|u] = \int_0^{\overline{Y}} g(y)[(1 - r(u))f(y|u) + r(u)f_I(y|u)]dy, \tag{14}$$

where $r(u) = 0$ if the manager does not make an investment, and $r(u) = 1$ if she invests. The managerial decision $r(u)$ is incentive-compatible if for every possible signal u when the manager is free to make the investment decision, $r(u)$ maximizes the expected compensation of the manager, $M(u)$.

In general, the discipline scheme $R(u)$ can have two potential consequences for the manager. First, if outsiders choose to pay for the information $(R(u) = 1)$ and successfully verify the signal $(w = 1)$, the manager loses the option to make investment and $r(u)$ is automatically equal to 0. Second, by acquiring verifiable information, the outsiders can enforce a change in managerial compensation of $s(y) - s(u, y)$.

The optimal discipline and managerial compensation are designed with a goal of maximizing ex ante firm value

$$\max_{R,p,s} \int_0^1 \{E_M[y|u] + p(u)R(u)[E[y|u] - E_M[y|u] - a] - M(u)\}\overline{h}(u)du, \tag{15}$$

subject to the incentive-compatibility constraint for the manager (exerting effort)

$$\int_0^1 M(u)[\overline{h}(u) - \underline{h}(u)]du \geq K, \tag{16}$$

and the optimality of decision $r(u)$ for the manager, i.e., that $r(u)$ maximizes the expected compensation $M(u)$.

We also make a natural simplifying assumption that the truncated-from-below distribution of y satisfies the MLRP condition, which is stated formally below.

Assumption 4. *For any value $v > 0$, we require*

$$\frac{\partial \left(\overline{f}_I(y|u > v)/\underline{f}_I(y|u > v)\right)}{\partial y} > 0, \tag{17}$$

where a truncated-from-below distribution of y is defined by

$$\overline{f}_I(y|u \, > \, v) \equiv \int_v^1 f_I(y|u)\overline{h}(u)du, \tag{18}$$

$$\underline{f}_I(y|u \, > \, v) \equiv \int_v^1 f_I(y|u)\underline{h}(u)du. \tag{19}$$

This assumption is not too restrictive and implies that the effect of effort is more important for higher cash flows, conditional on signal $u > v$. It is also consistent with our assumption that a higher signal indicates a higher profitability of the investment.

The proposition below summarizes the solution to the optimization problem (15).

Proposition 2. *(Optimal discipline and compensation) The optimal discipline $R(u)$ is*

$$R(u) = \begin{cases} 1 & \text{if } u \leq u^*, \\ 0 & \text{if } u > u^*, \end{cases} \tag{20}$$

with $u^* > \tilde{u}$. The associated precision is $p(u) = \overline{p}$ whenever $R(u) = 1$.

The optimal managerial compensation is given by

$$s(wu, y) = \begin{cases} 0 & \text{if } 0 < wu \leq u^*, \\ \max[y - y^*, 0] & \text{otherwise,} \end{cases} \tag{21}$$

where $y^* \in (0, \overline{Y})$. That is, the manager is paid 0 if both $u < u^*$ and $w = 1$; otherwise, he is paid with an option-like security. Given the optimal compensation contract, the manager always prefers risk-shifting, i.e., $r(u) = 1$ for all signals u.

This proposition establishes that there is scope for a discipline mechanism because it is impossible to solve the agency problem with compensation design alone. In particular, firm value is maximized by encouraging costly information acquisition and monitoring by outside investors when firm performance is poor.

The first important result that emerges from the proposition is that the optimal discipline is always tougher than the ex post efficient discipline, $u^* > \tilde{u}$, when compensation is structured optimally. Intuitively, the ex-post efficient threshold for the sole owner, $\tilde{u}$, does not take into account the beneficial effect of information acquisition on the incentives of the manager to exert effort, and hence information is collected in fewer states of the world.

This conclusion differs from the results in Dewatripont and Tirole (1994). In their setting, both passive and tough discipline can be optimal, conditional on the first-period cash flow. There are two reasons why we obtain a different result. First, we allow for

a more flexible compensation structure. This in particular implies that a high cost of managerial effort can always be compensated by a higher cash payment to the manager. Second, and more important, we allow the contract to be written on signal wu, which is possible in our setting because outsides can acquire costly verifiable information. This assumption improves the power of the compensation contract because outsiders are able to reduce the manager's compensation when information is acquired.[17] Passive discipline is therefore no longer optimal in our model because a compensation structure can always be designed to provide the appropriate level of incentives for the manager.

The second result is that the optimal compensation contract is akin to a simple option-like security, which is given to the manager when the accounting performance of the firm is above a certain threshold, $u > u^*$, or when information acquisition fails. Because cash flow y can be directly linked to the stock price of the firm, the optimal contract derived above can be interpreted as the stock option that vests when certain accounting-based performance targets are reached. These types of contracts are commonly used in practice (see, e.g., Bettis, Bizjak, Coles, and Kalpathy (2010)).

It is also worthwhile to point out that the optimal contract creates incentives for risk-shifting by the manager. The intuition for this result is that rewarding the manager in the right tail of the cash flow distribution is the most efficient way to induce high effort. Although with this contract the manager always prefers to make a risky investment, the outsiders can effectively shut down the investment if the project quality is low (with probability $\bar{p}$), thereby minimizing value-destroying investment. Furthermore, by decreasing the managerial compensation to zero at low signals u, the outsiders impose a punishment on the manager for producing low-quality projects. Therefore, a combination of a convex compensation structure with outside intervention at low signals becomes optimal in solving the managerial moral hazard problem and minimizing the information acquisition costs. Any other compensation contract that aims to deter risk-shifting and at the same time provide an incentive for exerting effort would be

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[17]In contrast, in Dewatripont and Tirole (1994) compensation can depend only on the realized cash flow; it cannot be made contingent on the signal.

suboptimal.[18]

Finally, note that a sole owner of the firm would not implement the optimal discipline because $u^* > \tilde{u}$ and

$$E[y|u^*] - E_I[y|u^*] < a = E[y|\tilde{u}] - E_I[y|\tilde{u}]. \tag{22}$$

Intuitively, for anybody holding a claim on the *total* firm cash flow (external securities and managerial compensation), it is too costly to acquire information for any signal above $\tilde{u}$. Can it then ever be optimal for a sole owner holding the external security, but not having the claim on the managerial compensation, to acquire information? The answer is no because of the possibility of renegotiation. When signal $u \in (\tilde{u}, u^*]$, the manager faces a possible punishment of zero compensation and understands that the punishment can only be enforced if the sole owner acquires verifiable information. Because the total firm value cannot be increased by information acquisition ex post, it is optimal for the manager to give up a fraction of his compensation to the sole owner in order to eliminate his incentive to gather information. Regardless of the relative bargaining power of the manager and the sole owner, the only possible outcome of renegotiation is that the sole owner does not acquire information. Therefore, a sole owner will not be able to commit to the implementation of the optimal discipline based on u^*.

C. Implementation of the Optimal Discipline

In this section we show that the optimal discipline can be implemented by a debtholder. In general, in order to implement the optimal discipline by a particular claim holder, it is essential to make the payoff from his claim sensitive to managerial behavior. Because debt is a concave claim, it is adversely affected by excessive investment of the manager (recall that investment increases risk), and therefore the debtholder is a natural candidate for the implementation of the optimal discipline. Another reason why the

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[18]To deter risk-shifting, compensation should be supported by the left tail of the cash flow distribution. In contrast, to induce high effort from the manager, compensation should be paid in the right tail of the distribution. Thus these two incentives would tend to offset each other.

debtholder can be an efficient monitor is that, under the current legal regulations of the United States, the manager cannot renegotiate her compensation package with a firm's debtholder. We take advantage of this institutional feature and assume throughout that the manager cannot renegotiate her compensation with debtholders.

