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Security Design, Insider Monitoring, and Financial Market Equilibrium

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Abstract. This paper considers a problem of security design in the presence of monitoring done by a large investor to discipline the management of a firm. Since the large investor enjoys only part of the benefits generated by her monitoring activities but incurs all the associated costs, the design and amount of security need to be structured so as to motivate her to maintain an efficient level of monitoring, if no other mechanism exists to make her commit to specific levels of monitoring in advance. By assuming that the large investor takes account of the effect of the issued amount of security on the revenues received, we show that the optimal security is a debt-like security such as standard debt with a positive probability of default, or debt with call options. We also verify that the financial market equilibrium is constrained Pareto optimal.

Key words: security design, insider monitoring, corporate governance.

JEL classification codes: D82, G10, G30, G32.

1. Introduction

Large investors – institutional investors such as pension funds, mutual funds, commercial banks, insurance companies, and finance companies, as well as private investors such as initial owners – monitor and control the management of companies on behalf of the other investors.[1] However, in recent years, the securitizing

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[1] In the United States, large shareholders are more common than is often believed (see Demsetz (1983), Shleifer and Vishny (1988), and Holderness and Sheehan (1988)). Furthermore, large investors such as pension funds and mutual funds have increasingly played active roles as delegated monitors in recent years (see Admati, Pfleiderer, and Zechner (1994)). In other countries, large investors are more prevalent. In Germany and Japan, commercial banks have significant powers because they vote significant blocks of shares, sit on boards of directors, play a dominant role in lending, and operate in a legal environment favorable to creditors (see Aoki (1990), Franks and Mayer (1994), OECD (1995), and Gorton and Schmid (1996)). Furthermore, in Japan, large cross-holdings also strengthen the role of large investors (Prowse (1992), Berglöf and Perotti (1994), and

of financial assets and a shift away from bank borrowing toward bond and equity financing have grown significantly.[2] If this tendency increases the number of shares owned by small and passive investors, it may reduce the incentive for large investors to monitor the performance of the management of a given company. This possibility arises from a free-rider problem: small and passive investors realize part of the benefits of monitoring performed by large investors but they incur none of the costs of the monitoring. This paper investigates how the design and issued amount of security can be organized so as to best enhance the role of the large investor as a delegated monitor who disciplines the performance of a company's management.

To attain our goal, we consider the problem of security design under asymmetric information when investors can freely trade in the market. In particular, we develop a model in which a large investor affects the return structure of a risky project by having access to costly monitoring technology but cannot be made to commit to monitoring the management of the firm at any particular level of intensity because her monitoring level is hidden from outside investors. In this framework, one natural question is whether standard debt or some other simple security design would be suitable under reasonable assumptions. Another question is how the interaction between the design of a security, amount of the security implemented, and the intensity of the large investor's monitoring is structured.

The main thesis of this paper depends on a mechanism in which the design and issued amount of security influences the intensity of the large investor's monitoring, not only through a direct effect on her ex ante payoff but also through an indirect effect via the market security price on her ex ante payoff. To clarify the basic idea, consider first an entrepreneur (a large investor) who holds a project that generates risky returns in future periods. She may keep some of the future returns for herself and securitize the other portion of the future returns to raise capital and maintain liquidity. Once the large investor issues a security, she turns effective control of the firm over to a manager. However, the large investor is assumed to have access to costly technology for monitoring the management of the firm and thus can affect the return structure of the project.[3] However, if the large investor carries out such monitoring, small and passive investors can free-ride on part of the benefits of the control function of the large investor, although these investors incur none of the costs of monitoring. This externality reduces the likelihood of the large investor's

OECD (1995)). In France, cross-ownership and core industries are the norm (OECD (1995)). Finally, in most of the rest of the world except the United Kingdom, firms are controlled by large owners such as the families of founders or the State. For the literature and empirical evidence on this issue, see Shleifer and Vishny (1997) and La Porta, Lopez-de-Silanes, and Shleifer (1999).

[2] For the decline in the importance of bank financing in Japan, see Hoshi, Kashyap, and Scharfstein (1990) and Campbell and Hamao (1994). For the German evidence, see Baums (1994).

[3] The monitoring level of the large investor may also be interpreted as her managerial effort or her investment level in the production or investment processes. If we follow this interpretation, our research enables us to investigate the underinvestment problem such as Williamson (1985), Klein, Crawford, and Alchian (1978), and Grout (1984) within the financial market equilibrium where the design and issued amount of security are endogenously determined.

carrying out high intensity monitoring unless she can be made to commit to prior monitoring levels before she designs and issues the security.