The main result that we obtain is that a debt contract with a covenant giving the legal right to intervene can induce sufficient information acquisition and implement the optimal discipline. The equity holder, on the other hand, has a residual claim on a firm's cash flow and is inactive in corporate governance. To be specific, there exists a proper capital structure with the optimal level of debt, D^*, which induces the single debtholder to commit to enforcement of the optimal discipline u^*. Then the discrepancy between the optimal discipline u^* and the ex post efficient discipline $\tilde{u}$ is eliminated. In this sense, a debt contract with a level of debt D^* and a covenant written on information w *implements* the optimal discipline.

In particular, for each signal u and face value of debt D, let us define by $\Delta(u, p, D)$ the increase in the value of debt associated with acquiring information of precision p by the debtholder

$$\Delta(u, p, D) = p\left[d(u) - d_I(u)\right], \tag{23}$$

where $d(u)$ is the value of debt if managerial investment is shut down

$$d(u) = \int_0^D yf(y|u)dy + D\int_D^{\bar{Y}} f(y|u)dy, \tag{24}$$

and $d_I(u)$ is the value of debt if the manager makes investment

$$d_I(u) = \int_0^D yf_I(y|u)dy + D\int_D^{\bar{Y}} f_I(y|u)dy. \tag{25}$$

Using integration by parts, we can rewrite $\Delta(u, p, D)$ in a more convenient form

$$\Delta(u, p, D) = p\int_0^D \left[F_I(y|u) - F(y|u)\right]dy. \tag{26}$$

The increase in the value of debt because of information acquisition, $\Delta(u, p, D)$, measures the debtholder's incentive to gather information. The following lemma summarizes the properties of function $\Delta(u, p, D)$.

Lemma 1. *The incentive of a debtholder to acquire information, $\Delta(u, p, D)$, is a continuous function with $\Delta(u, p, 0) = 0$ and $\Delta(u, p, \overline{Y}) = E[y|u] - E_I[y|u]$ that has the following properties:*

(a) $\Delta(u, p, D)$ is monotonically decreasing in u, i.e.,

$$\frac{\partial \Delta(u, p, D)}{\partial u} < 0. \tag{27}$$

(b) For each pair (u, p), the level of debt $D = \hat{y}(u)$ maximizes function $\Delta(u, p, D)$, i.e.,

$$\frac{\partial \Delta(u, p, D)}{\partial D} > 0 \ for \ 0 < D < \hat{y}(u), \tag{28}$$

$$\frac{\partial \Delta(u, p, D)}{\partial D} < 0 \ for \ \hat{y}(u) < D < \overline{Y}, \tag{29}$$

where $\hat{y}(u)$ is given in Assumption 1.

(c) The marginal incentive to collect information is independent of information precision,

$$\Delta_p(u, p, D) \equiv \frac{\partial \Delta(u, p, D)}{\partial p} = \Delta(u, 1, D), \tag{30}$$

and also satisfies conditions (a) and (b).

Figure 1 illustrates the shape of function $\Delta(u, p, D)$. The first result in the lemma states that the debtholder's incentive to acquire information decreases with the quality of the project. This is natural because the debtholder has a partial claim on the firm's final cash flow and must prefer to make more profitable investment. The second result establishes that the incentive to collect information depends on the level of debt in a non-monotonic way. First, this incentive increases with the amount of debt D, it achieves its maximum at the level of debt $D = \hat{y}(u)$, and then decreases and approaches $E[y|u] - E_I[y|u]$ when debt level increases to maximum. Finally, the last result shows that the marginal incentive to acquire information, $\Delta_p(u, p, D)$ does not vary with precision p.

To make a debtholder implement some discipline, it is necessary to coordinate the debtholder's own information acquisition decision with the optimal discipline scheme.

From Lemma 1, it follows that the debtholder prefers to acquire information at low signals because then the benefit of blocking investment is greater. Furthermore, the *marginal* incentive to acquire information, $\Delta_p(u, p, D)$, also decreases with u. As a result, to implement the optimal discipline based on u^*, we just need to pick a level of debt D^* at which the debtholder's marginal incentive is exactly equal to the marginal cost at the threshold u^*. This result is stated in the following lemma.

Lemma 2. *The debtholder implements a discipline scheme $R(u)$ based on a threshold u^*, if the debt level D^* satisfies the following equation*

$$\Delta_p(u^*, p^*, D^*) = a. \tag{31}$$

To find the optimal level of debt, D^*, recall that the optimal threshold u^* is greater than the ex post efficient threshold $\tilde{u}$, implying that the manager needs to be restricted more often from making investment. We need an additional condition to implement the optimal discipline: the highest possible incentive to intervene for a debtholder must exceed the cost of information acquisition. In particular, we require

$$\Delta_p(u^*, p^*, \hat{y}(u^*)) > a. \tag{32}$$

Proposition 3 below establishes the existence of the level of debt that implements the optimal discipline.

Proposition 3. *(Implementation by a debtholder) If condition (32) holds, then there are two levels of debt, $D^{*,L}$ and $D^{*,H}$ ($D^{*,L} < D^{*,H}$), such that*

$$\Delta_p(u^*, p^*, D^{*,L}) = \Delta_p(u^*, p^*, D^{*,H}) = a. \tag{33}$$

Furthermore, $D^{*,L} < y^*$, where y^* is defined in (21). Therefore, a debtholder who holds a debt with face value $D^* = D^{*,L}$ always implements the optimal discipline u^*.

A sole owner cannot commit to implement the optimal discipline because of condition (22). In contrast, a debtholder with the level of debt $D^* \in \left\{ D^{*,L}, D^{*,H} \right\}$ can

commit to implement the optimal discipline based on threshold u^*. The intuition behind this result is illustrated in Figure 2. Because $E[y|u^*] - E_I[y|u^*] \leq a$, the curve $\Delta_p(u^*, p, D)$ intersects with $c'(p^*)$ twice, at levels $D^{*,L}$ and $D^{*,H}$. Thus either of these two debt levels solves equation (31). However, since the debt contract is designed under the optimal managerial compensation, we need make sure that $D^* \leq y^*$, otherwise the debtholder's claim would conflict with the managerial compensation. Proposition 3 ensures that at least the lower debt level, $D^{*,L}$, satisfies this condition, so we can set $D^* = D^{*,L}$.

It also follows from Figure 2 that a moderate level of debt $D \in \left(D^{*,L}, D^{*,H} \right)$ induces the debtholder to intervene too often because the debt claim in this case is highly sensitive to managerial investment. A value of debt is reduced most by the managerial investment if the debt level is $D = \hat{y}(u^*)$. For a low level of debt, the debtholder's incentive to acquire information is not sufficient to cover the cost because the expected change in debt value due to $w = 1$ is small. For a high level of debt, however, the debt security has properties that are similar to equity. Specifically, the debtholder benefits from the fat upper tail of the cash flow distribution that comes with investment, and therefore is less inclined to block investment.

As for the design of debt covenants, signal u can be interpreted as noisy information (e.g., accounting ratios), which can be observed but does not provide sufficient legal evidence to warrant intervention by the outside investors. Threshold u^* then represents the *minimum* level of the *tightness* of a debt covenant at which the debtholder starts to consider intervention.[19] For any signal below threshold u^*, the debtholder seeks additional information w, and if verifiable information is obtained ($w = 1$), he has sufficient evidence to block the investment. The implementation of discipline by a debtholder suggested by the model offers a reasonable explanation of the real-world enforcement of debt covenants.

Under this implementation, the debtholder disciplines the manager and can there-

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[19]Threshold u^* is the minimum tightness because it represents the highest signal at which the debtholder has an incentive to intervene.

fore improve the firm's corporate governance. The shareholders, on the other hand, remain passive and do not participate in corporate governance. Their role is simply to absorb the firm's residual cash flow, which preserves the debtholder's optimal monitoring incentive. The following corollary shows that shareholders generally have a weaker incentive to acquire information than does the debtholder.

Corollary 1. *(Uninformed equity) Under the implementation of Proposition 3, shareholders never have a stronger incentive than the debtholder to acquire costly information, regardless of their holdings.*

The lack of incentive to acquire additional information regardless of their holdings makes shareholders uniformly uninformed in the model. Because shareholders rely only on public information (signal u), the equity securities are perfectly liquid in the secondary market.

As in Dewatripont and Tirole (1994), shareholders and the manager are more congruent in their interests than are bondholders and the manager. The congruence comes from the security design. Both the optimal managerial compensation and the levered equity security are option-like claims that are supported by the right tail of the cash flow distribution. Because of the similarity of their payoff structures, shareholders and manager have similar risk attitudes in choosing projects. As a result, shareholders are less likely to restrict the risk-shifting behavior of the manager than are bondholders. Therefore compared to a debt claim, an equity claim is less likely to induce information acquisition to discipline the manager.

To make the implementation renegotiation-proof, we need to ensure that after the signal of project quality is realized shareholders will not be able to renegotiate with the debtholder. We discuss the possibility of renegotiation between shareholders and the debtholder at length in Section V. In the next section, we show that a debt contract with debt level D^* is the (weakly) optimal security to implement the optimal discipline among all financial securities.

IV. Optimality of the Debt Contract

A. Maximal Incentive Provision

We have established that when the maximal marginal incentive of the debtholder to acquire information is *larger* than the marginal information cost, a debt contract with covenants can implement the optimal discipline and therefore cannot be improved upon. The incentive for information acquisition is maximized with a debt level $\hat{y}(u)$.

In this section, we analyze whether there is any contract that dominates a debt contract in inducing its holder to acquire information and impose discipline when the debtholder's maximal incentive is *smaller* than the marginal cost of information acquisition. We show that in the set of normal securities, a debt contract is weakly optimal in implementing the optimal discipline based on u^* and there is no other contract that creates greater incentives for information acquisition.

Proposition 4. *(Optimality of debt) If the debtholder's maximal marginal incentive to acquire information and implement a discipline scheme based on u^* is less than the marginal cost of information, i.e.,*

$$\Delta_p(u^*, \, p^*, \, \hat{y}(u^*)) < a, \tag{34}$$

then no normal contract induces its holder to acquire information and restrict the manager according to the discipline scheme based on u^*. Among all normal securities, the debt security has the highest marginal incentive to acquire information.

An interesting result that emerges from Proposition 4 is that the debtholder is the best candidate to mitigate the agency problem associated with risk-shifting. Intuitively, a debt contract is a concave claim, and therefore the debtholder is negatively affected by the additional risk stemming from managerial investment. A debt contract with $D = \hat{y}(u)$ that bears all downside risk but does not share in the benefits of higher profits must be most adversely affected by risk-increasing investment, and therefore provides the most incentives for its holder to restrict investment.

When the maximal incentive of a debtholder at u^* is greater than the information cost, i.e., condition (32) holds, it is always possible to find a *debt* contract with debt level D^* that implements the optimal discipline scheme based on u^*. In other situations, debt contract simply has the highest incentive to discipline the manager among all normal securities.

Our theory thus predicts that the debtholder can improve the firm's corporate governance before firm default and the transfer of control rights. This view runs counter to the general assumption in the corporate governance literature that it is the shareholders who monitor the manager and implement managerial discipline. We next demonstrate that shareholders are unable to implement tough discipline, although it is necessary to maximize firm value.

B. Difference between a Debtholder's and a Shareholder's Ability to Implement Optimal Discipline

To illustrate the dominance of a debtholder's implementation of the optimal discipline scheme, a comparison with the large shareholder governance proposed in Burkart, Gromb, and Panunzi (1997) is useful. Briefly, Burkart, Gromb, and Panunzi (1997) show that a sole owner's ex post incentive to intervene is too strong, and it destroys the ex ante incentive for the manager to exert a high effort. The authors thus propose to turn down the equity holder's incentive by splitting equity into two parts: a large blockholder (who may exercise control of the manager) and passive minority shareholders (who remain silent).

Our model allows for a direct comparison with Burkart, Gromb, and Panunzi (1997). If the optimal discipline scheme were less strict than the ex post efficient scheme, $u^* < \tilde{u}$, implementing the optimal discipline via a large shareholder would indeed be possible, as shown in Figure 3. In a firm owned by a large shareholder with holdings $l \in [0, 1]$ and a set of dispersed shareholders, the large shareholder's marginal incentive to acquire information at u^* is

$$l \left[E[y|u^*] - E_I[y|u^*] \right]. \tag{35}$$

The optimal holdings l^* that allow the large shareholder to implement the optimal discipline scheme u^* can be derived by making him indifferent between enforcing a restriction and not enforcing it at the threshold u^*

$$l^* \left[E[y|u^*] - E_I[y|u^*] \right] = a. \tag{36}$$

It follows that the optimal ownership l^* of the large shareholder is

$$l^* = \frac{a}{E[y|u^*] - E_I[y|u^*]}. \tag{37}$$

Thus a large shareholder with a stake l^* in an unlevered firm will have the right marginal incentive to acquire information and implement the optimal discipline scheme. In this case, however, it is also possible to find a debt level D^* such that the optimal discipline is equivalently implemented by a debtholder (see Figure 3).

However, when outside investors are able to offer compensation to the manager, Proposition 2 shows that the desired discipline is tougher than the ex post efficient discipline, i.e., $u^* > \tilde{u}$. In this case, we have $E[y|u^*] - E_I[y|u^*] \leq a$, which implies that implementation by a large shareholder would require holdings to exceed one, $l^* > 1$. Because it is impossible to pledge a larger cash flow to a shareholder than is generated by a firm, the large shareholder implementation proposed by Burkart, Gromb, and Panunzi (1997) fails. Notably, a debtholder's implementation of the optimal discipline scheme still works in this case.

To summarize, whether or not a security induces information acquisition depends on how the information affects the cash flow distribution that backs the value of the claim. In our model, facing the manager's preference for risk-shifting, the debtholder collects the essential information for optimal corporate governance. This result is based on two key managerial agency problems, managerial moral hazard and non-contractible investment. As these agency problems seem to be pervasive in the real world, debtholders' information acquisition should be an important factor when the firm determines its governance structure. Combined with the information-inactive equity, this result explains the illiquidity of corporate debt, which we discuss next.

V. Secondary Market Liquidity and Securitization of Corporate Debt

A. Stability of the Debtholder's Implementation

To implement the optimal discipline scheme, the debt contract should have the highest seniority in the firm and be owned by a single debtholder, as otherwise the incentive to acquire information would be attenuated. This suggests that a best real-world candidate for such a contract is bank debt.

For a bank, the incentive to implement a certain discipline scheme is directly built into the debt contract. If, however, this contract can be modified ex post or sold to someone else, then the incentive to acquire information and restrict the manager would change, and implementation may fail. This is a common issue present in many theoretical models that implement managerial discipline using a security design approach (e.g., Dewatripont and Tirole (1994)). While such models typically allow for ex post renegotiation between a firm manager and claim holders, the renegotiation *among* different claim holders has to be shut down. If such renegotiation were indeed allowed, the capital structure would reduce to a structure that implements the ex post efficient discipline, as predicted by the Coase theorem (Coase (1960)).

Under current market regulations in the United States, banks as the major debtholders are not allowed to hold equity in the firm and carry controlling interest unless they are restructuring bad loans (when control rights are transferred) or through a venture capital division (Drucker and Puri (2008)). Therefore, the possibility of a bank buying all equity of the firm and implementing an ex post efficient scheme is not a concern.

It is possible, however, for a bank to *liquidate* its debt to the firm's shareholders in the secondary market. For example, banks may be able to sell low-quality corporate loans through collateralized loan obligations (CLOs). If a bank sells the debt D^* that is supposed to implement an optimal discipline scheme, the implementation fails and the governance of the firm reduces to an ex post efficient scheme.