In this model, the design and issued amount of security affects the large investor's monitoring because of both the direct effect on her ex ante payoff and the indirect effect on her ex ante payoff through a change in the security price. The logic of the indirect effect is explained as follows. If small and passive investors are aware that a change in the design and issued amount of security affects the large investor's monitoring, the security price at which the trade takes place will reflect this awareness.

More specifically, small and passive investors rationally anticipate a low intensity of monitoring if the large investor designs and sells to small and passive investors a security that is more sensitive to the variations of future returns or if she sells a security more aggressively. This expectation implies that in this situation a lower security price will prevail. Such an indirect effect of the design and issued amount of security causes a liquidity cost that is borne by the large investor, who issues the security. Thus, the large investor needs to consider not only the direct effect of the design and issued amount of security, including a *retention cost* associated with a high unsecuritized or unsold portion of the cash flows, but also the indirect effect of the design and issued amount of security through a change in the security price, including a *liquidity cost* associated with a low rate of monitoring.

The above arguments show that there is a potential conflict between the need for liquidity preference and the efficiency of monitoring. Furthermore, these arguments indicate that the design of the security and the amount issued are incentive devices independent of one another for reconciling the friction between these two aims. Nevertheless, the interaction between the design of the security, the amount issued, and the large investor's monitoring remains imperfectly understood in the literature of corporate governance or finance. Indeed, the literature reveals several difficulties. The first problem is that only a limited menu of debt and equity has been studied. The second problem is that most of the arguments in this field depend on the bilateral contract framework but not on the market equilibrium framework.[4]

To avoid these difficulties and formalize the trade-off between the retention cost and the liquidity cost, we incorporate four key issues into our model. First, to motivate the entrepreneur (large investor) to issue a security backed by future risky returns, we assume that she must sell her issued security for liquidity reasons, as studied in Allen and Gale (1988, 1991), Gale (1992), and DeMarzo and Duffie (1999). Thus, the retention cost arises from retaining a large amount of unsecuritized returns or unsold securities. Second, we assume that the large investor can choose a level of monitoring to discipline the management of the firm and affect the structure of risky returns in future periods, while she cannot be committed to any specific levels of monitoring until she designs and issues a security. As a result, the free-rider problem associated with monitoring in the presence of small and

[4] Holmström and Tirole (1993) and Admati, Pfleiderer, and Zechner (1994) are the exceptional ones.

passive investors naturally occurs. This causes a liquidity cost to the large investor because her weaker incentive to monitor makes the security price lower. Third, we do not take the forms of financial claims as given, such as debt and equity, but rather try to derive these instruments as an optimal security design. By designing securities, the large investor can balance the retention cost against the liquidity cost. Finally, instead of a bilateral contract model, we set up a simple market (general) equilibrium model in which the large investor sells her issued security to small and passive investors, taking account of the effect of the amount sold on the revenues received. This framework enables us to investigate the price effect of the design and issued amount of security. This framework also allows us to consider how the recent trend in the financing patterns of nonfinancial firms away from (indirect) bank borrowing and toward (direct) bond financing in Germany and Japan affects their corporate governance systems.

By considering these four issues, we show that the optimal security is a debt-like security such as standard debt with a positive probability of default, or debt with call options in the presence of the monitoring problem. This result suggests that it cannot be necessarily optimal to issue risk free debt with zero default probability. The intuitive reason for this result is that in the present model, the large investor wants to sell some portion of the security and receive the revenues from the sale of the security in the initial period to maintain liquidity; as a result, to promote sales revenues, the large investor is motivated to set security claims at each possible contingency to increase by the maximum amount that the firm can pay by taking account of the adverse effect on monitoring. If the security claims were not constrained by monitoring considerations, then the optimal security would become equity. In fact, since the security claims must be constrained to some extent by monitoring considerations, the optimal security becomes a debt-like security such as standard debt with a positive probability of default or debt with call options.

We also compare the allocation of the financial market equilibrium with three benchmark allocations. The first benchmark case is concerned with the competitive equilibrium allocation, in which the large investor does not take account of the effect of the amount of security issued on her sales revenues. The second benchmark case is the "passive" equilibrium allocation, in which the large investor becomes a passive investor, that is, she chooses the minimum monitoring level. The final benchmark case deals with the constrained social surplus maximizing allocation, in which the social planner maximizes the social surplus subject to the constraints: (i) that the large investor initially owns the risky project,[5] (ii) that her monitoring level is unobservable to outside investors, and (iii) that she cannot be committed to any specific levels of monitoring before she designs and issues the security. In the first two benchmark cases, we show that the competitive equilibrium allocation is identical with the passive one. More specifically, under these two equilibrium allocations, either the optimal security is equity or the financial market breaks

[5] Unless we assume that the large investor initially owns the risky project, we cannot incorporate her liquidity benefits into the social surplus.

down, and the monitoring level of the large investor is minimized. Compared to the final benchmark allocation, the allocation of the financial market equilibrium, in which the large investor considers the effect of the amount sold on the revenues received, is proved to be constrained Pareto optimal: it attains the constrained social surplus maximizing allocation.

Our research is related to two strands of the literature. One is concerned with security design under the bilateral contract or the general equilibrium model, while the other is involved with insider or speculator monitoring under the general equilibrium model. In the analysis of security design under the bilateral contract model, Hart and Moore (1989) and Bolton and Scharfstein (1990) show that standard debt is an optimal contract when managers can appropriate to themselves income not paid out. Berglöf and von Thadden (1994), incorporating partial liquidation and multiple investors into the Hart and Moore model, discuss whether short-term debt, long-term debt, or equity are the best securities the firm can issue. However, these papers do not investigate the monitoring activity of investors. Townsend (1979), Diamond (1984), Gale and Hellwig (1985), and von Thadden (1995) do consider the monitoring activity of investors under the bilateral contract model, and prove that standard debt is an optimal contract. Although these papers make important contributions, they shed little light on the effect of security design on the market security price because their framework is restricted to bilateral contracts.

The problem of optimal security design in the general equilibrium model is analyzed with symmetric information by Allen and Gale (1988, 1991), and with adverse selection by Boot and Thakor (1993), Nachman and Noe (1994), Demange and Laroque (1995), Ohashi (1995), Rahi (1995, 1996), and DeMarzo and Duffie (1999). This line of research, however, does not examine the implications of monitoring done by investors under asymmetric information.

In work most closely related to ours, Holmström and Tirole (1993) and Admati, Pfleiderer, and Zechner (1994) explore the implications of monitoring done by investors under the general equilibrium model with asymmetric information.[6] Holmström and Tirole develop a model in which the equity ownership structure of firms affects the value of market monitoring through its effect on market liquidity. Admati, Pfleiderer, and Zechner study the effect of monitoring done by large shareholders on security market equilibrium. Our analysis goes beyond these two interesting papers by considering the problem of security design endogenously instead of focusing on particular financial claims such as equity.

The paper is organized as follows. Section 2 describes the basic model. Section 3 characterizes the allocation at financial market equilibrium. Section 4 compares

[6] The recent work of Bolton and von Thadden (1998) and Maug (1998) compares the liquidity benefits obtained through dispersed corporate ownership with the benefits from efficient management control achieved by some degree of ownership concentration. Kahn and Winton (1998) also demonstrate that market liquidity can undermine effective control by a large shareholder because it gives the large shareholder excessive incentives to speculate rather than monitor.

the allocation at financial market equilibrium with the three benchmark allocations. Section 5 summarizes our results and discusses some directions for future study.

2. The Model

We consider a model in which there exist one large investor (the issuer) and a set of outside investors. The large investor owns a risky project that generates future cash flows, and also has access to some monitoring activities by which she can affect the structure of the returns of the risky project. We assume that all investors are risk neutral and normalize the market interest rate to zero.

The model has three periods, indexed $t = 0, 1, 2$. In the initial period, the large investor designs a security whose return represents a claim backed by some part of the risky project returns of the firm, with the total supply normalized to one. The large investor also offers the security for sale on the security market. The large investor then decides to sell a fraction $q_L \in [0, 1]$ of the security to the market at a price p. The large investor herself keeps the fraction $(1 - q_L)$ of the security.[7] On the other side of the market, outside investors establish their share of security allocations, $q_O \in [0, 1]$. Once the large investor issues the security, she turns effective control of the risky project (firm) over to the management. In period 1, the large investor has access to costly technology of monitoring the management, and can affect the return structure of the risky project. Given the costs and benefits of monitoring, the large investor chooses the level of monitoring. Note that the large investor makes the monitoring decision by taking into account the share of security allocations established in period 0. There is no further trading from period 1 to period 2. In period 2, the returns of the risky project are realized and the claims of the security are paid off to security holders. The large investor also receives the residual claims that remain after the security claims are paid to security holders including the large investor herself.