Therefore, we next discuss the secondary market liquidity of a corporate debt which

affects the ease with which debt can be liquidated and a firm's corporate governance.

B. Liquidity of Corporate Debt

Our model is well equipped for the analysis of information acquisition decisions and liquidity of corporate debt in the secondary market. The recent security design literature aims to achieve higher liquidity in a setting with exogenous asymmetric information and social benefits of trading (e.g., DeMarzo and Duffie (1999), Dang, Gorton, and Holmstrom (2011), and Farhi and Tirole (2014)). The purpose of security design in our model is different because we focus on the implementation of optimal corporate governance. Nevertheless, information asymmetry emerges endogenously in our setting when information w is private to its acquirer, and it affects the liquidity of corporate securities in the secondary market. We show that the information asymmetry impedes the debtholder from selling his debt in the uninformed secondary market. But the illiquidity of debt is actually desirable for better corporate governance. The simple insight is that debt has to be retained on the debtholder's balance sheet in order to induce sufficient monitoring of the manager.

We restrict discussion to the case where a debtholder (a bank) initially holds the optimal amount of debt, D^*. Since the shareholders can renegotiate with the manager over compensation, we can view the shareholders and the manager as a coalition. We refer to this coalition as a hedge fund. Without any secondary market trading between the bank and the hedge fund at $t = 1$, the optimal discipline based on u^* would be implemented by the bank.

Now suppose that, at the end of the first period, the public signal u is observed. If the bank acquires information w with the associated precision p, then whenever $w = 1$, the debt value is $d(u)$ given by (24), and whenever $w = 0$, the debt value is $d_I(u)$ given by (25). We denote the "safe" part of debt, which is insensitive to new information, as

$$B(u) = d_I(u), \tag{38}$$

and the "risky" part of debt as

$$wS(u) = w\left[d(u) - d_I(u)\right].\qquad(39)$$

The value of debt is then a function of acquired information

$$d^w = wS + B.\qquad(40)$$

We assume that information w is private to the bank, if it collects it by paying the acquisition cost $c(p)$. Whether the bank acquires information is also private, which implies that the bank can secretly seek information.[20] As we have shown in Corollary 1, the hedge fund, which holds all equity of the firm, does not have an incentive to acquire information in this situation.[21]

Formally, we define *liquidity* in the secondary market as probability of trading the corporate debt d^w or its securitized forms between the bank and the uninformed market (the hedge fund) at $t = 1$, after signal u is observed, but before the investment decision of the manager is made public. The model generates an endogenous trading motive, which stems from the ex post incentive to minimize the information acquisition costs. Specifically, it is ex post efficient not to acquire information for signal $u \in (\tilde{u},\, u^*]$. If bank sells its debt to the hedge fund that then becomes the sole owner of the firm, the hedge fund will choose not to acquire information. Therefore, a successful trade between the bank and the hedge fund (secondary market liquidity) implies that the managerial discipline will reduce to the ex post efficient scheme based on $\tilde{u}$.

In the trading game described above, acquisition of information has a dual role. First, acquiring information is a disciplining tool that can restrict excessive managerial investment and increase the fundamental value of the debt.[22] If the information

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[20]In equilibrium, the bank will acquire information once a publicly observed signal u falls below a known threshold, u^*. Hence the hedge fund will correctly anticipate information acquisition by the bank. However, to establish the existence of this equilibrium, we need to consider all possible deviations by the bank that are unobservable to the hedge fund.

[21]When w is private information of the bank, the hedge fund can only infer w from the investment decision of the manager, i.e., after the outcome of corporate governance action by the bank is realized.

[22]In other words, the information acquisition cost in the model is not a pure deadweight cost that does not change the distribution of the value of asset, as is commonly assumed in the previous literature (e.g., Dang, Gorton, and Holmstrom (2011) and Farhi and Tirole (2014)). To discipline the manager and change the cash flow distribution, the information acquisition cost must be paid.

acquisition cost $c(p)$ is not incurred, the value of the risky part of debt, wS, is always zero. Second, acquiring information also creates an information asymmetry between the bank and the hedge fund, which impedes the sale of the bank debt to the hedge fund. For the sake of corporate governance, it is then optimal to retain the information acquisition incentive of the bank.

As we show in the following proposition, the bank's monitoring incentive and the illiquidity of its debt are complements. When the public signal u is high, the bank will not monitor since the benefit is less than the cost. In contrast, when signal u is low, the benefit of monitoring increases (as the quality of the investment worsens), and the bank collects information to discipline the manager. The information acquisition results in adverse selection for the risky part of debt, wS, and makes it illiquid. Therefore, debt D^* is retained on the bank's balance sheet, which preserves the bank's incentive to seek information and discipline the manager.

Proposition 5. *(Liquidity crisis) Suppose w is private information. For signal $u \in (u^*, 1]$, the bank will not acquire information, debt has value B, and it is fully liquid. For signal $u \in (0, u^*)$, the bank acquires information and the debt d^w is only liquid if $w = 0$. The bank implements the optimal discipline scheme based on u^*.*

Essentially, private information w makes the risky part of debt, wS, subject to adverse selection, and as a result, the whole debt D^* becomes illiquid. The intuition is that the private information generates information rent for the bank when the hedge fund proposes to buy the risky part of debt. To obtain this information rent, the bank needs to acquire information, but the hedge fund anticipates it and can offer only a low price for the risky part of debt. When the public signal u is high, the equilibrium is a non-informed one, i.e., the bank does not acquire any information and the debt is fully liquid. However, when the signal is low, the equilibrium switches to an informed one, in which the bank monitors by acquiring w and the debt becomes illiquid. The switch of the equilibrium from uninformed to informed due to a worsening public signal u offers an explanation for the lack of liquidity of banks' assets during a financial crisis.

Dang, Gorton, and Holmstrom (2011) also provide an explanation of the liquidity crisis when the public signal worsens, as a low public signal amplifies adverse selection. Our mechanism of the crisis is different from theirs because the amplified adverse selection in our model is driven by higher monitoring incentive of the bank, and we provide different policy implications. It is the informational frictions in trading (adverse selection on w) that make the bank unable to liquidate the whole debt issue D^*. But then the bank has an incentive to acquire information and to implement the optimal discipline.

We also consider the possibility that the bank can obtain higher liquidity by securitizing its debt D^*. For example, the bank can try to sell different "tranches" of debt, with each tranche being a normal security. We find, however, that debt tranching does not increase liquidity. As in Farhi and Tirole (2014), selling the firm's debt piecemeal does not stop the bank from acquiring information as long as it increases the total value of debt. As a result of adverse selection, any tranche of debt cannot be sold to the uninformed hedge fund. We state this result formally in the following corollary.

Corollary 2. *Suppose w is private information. For signal $u \in (0, u^*)$, securitizing debt does not increase its liquidity. The bank acquires information w and implements the optimal discipline scheme based on u^*.*

Using normal securities, it is impossible to construct a safe debt tranche that is insensitive to information w.[23] Generally, any tranche of debt offered by the bank is subject to adverse selection, and securitization does not change the incentive of the bank to acquire information. This allows us to make a general conclusion that as long as w is private information, the debt D^* has no liquidity at $t = 1$, and the bank needs to monitor the manager to increase the value of its debt. Thus the optimal discipline is still implemented.

On the other hand, if w were public, it would be fully revealed to the uninformed

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[23]This is because the safe part of debt, B, is equal to the expected value of debt when the firm's cash flow is drawn from distribution $f_I(y)$. A payoff of the normal security can only depend on the realized cash flow y at $t = 2$, but not on the expectation at $t = 1$.

hedge fund whenever the bank collects it, and the bank debt would be fully liquid at $t = 1$. However, higher liquidity comes at a cost because the bank would no longer be interested in information acquisition, as shown in the following proposition.