To formalize the model, we require specific assumptions about the liquidity motive of the large investor, the preference of outside investors, and the monitoring technology of the large investor.

To provide the motivation for liquidation, we assume that the large investor evaluates the period 2 cash flows at a rate $\delta \in (0, 1)$. This assumption implies that the large investor is indifferent as to whether she keeps future project returns or sells them for δ cents in the dollar in cash by securitizing them. This also means that, if the large investor retains a portion of the security, the private value of one dollar's worth of security returns to the large investor is δ. Similar assumptions are made in Allen and Gale (1988, 1991), Gale (1992), and DeMarzo and Duffie

[7] The fraction q_L sold to the market does not necessarily equal to 1 because the large investor cannot sell all the holding fraction of the security even though she adjusts the design of the security. In other words, a change in the fraction of the security sold affects the revenues of the large investor in a different way from a change in the design of the security (see equation (3)). Thus, the fraction of the security sold is not a perfect substitute for the design of the security in our model.

(1999).[8] Since we assume that high transaction costs deter the large investor and outside investors from building a bilateral contract relation, the large investor has an incentive to securitize some portion of the future risky project returns and sell the security to outside investors.

In contrast, outside investors are assumed to have no liquidity motives. Since outside investors do not care when asset returns are generated, they have no concern about the timing of payments.

The large investor has access to costly technology of monitoring the management. The technology affects the structure of the returns of the risky project as follows:[9,10]

$$\widetilde{X} = \begin{cases} X_g, & \text{with probability } \sigma_g(m), \\ X_b, & \text{with probability } \sigma_b(m), \end{cases}$$

where $X_g > X_b \geq 0$, $(\sigma_g(m), \sigma_b(m)) \in \{(\sigma_g(m), \sigma_b(m)) \mid \sigma_g(m) + \sigma_b(m) = 1, \sigma_g(m) > 0, \sigma_b(m) > 0\}$, and m is the intensity of monitoring.[11] One part of the efficiency of monitoring is captured by the function $\sigma_g(m)$, where $\sigma_g'(m) > 0$ and $\sigma_g''(m) < 0$. The other part of the efficiency of monitoring is characterized by the cost of monitoring at level m, expressed by cm, where c is the unit monitoring cost. Let $\underline{m}$ be the minimum monitoring level required to sustain the monitoring process.[12]

All the project returns at each state, (X_g, X_b), and the fraction of the security sold by the large investor to the market, q_L, can be verified with no cost. On the other hand, the monitoring level chosen by the large investor, m, cannot be observed by any outside agents. Thus, the large investor cannot be committed to any specific levels of monitoring until period 1. The functions $(\sigma_g(m), \sigma_b(m))$ and the parameters (X_g, X_b, c, δ) are assumed to be common knowledge.

The security is represented by a claim, that is, any promise to make a future payment, contingent on the state of nature (that is, the project returns). Let $\widetilde{F}$ be a real-valued random variable that generates a security claim F_g at the good state, and a security claim F_b at the bad state, respectively. We focus our attention on the

[8] More specifically, $\delta = 0$ in Allen and Gale (1988, 1991) and Gale (1992), while $\delta \in (0, 1)$ in DeMarzo and Duffie (1999). Another line of literature assumes the presence of noise or liquidity traders, instead of assuming the liquidity motive for the issuer. See Boot and Thakor (1993), Holmström and Tirole (1993), and Demange and Laroque (1995). As pointed out in DeMarzo and Duffie (1999), this kind of assumption ($\delta < 1$) is justified if the issuer faces strict credit constraints or binding minimal capital requirements. It is also plausible to impose this assumption if firms need to raise capital to fund other valuable investment opportunities under various forms of market imperfections.

[9] To simplify the analysis, we do not specify the action of managers nor the structure of managerial contracts. Holmström and Tirole (1993) throw light on this problem in their model of market monitoring.

[10] In the subsequent discussion, "tildes" is used to denote random variables.

[11] As mentioned in note 3, the monitoring level of the large investor, m, may also be interpreted as her managerial effort or her investment level.