Proposition 6. *(Liquidity harms corporate governance) Suppose w becomes public whenever the bank collects it. Prior to information acquisition, the price of the debt D^* is $B + \bar{p}S - c(\bar{p})$ for signal $u \in (\tilde{u}, u^*)$, and the bank sells the whole debt issue at this price without acquiring any information. The discipline scheme of the firm reduces to the ex post efficient scheme $\tilde{u}$.*

If w is made public, the bank loses the incentive to acquire information and is willing to sell the whole debt issue at price $B + \bar{p}S - c(\bar{p})$. Because for $u \in (\tilde{u}, u^*)$, $E[y|u] - E_I[y|u] < a$, the hedge fund will choose not acquire information. The optimal managerial discipline therefore cannot be implemented, and corporate governance is impaired.

A comparison between Propositions 5 and 6 shows that illiquidity of corporate debt is necessary for implementation of best corporate governance, and transparency in the secondary market for corporate debt reduces the fundamental firm value. Regulators, who are interested in increasing the fundamental value of corporate debt, should therefore allow w to be kept private.

To conclude, the real threat to the debtholder's implementation of optimal managerial discipline is the secondary market liquidity, which could be prevented by keeping w private to the bank. To derive this counter-intuitive result that "no disclosure of information by banks is good" for corporate governance, we abstract away from the other benefits of securitization of corporate debt (e.g., liquidity gain from trading the assets). Nevertheless, the simple economic insight from the model is powerful. If we want the debtholder to implement optimal corporate governance, the incentive built into the debt contract must not be off-loaded by the bank. The informational friction between the banks and the uninformed market is the force that should stop the bank from liquidating its assets.

Interestingly, we show that when w is private, the implementation of the optimal discipline by a debt contract D^* cannot be undone through debt securitization. Thus the ex post renegotiation by the claim holders does not invalidate the optimal discipline implementation (as it is often the case in the prior security design literature).[24]

VI. Conclusion

In this paper, we analyze the optimal security design and compensation in a corporate setting where there is managerial moral hazard and the acquisition of information is costly. We show that the optimal corporate governance of the firm is implemented by a debt contract with a particular level of debt and restrictive covenants. Essentially, the debtholder has the highest incentive to acquire costly information and to discipline the firm manager when the firm performance is poor. The possibility of debtholder's intervention together with a convex compensation contract creates a strong incentive for the manager to exert effort and maximize ex ante firm value.

Further, we show that the interests of the firm's shareholders are congruent with those of the manager, and as a result shareholders have less interest than debtholders in seeking costly information. The difference in incentives to collect information explains why debt is information-rich and illiquid in the uninformed secondary market, while junior claims such as equity are perfectly liquid.

Finally, the theory developed in this paper suggests that the illiquidity of bank debt has certain benefits. Banks are special in their monitoring role and are irreplaceable for corporate governance purposes. We argue that banks' incentive to monitor stems from the information asymmetry between the banks and the uninformed market. When debtholders have private information, debt claims are subject to a great degree of adverse selection, which makes it hard for the banks to liquidate their corporate debt. The model shows that the required information asymmetry could be generated by

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[24]We show in Proposition 5 that the uninformed hedge fund cannot buy debt from the bank to undo managerial discipline. However, to prevent the informed bank from buying uninformed equity, we need to rely on current regulation, which is exogenous to the model.

keeping the information acquisition private to the banks. Thus policies that promote information disclosure and enhance the securitization of corporate debt can negatively affect corporate governance and firm value in the long run.

VII. Appendix: Proposition Proofs

Proof of Proposition 1. Program (7) is linear in $R(u)$, therefore we deal with a corner solution. Whenever the term in brackets is positive, the maximum R and p are optimal. It follows from Assumption 2 that for signals $u < \tilde{u}$, the marginal benefit of collecting information and increasing precision p is greater than the cost a. Therefore, for $u < \tilde{u}$, we have $R(u) = 1$ and $p = \bar{p}$, whereas for $u > \tilde{u}$, we have $R(u) = 0$. Given a signal u, if the manager and the outsiders can renegotiate over the compensation and the project choice, the outcome of such ex post renegotiation always restores ex post efficiency, that is, $\tilde{u}$ is the threshold for information acquisition and choosing projects, regardless of their relative bargaining power. $\qquad\square$

Proof of Proposition 2. The expected compensation in (13) can be rewritten as

$$M(u) = E_M\left[s(y)|u\right] - p\left(u\right)R(u)\delta(u), \tag{41}$$

where $\delta(u) = E\left[s(y) - s(u,y)|u\right]$. Designing optimal compensation then amounts to determining functions $s(y)$ and $\delta(u)$. Because $s(u,y)$ is a normal security and $0 \le s(u,y) \le y$, penalty $\delta(u)$ is bounded

$$E_I\left[s\left(y\right)|u\right] - E\left[y|u\right] \le \delta(u) \le E_I\left[s(y)|u\right]. \tag{42}$$

The optimization program is given by (15), subject to the incentive-compatibility condition for the manager's effort (16), the limited liability constraint (42), and the incentive-compatibility constraint for the manager's investment decision, i.e.,

$$r^*(u) = \arg\max_{r(u)} M(u) = \arg\max_{r(u)} \int_0^{\overline{Y}} s\left(y\right)\left[f(y|u) + r\left(u\right)\left(f_I(y|u) - f(y|u)\right)\right]dy. \tag{43}$$

Because $M(u)$ is linear in $r(u)$ and because of Assumption 2, we have

$$\frac{\partial}{\partial u}\left(\frac{\partial M}{\partial r}\right) = \int_0^{\overline{Y}} \frac{\partial\left[F_I(y|u) - F(y|u)\right]}{\partial u}s'(y)dy > 0. \tag{44}$$

It then suffices to consider a monotonic function $r(u)$, such that $r(u) = 0$ for $u \le u^r$ and $r(u) = 1$ for $u > u^r$. We conjecture that $u^r = 0$, so that $r^*\left(u\right) = 1$ for all signals u, and we verify this conjecture in Step 5. Then $E_M\left[.|u\right]$ is equal to $E_I\left[.|u\right]$.

Ignoring for a moment a requirement that $s(y)$ is a normal security, we can write the Lagrangian for the maximization problem as

$$\mathcal{L} = \int_0^1 \{E_I[y|u] + p(u)R(u)\left(E[y|u] - E_I[y|u] - a\right) - M(u)\}\overline{h}(u)du \tag{45}$$

$$+\lambda \left(\int_0^1 M(u)\left(\overline{h}(u) - \underline{h}(u)\right) du - K \right) + \int_0^1 \overline{\lambda}_\delta(u)\left(E_I\left[s\left(y\right)|u\right] - \delta(u)\right) du$$

$$+\int_0^1 \underline{\lambda}_\delta(u)\left(E\left[y|u\right] - E_I\left[s\left(y\right)|u\right] + \delta(u)\right) du,$$

where λ, $\overline{\lambda}_\delta(u)$, and $\underline{\lambda}_\delta(u)$ are the Lagrange multipliers for different constraints. Because the problem is linear, it is more convenient to work with integrands. We define the following integrand with respect to u

$$\mathcal{L}_u = \{E_I[y|u] + p(u)R(u)\left[E[y|u] - E_I[y|u] - a\right] - M(u)\}\overline{h}(u) \tag{46}$$

$$+\lambda M(u)\left[\overline{h}(u) - \underline{h}(u)\right] + \overline{\lambda}_\delta(u)\left(E_I\left[s\left(y\right)|u\right] - \delta(u)\right)$$

$$+\underline{\lambda}_\delta(u)\left(E\left[y|u\right] - E_I\left[s\left(y\right)|u\right] + \delta(u)\right),$$

and the integrand with respect to y

$$\mathcal{L}_y = \int_0^1 \{(y - s(y))\, f_I(y|u) + p(u)R(u)\left[yf(y|u) - yf_I(y|u) - a + \delta(u)f(y|u)\right]\}\overline{h}(u)du \tag{47}$$

$$+\lambda \int_0^1 \left[s(y)f_I(y|u) - p(u)R(u)\delta(u)f(y|u)\right]\left(\overline{h}(u) - \underline{h}(u)\right) du$$

$$+\int_0^1 (\overline{\lambda}_\delta(u) - \underline{\lambda}_\delta(u))(s(y)f_I(y|u) - \delta(u)f(y|u))du + \int_0^1 \underline{\lambda}_\delta(u)yf(y|u)du.$$

The first order derivatives with respect to $R(u)$, $\delta(u)$, and $s(y)$ are

$$\frac{\partial\mathcal{L}_u}{\partial R} = p(u)\left\{(E[y|u] - E_I[y|u] - a)\overline{h}(u) + \delta(u)\left[(1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u)\right]\right\}, \tag{48}$$

$$\frac{\partial\mathcal{L}_u}{\partial\delta} = p(u)R(u)\left[(1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u)\right] - \overline{\lambda}_\delta(u) + \underline{\lambda}_\delta(u), \tag{49}$$

$$\frac{\partial\mathcal{L}_y}{\partial s} = -\int_0^1 \left[(1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u) - \overline{\lambda}_\delta(u) + \underline{\lambda}_\delta(u)\right] f_I(y|u)du. \tag{50}$$

Expressions (48), (49), and (50) are all linear in controls $p(u)$, $R(u)$, $\delta(u)$, and $s(y)$, so there is a corner solution. We analyze the solution in the following steps.

Step 1: Reduce the set of possible solutions.

Because $\partial\mathcal{L}_u/\partial R$ is of the same sign as $\partial\mathcal{L}_u/\partial p$, $p(u) = \bar{p}$ whenever $R(u) = 1$.

When $R(u) = 0$ penalty $\delta(u)$ cannot be enforced, i.e., without loss of generality, we can set $\delta(u) = 0$. When $R(u) = 1$ for some u, (49) implies that the limited liability constraint binds at the upper limit, i.e., $\delta(u) = E_I[s(y)|u]$, $\overline{\lambda}_\delta(u) \geq 0$ and $\underline{\lambda}_\delta(u) = 0$. The other possibility $(\underline{\lambda}_\delta(u) \geq 0$ and $\overline{\lambda}_\delta(u) = 0)$ is not a valid solution. To see this, note that for any u where $R(u) = 1$ we have

$$(1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u) \leq 0,$$

which together with (49) implies that firm value would be maximized by choosing the lowest $\delta(u)$ (constrained by the negative lower bound of $E_I[s(y)|u] - E[y|u]$). However, then $R(u) = 1$ would not be justified for such signals u because firm value would be even higher if information is not acquired $(R(u) = 0)$ and the whole firm is given to the manager. Since information acquisition is costly, it is wasteful to acquire information to reward the manager. Therefore, a candidate solution must satisfy $\delta(u) = 0$ if $R(u) = 0$ and $\delta(u) = E_I[s(y)|u]$ if $R(u) = 1$.

Step 2: Characterize information acquisition decision $R(u)$.

Because $\delta(u) \geq 0$ for all u, condition (48) and MLRP of $\overline{h}(u)/\underline{h}(u)$ imply $R(u) = 1$ for lower u and $R(u) = 0$ for higher u. To avoid a trivial solution, we assume there exists such $u^* \in (0, 1]$ that

$$\frac{\partial\mathcal{L}_u}{\partial R}|_{u^*} = \bar{p}\left\{(E[y|u^*] - E_I[y|u^*] - a)\overline{h}(u^*) + \delta(u^*)\left[(1 - \lambda)\overline{h}(u^*) + \lambda\underline{h}(u^*)\right]\right\} = 0. \quad (51)$$

For $u \in (0, u^*]$, $R(u) = 1$ and for $u \in (u^*, 1]$, $R(u) = 0$. Note that $R(u^*) = 1$ and $\delta(u^*) = E[s(y)|u^*]$, so that $\bar{p}\left[\overline{h}(u^*)(1 - \lambda) + \lambda\underline{h}(u^*)\right] = \overline{\lambda}_\delta(u^*) > 0$ and we have

$$\left[\overline{h}(u^*)(1 - \lambda) + \lambda\underline{h}(u^*)\right]\delta(u^*) > 0. \quad (52)$$

Expression (51) can then be rewritten as

$$E[y|u^*] - E_I[y|u^*] = a - \delta(u^*)\left[(1 - \lambda)\overline{h}(u^*) + \lambda\underline{h}(u^*)\right], \quad (53)$$

which, when compared with the definition of the ex post efficient scheme in (11), establishes that $u^* > \tilde{u}$. The term $\delta(u^*)\left[(1 - \lambda)\overline{h}(u^*) + \lambda\underline{h}(u^*)\right]$ can be interpreted as the marginal benefit of information acquisition for motivating the manager.

Step 3: Characterize $s(y)$ and optimal compensation.

Given $R(u) = 1$, $\overline{\lambda}_\delta(u) > 0$ for $u \in (0, u^*]$ and $R(u) = 0$, $\overline{\lambda}_\delta(u) = 0$ for $u \in (u^*, 1]$, we can combine (49) and (50):

$$\frac{\partial \mathcal{L}_y}{\partial s} = -\overline{p} \int_{u^*}^1 f_I(y|u) \left((1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u)\right) du - (1 - \overline{p}) \int_0^1 f_I(y|u) \left((1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u)\right) du.$$

$$= \overline{p}\,\overline{f}_I(y|u > u^*) \left[\lambda - 1 - \lambda\frac{\underline{f}_I(y|u > u^*)}{\overline{f}_I(y|u > u^*)}\right] + (1 - \overline{p})\overline{f}_I(y) \left[\lambda - 1 - \lambda\frac{\underline{f}_I(y|u)}{\overline{f}_I(y|u)}\right]. \tag{54}$$

Because of the MLRP property for $\overline{f}_I/\underline{f}_I$ (see Assumption 4), it must be that $\frac{\partial \mathcal{L}_y}{\partial s} < 0$ for low y, and $\frac{\partial \mathcal{L}_y}{\partial s} > 0$ for high y. Then from (54) it follows that the design of $s(y)$ is a standard problem solved in Proposition 1 of Innes (1990), and hence the solution is

$$s^*(y) = 0 \text{ if } y \leq y^*, \text{ and } s^*(y) = y - y^* \text{ if } y > y^*, \tag{55}$$

where y^* exists when K is not too large (to be defined in Step 5).

Now we implement $\delta(u)$, which is the expected value of the penalty at $t = 1$. $\delta(u)$ is not a normal security that pays off at $t = 2$, so it needs to be implemented. To do this, we simply set $s^*(u, y) = 0$ in $\delta(u) = E\left[s(y) - s(u, y)|u\right]$, which implies $\delta(u) = E\left[s^*(y)|u\right]$ whenever $w = 1$ and fits the optimal solution. Therefore, the optimal compensation (12) can be written as

$$s^*(wu, y) = 0 \qquad \text{if } 0 < wu \leq u^*, \tag{56}$$

$$s^*(wu, y) = \max\left[y - y^*, 0\right], \text{ otherwise.} \tag{57}$$

Step 4: Solve for u^* and λ.