[12] The minimum level of monitoring $\underline{m}$ may be set equal to zero.

set of admissible securities. These are defined by a set of functions satisfying the following limited liability and monotonicity conditions:

$$0 \leq F_s \leq X_s, \qquad s = g,\ b, \tag{1}$$

$$F_b \leq F_g. \tag{2}$$

In the subsequent discussion, we denote the set of admissible securities as Δ. In the limited liability condition (1), the restriction of $0 \leq F_s$ for $s = g,\ b$ expresses limited liability for security holders. The restriction of $F_s \leq X_s$ for $s = g,\ b$ implies limited liability for the large investor as a residual claimant. The monotonicity condition (2) shows that the security claim is nondecreasing in the available firm cash flows.[13] These assumptions are quite common in the finance literature, and are justified in Innes (1990), Nachman and Noe (1994), Hart and Moore (1994), and DeMarzo and Duffie (1999).

Now, the security represented by the claim $(F_g,\ F_b)$ pays an amount $\min(F_s,\ X_s)$ for $s = g,\ b$ when the returns of the project are realized in period 2.[14] The large investor then receives the cash revenues from the sale of the fraction q_L of the security in period 1, and the residual cash flows of $\max(X_s - F_s,\ 0)$ for $s = g,\ b$ and the claims for the unsold fraction $(1 - q_L)$ of the security in period 2.

The trading process is described as a Walrasian process in which the large investor is strategic. The large investor chooses the fraction of the security sold to the market, q_L, by taking into account the effect of the issued amount on the security price, p. We assume that the large investor perceives an inverse demand correspondence $p \in P(q_L;\ \widetilde{F})$ for the issued security $\widetilde{F}$, where $P : [0,\ 1] \rightarrow \Re_+$. In the next section, we specify how $P(q_L;\ \widetilde{F})$ is determined. On the other hand, outside investors behave as representative, risk neutral, price-taking investors. Thus, outside investors do not receive expected net gains from buying any security at market equilibrium.

The expected payoff of the large investor in period 0 is then given by

$$\begin{aligned} R_L(m,\ \widetilde{F},\ q_L) \ = \ & \delta E \max(\widetilde{X} - \widetilde{F},\ 0) + \delta(1 - q_L) E \min(\widetilde{F},\ \widetilde{X}) \\ & + q_L P(q_L;\ \widetilde{F}) - cm, \end{aligned} \tag{3}$$

where E is the expectation operator. The right-hand side of (3) consists of the expected residual claims retained by the large shareholder, $E \max(\widetilde{X} - \widetilde{F},\ 0)$, the expected claims for the unsold fraction $(1 - q_L)$ of the security, $(1 - q_L) E \min(\widetilde{F},\ \widetilde{X})$,

[13] As indicated in Innes (1990) and Nachman and Noe (1994), the monotonicity assumption is important in establishing the optimality of the debt-like security because this assumption can exclude the type of "do or die" contract under which the firm pays everything to investors in the bad state and nothing in the good state. Nachman and Noe (1994) additionally assume another monotonicity condition that the residual claims $X_s - F_s$ are nondecreasing in the available project returns, X_s. Even when this assumption is additionally imposed, all of our results in this paper still remain valid.

[14] If the security belongs to the set of admissible securities, Δ, then we always have $\min(X_s,\ F_s) = F_s$.

the cash revenues raised from the sale of the security, $q_L P(q_L;\ \widetilde{F})$, and the monitoring cost, $-cm$. The first two terms are discounted by the rate δ because the returns of these two claims accrue only in period 2. The monitoring cost is not discounted, since it must be paid in period 1. Note that the first two terms clearly depend on the monitoring level m because the realized probability of the state is affected by the choice of m.

The expected payoff of outsiders in period 0 is similarly represented by

$$R_O(q_O,\ p) = q_O[E \min(\widetilde{F},\ \widetilde{X}) - p]. \tag{4}$$

Since outside investors do not behave strategically, they take the security price p as given.

A financial market equilibrium is now characterized by $(m^\circ,\ \widetilde{F}^\circ,\ q_L^\circ,\ q_O^\circ,\ p^\circ)$ that satisfies the following conditions (see Figure 1):

FINANCIAL MARKET EQUILIBRIUM: (i) *Sequential Optimality of the Large Investor.* In period 1, the large investor chooses a monitoring level m° such that

$$\Pi_{L1}(\widetilde{F},\ q_L) = \max_{m \geq \underline{m}} R_L(m,\ \widetilde{F},\ q_L). \tag{5}$$

In period 0, given the knowledge of the price correspondence $P(q_L;\ \widetilde{F})$, the large investor chooses a design $\widetilde{F}^\circ$ and a fraction q_L° of the security sold to the market such that

$$\Pi_{L0} = \max_{\widetilde{F} \in \Delta,\ q_L \in [0,1]} \Pi_{L1}(\widetilde{F},\ q_L), \tag{6}$$

where Δ is the set of admissible securities defined by (1) and (2).
(ii) *Optimality of Outsider Investors.* In period 1, outside investors purchase a fraction q_O° of the security supplied in the market, relative to an observed price p°, such that

$$\Pi_O(p^\circ) = \max_{q_O \in [0,1]} R_O(q_O,\ p^\circ). \tag{7}$$

(iii) *Market Equilibrium.* The security price p° and the sold and purchased fractions $(q_L^\circ,\ q_O^\circ)$ must satisfy

$$p^\circ \in P(q_L^\circ;\ \widetilde{F}^\circ), \tag{8}$$

and

$$q_L^\circ = q_O^\circ. \tag{9}$$

Note that the large investor selects a security design $\widetilde{F}$ from the set of admissible securities Δ, a sold fraction q_L from $[0,\ 1]$, and a monitoring level m from

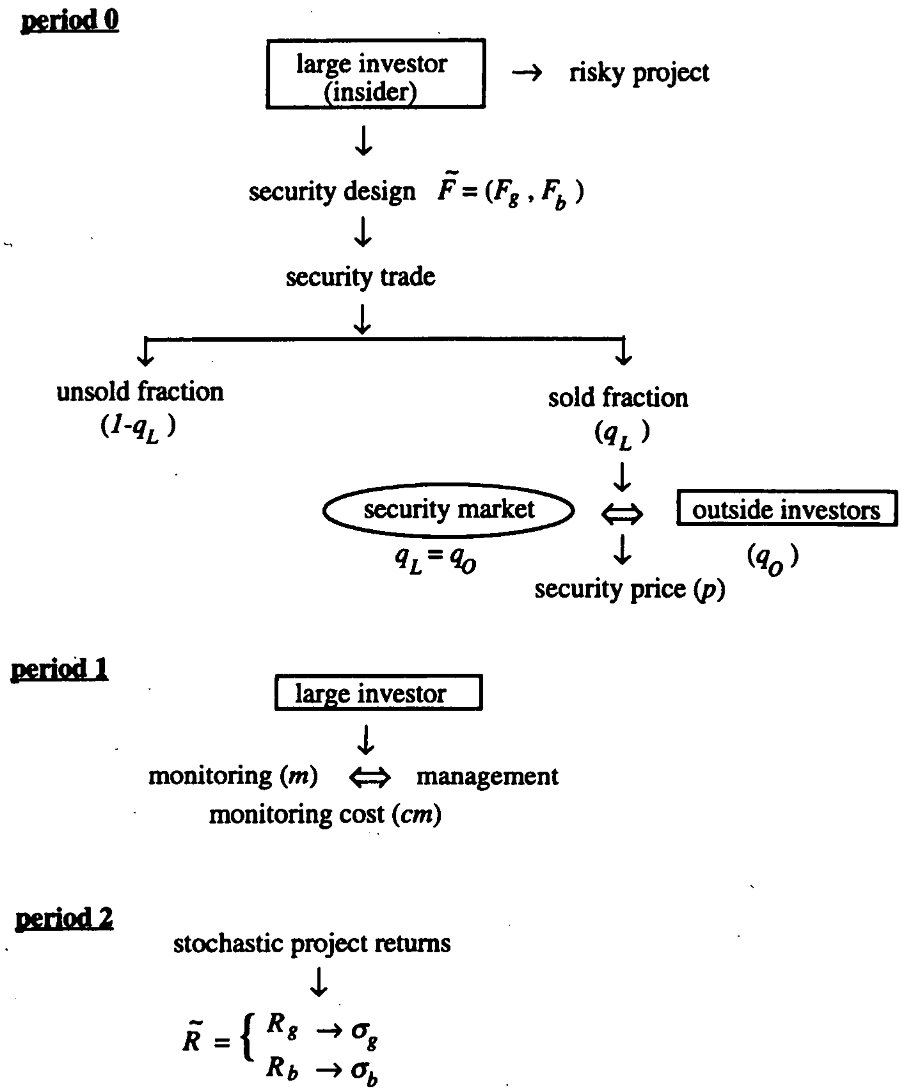

Figure 1. Sequence of the events.