We now solve for the threshold u^* and the Lagrange multiplier λ for the manager's IC condition. Given an interior solution for optimal compensation s^*, there exists such y^0 where

$$\frac{\partial \mathcal{L}_y}{\partial s}(y^0) = 0. \tag{58}$$

By defining function $G(v)$ on support $(0, 1]$

$$G(v) = \int_0^v f_I(y^0|u) \left((1 - \lambda)\overline{h}(u) + \lambda\underline{h}(u)\right) du, \tag{59}$$

we can rewrite condition (58) as

$$G(u^*) = G(1)/\overline{p}. \tag{60}$$

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Because

$$G'(v) = f_I(y^0|v)\left((1-\lambda)\overline{h}(v) + \lambda\underline{h}(v)\right),\tag{61}$$

and the MLRP condition holds, we have: $G'(v) > 0$ for low v, and $G'(v) < 0$ for high v, which implies that function $G(v)$ is hump-shaped. Then equation (60) has at most two solutions, $u^* = v_L$ and $u^* = v_H$, with $v_L < v_H$, characterized by

$$(1-\lambda)\overline{h}(v_L) + \lambda\underline{h}(v_L) > 0,\tag{62}$$

$$(1-\lambda)\overline{h}(v_H) + \lambda\underline{h}(v_H) < 0.\tag{63}$$

Because $(1-\lambda)\overline{h}(u^*) + \lambda\underline{h}(u^*) \geq 0$ the right solution is $u^* = v_L$. Combining $u^* = v_L$ where v_L is a solution for (60) with (51), we have two equations and two unknowns, so that u^* and λ can be obtained and the optimal solution is complete.

Step 5: Define the upper bound for K and verify $r(u) = 1$ for any u.

Finally, we find the condition for K that needs to be satisfied in order to have $r(u) = 1$ for all signals u and to guarantee the existence of an interior solution for the optimal compensation $s^*(y)$. Specifically, if y^* satisfies

$$y^* \geq \sup\{\hat{y}(u)|u \in (0,1]\} = \hat{y}(0),\tag{64}$$

then the manager always prefers distribution $F_I(.)$ to distribution $F(.)$ and chooses $r(u) = 1$, for $\hat{y}(u)$ is the point at which function $F_I(.|u)$ intercepts function $F(.|u)$. To see why the last equality in (64) obtains, note that

$$\frac{d\hat{y}}{du} = -\frac{\frac{\partial[F_I(y|u)-F(y|u)]}{\partial u}}{f_I(\hat{y}|u) - f(\hat{y}|u)} < 0.\tag{65}$$

Because function $F(y|u)$ crosses $F_I(y|u)$ from below at $\hat{y}$, we have $F(\hat{y}|u) = F_I(\hat{y}|u)$ and $f_I(\hat{y}|u) - f(\hat{y}|u) < 0$.

Condition (64) is satisfied if the cost of effort K is not too large, i.e., the higher cost of effort can be compensated by higher managerial pay

$$\int_{\hat{y}(0)}^{\overline{Y}} (y - \hat{y}(0))\left[\overline{f}_I(y|u > u^*) - \underline{f}_I(y|u > u^*)\right] dy \geq K.\tag{66}$$

$\square$

Proof of Lemma 1. (a) Monotonicity in u is ensured by equation (26) and Assumption 2.

(b) At each (u, p),

$$\Delta(u,\, p,\, D) \;=\; p\left\{ \int_0^{\hat{y}} [F_I(y|u) - F(y|u)]\, dy + \int_{\hat{y}}^{D} [F_I(y|u) - F(y|u)]\, dy \right\}.$$

From Assumption 1 it follows that $\Delta(u,\, p,\, D)$ is maximized at $D = \hat{y}(u)$.

(c) It follows from equation (26). $\qquad\square$

Proof of Lemma 2. The debtholder acquires information whenever

$$\Delta(u,\, p,\, D) \geq c(p), \tag{67}$$

which is equivalent to $\Delta_p(u,\, p,\, D) \geq a$. The optimal precision p^* solves

$$\max_p \Delta(u,\, p,\, D) - c(p). \tag{68}$$

Therefore, we have $p = \bar{p}$ and $R(u) = 1$ whenever $\Delta_p(u,\, p,\, D) \geq a$. The threshold u^* at which the debtholder is indifferent between acquiring information or not is determined by (31). $\quad\square$

Proof of Proposition 3. From Proposition 2 it follows that at u^*, the marginal benefit of acquiring information is smaller than the marginal cost, $E[y|u^*] - E_I[y|u^*] < a$. This means $\Delta_p(u^*,\, p,\, \overline{Y}) < a$. From Lemma 1, if $\Delta_p(u^*,\, p,\, \hat{y}(u^*)) \geq a$, then there must be two solutions, $D^{*,L} \in (0, \hat{y}(u^*)]$ and $D^{*,H} \in [\hat{y}(u^*), \overline{Y})$. From (64), we have $D^{*,L} \leq \hat{y}(u^*) \leq y^*$. $\qquad\square$

Proof of Corollary 1. For the levered equity, the marginal benefit of acquiring information is negative at the threshold u^*

$$E[y|u^*] - E_I[y|u^*] - \Delta_p(u^*, p^*, D^*) = E[y|u^*] - E_I[y|u^*] - a < 0, \tag{69}$$

so that the equity holders are not interested in information acquisition. For any signal abobe u^*, the incentive to collect information is even weaker. Note that for $u > u^*$, it is impossible for the equity holders to transfer to themselves some of the managerial compensation because a verified signal $wu > u^*$ ensures that the manager is paid in full. For $u < u^*$, the shareholders can free-ride on the debtholder to discipline the manager. $\qquad\square$

Proof of Proposition 4. The aim is to choose a normal contract that maximizes the marginal incentive to acquire information. Denote by $\Delta_p(u^*, p; h(y))$ the marginal incentive to acquire information, where $h(y)$ is the payoff of the contract. We need to solve the following program:

$$\max_{h(.)} \Delta_p(u^*, p; h(y)) = \int_0^{\overline{Y}} h(y) \left[f(y|u^*) - f_I(y|u^*) \right] dy. \tag{70}$$

Using integration by parts, we can rewrite it as

$$\max_{h(.)} \int_0^{\overline{Y}} h'(y) \left[F_I(y|u^*) - F(y|u^*) \right] dy. \tag{71}$$

Because the first derivative of the payoff of a normal contract, $h'(y)$, is bounded between 0 and 1, it must be that $h'(y) = 1$ when $F_I(y|u^*) - F(y|u^*) > 0$ and $h'(y) = 0$ when $F_I(y|u^*) - F(y|u^*) < 0$. This is a debt contract with the debt level $D = \hat{y}(u^*)$. $\qquad \square$

Proof of Proposition 5. We characterize the equilibrium in which the bank acquires w and the hedge fund is uninformed. The hedge fund always makes an offer equal to B for the whole bundle $(wS + B)$, and the bank accepts the offer when $w = 0$.

We first focus on the case $u \leq u^*$. Clearly, any price below B will be rejected by the bank. Suppose the hedge fund offers a price P for the whole issue, such that $B < P < S + B$. Since the bank gathers information, it does not want to sell debt when $w = 1$ because the value of debt is $S + B$ (the bank blocks undesirable investment). Since the bank sells only when $w = 0$, the hedge fund loses money by trading with the bank. Therefore, if in equilibrium the bank collects information, $P = B$. Another candidate price, $P \geq S + B$, also cannot be the equilibrium price because then the bank will not acquire any information, and hence the hedge fund will make a loss by buying debt that is worth B by paying price greater than $S + B$.

It is left to show that the bank will not deviate from information acquisition. Suppose the bank does not acquire w (but the hedge fund does not know this). Facing an offer price B, the bank does not sell debt since the expected value of the asset with information acquisition is $\overline{p}S + B - c(\overline{p})$, which is strictly greater than B for a signal $u \in (0, u^*)$.

In case when $u > u^*$, both parties have no incentive to acquire information, and hence the information is symmetric. Trading can occur at the price $P = B$. $\qquad \square$

Proof of Corollary 2. Without loss of generality, suppose the bank tranches its debt contract, D^*, into two securities, $\theta_0(y)$ and $\theta_1(y)$, such that

$$\theta_0(y) + \theta_1(y) = \min\left[y,\, D^*\right]. \tag{72}$$

The bank wants to sell security $\theta_1(y)$ and to retain security $\theta_0(y)$. Because both securities are normal, we must have $\theta_1'(y) = 0$ for $y \geq D^*$. It is convenient to decompose the expected payoff of security θ_1 at $t = 1$ into

$$B^\theta = E_I\left[\theta_1(y)|u\right], \tag{73}$$

and

$$wS^\theta = w\left[E\left[\theta_1(y)|u\right] - E_I\left[\theta_1(y)|u\right]\right]. \tag{74}$$

As in the proof of Proposition 5, if we can show that for any θ_1, $S^\theta > 0$ for $u < u^*$, then in equilibrium the hedge fund will only offer price B^θ for θ_1 and the bank will only sell it when $w = 0$. Therefore, the bank will still acquire information w.

To see that $S^\theta > 0$, note

$$S^\theta = \int_0^{\overline{Y}}\left[F_I(y|u) - F(y|u)\right]\theta_1'(y)dy = \int_0^{D^*}\left[F_I(y|u) - F(y|u)\right]\theta_1'(y)dy. \tag{75}$$

For $u < u^*$, we have

$$D^* < \hat{y}(u^*) < \hat{y}(u). \tag{76}$$

The first inequality follows from the definition of D^* (Proposition 3), whereas the second inequality follows from (65). Thus, for $u \leq u^*$ and $0 < y \leq D^*$, we have $F_I(y|u) - F(y|u) > 0$. Since $\theta_1'(y) \geq 0$ for any y and $\theta_1'(y) > 0$ for some y (otherwise $\theta_1(y) \equiv 0$), it must be that $S^\theta > 0$. $\qquad\square$

Proof of Proposition 6. If w becomes public immediately after it is collected, then debt could be traded at fair full-information prices conditional on w. Prior to acquiring information w, the bank's expected value of the risky part of debt, wS, is equal to $\overline{p}S$, and the cost of information is $c(\overline{p})$. If the hedge fund offers a price $\overline{p}S - c(\overline{p})$ to the bank prior to information acquisition, the bank is willing to accept the offer. The hedge fund who has bought this part of debt will not acquire information, so the discipline reduces to the ex post efficient one. $\quad\square$

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Figure 1. The incentive to acquire information as a function of debt

This figure plots the incentive of a debtholder to acquire information, $\Delta(u, p, D)$, as a function of level of debt, D, for a given p and u. The level of debt D is on the horizontal axis. The change in the dollar value of debt due to information acquisition by the debtholder is on the vertical axis. $\Delta(u, p, D)$ is maximized at $\hat{y}(u)$ $(0 < \hat{y}(u) < \overline{Y})$. At $D = \overline{Y}$, the debtholder is the sole owner of the firm, and the incentive to enforce the covenant is equal to the expected change in firm value associated with restricting investment, $p(E[y|u] - E_I[y|u])$.
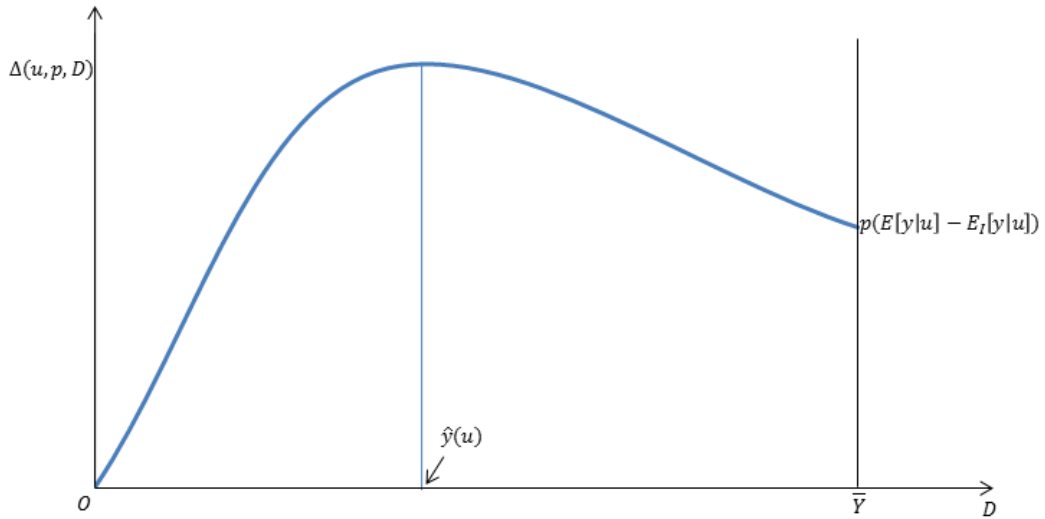
Figure 2. The marginal incentive to acquire information as a function of debt

This figure plots the marginal incentive of a debtholder to acquire information, $\Delta_p(u^*, p, D)$, as a function of level of debt, D, for a case when $E[y|u^*] - E_I[y|u^*] < a$. The level of debt D is on the horizontal axis. The thick curve is the marginal incentive to collect information $y = \Delta_p(u^*, p, D)$. The thin horizontal line is $y = a$. D^* is such level of debt, at which lines $y = \Delta_p(u^*, p, D)$ and $y = a$ intersect, so there are two solutions, $\{D^{*,L}, D^{*,H}\}$. When $u = u^*$, the debtholder with a level of debt D^* is indifferent between acquiring information or not.
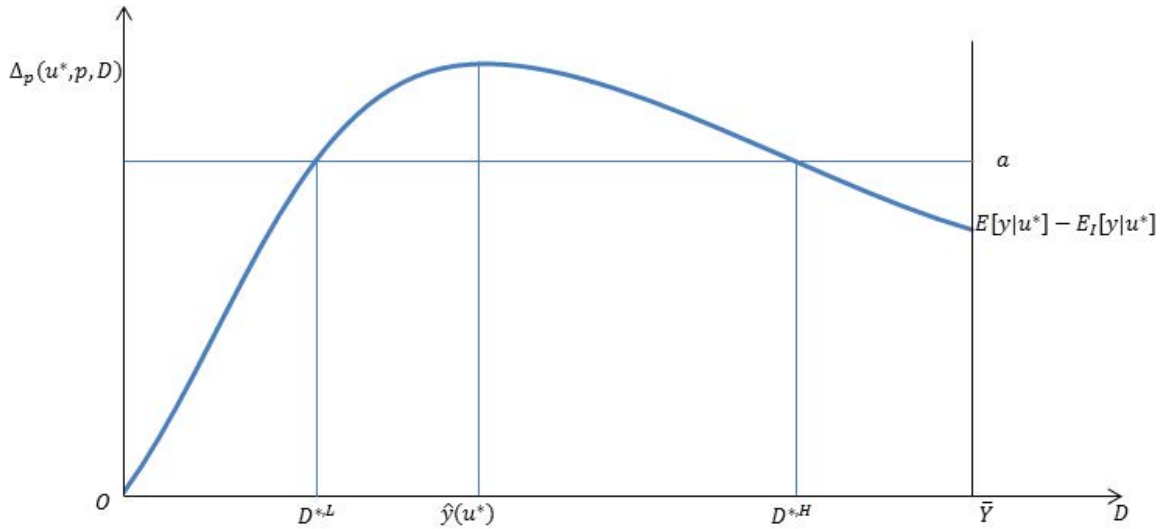
Figure 3. The marginal incentive to acquire information for a debtholder vs. a shareholder

This figure plots the debtholder's marginal incentive to acquire information, $\Delta_p(u^*, p, D)$, and the marginal incentive of a large shareholder who owns a stake l in the firm when $a < E[y|u^*] - E_I[y|u^*]$. The level of debt $D \in [0, \overline{Y}]$ and holdings $l \in [0, 1]$ are on the horizontal axis. The thick curve is the change in the value of debt $y = \Delta_p(u^*, p, D)$. The horizontal thin line is $y = a$. D^* is the point of intersection of lines $y = \Delta_p(u^*, p, D)$ and $y = a$. The dashed line is the marginal incentive to collect information for a large shareholder, $y = l[E[y|u^*] - E_I[y|u^*]]$. The optimal large shareholder's holding l^* is solved by equating $y = l[E[y|u^*] - E_I[y|u^*]]$ and $y = a$.