$[\underline{m}, \infty)$. Outside investors select a purchased fraction q_O from [0, 1]. Since the large investor cannot be committed in advance to any specific levels of monitoring, she must solve the sequential problem made up of (5) and (6).

3. Financial Market Equilibrium

In this section, we first derive the inverse demand correspondence $P(q_L; \tilde{F})$ from the condition of the optimality of outside investors and the condition of market equilibrium by taking as given a security design chosen by the large investor, $\tilde{F}$.

We next solve the sequential optimization problem of the large investor in two steps, and determine the remaining variables endogenously.

3.1. INVERSE DEMAND CORRESPONDENCE

Solving the optimization problem of outside investors, (7), with (4), we see

$$q_O \begin{cases} = 0 & \text{if } E \min(\widetilde{F}, \widetilde{X}) < p, \\ \in [0, 1] & \text{if } E \min(\widetilde{F}, \widetilde{X}) = p, \\ = 1 & \text{if } E \min(\widetilde{F}, \widetilde{X}) > p. \end{cases} \tag{10}$$

Combining (9) and (10), we have

$$q_L \begin{cases} = 0 & \text{if } E \min(\widetilde{F}, \widetilde{X}) < p, \\ \in [0, 1] & \text{if } E \min(\widetilde{F}, \widetilde{X}) = p, \\ = 1 & \text{if } E \min(\widetilde{F}, \widetilde{X}) > p. \end{cases} \tag{11}$$

The relation between q_L and p determined by (11) gives the inverse demand correspondence $p \in P(q_L;\ \widetilde{F})$.

3.2. THE MONITORING PROBLEM FACED BY THE LARGE INVESTOR

We now proceed to the sequential optimization problem of the large investor. We discuss the optimality conditions for this problem by moving backward from period 1 to period 0.

We begin with solving the monitoring problem (5) faced in period 1 by the large investor, who designs a security $\widetilde{F}$ and holds a fraction $1 - q_L$ of the security after trading. Since the large investor takes the price correspondence $p \in P(q_L;\ \widetilde{F})$ as given because q_L and $\widetilde{F}$ are determined in period 0, it follows from (11) that the following three cases are distinguished: $E \min(\widetilde{F}, \widetilde{X}) < p$, $E \min(\widetilde{F}, \widetilde{X}) = p$, or $E \min(\widetilde{F}, \widetilde{X}) > p$.

We first discuss the case of $E \min(\widetilde{F}, \widetilde{X}) < p$, where $q_L = 0$ from (11). Given (1), (3) and $q_L = 0$, the objective function of (5) is reduced to

$$R_L(m, \widetilde{F}, 0) = \delta E \widetilde{X} - cm. \tag{12}$$

Rewriting (12) with the definition of $\widetilde{X}$, we specify the interim maximization problem of the large investor as follows:

$$\max_{m \geq \underline{m}} R_L(m, \widetilde{F}, 0) = \max_{m \geq \underline{m}} \left[\delta \sum_{i=g,b} X_i \sigma_i(m) - cm \right]. \tag{13}$$

Let us assume that the maximization problem (13) has an interior solution. Since the objective function (13) is globally concave with respect to m under $X_g > X_b$, the first-order condition for this problem becomes a global optimality condition. Solving (13) with $\sigma_g(m) + \sigma_b(m) = 1$, we see the following first-order condition:

$$\delta(X_g - X_b)\sigma_g'(m) - c = 0. \tag{14}$$

In this case, the monitoring level is ex post efficient because the large investor holds all the issued security. However, she cannot satisfy her liquidity needs.

We next examine the case of $E \min(\widetilde{F}, \widetilde{X}) = p$, where $q_L \in [0, 1]$ from (11). Rearranging (3) with the definitions of $\widetilde{X}$ and $\widetilde{F}$, we explicitly describe the interim maximization problem (5) by

$$\max_{m \geq \underline{m}} R_L(m, \widetilde{F}, q_L) = \max_{m \geq \underline{m}} \left[\delta \sum_{i=g,b} \max(X_i - F_i, 0)\sigma_i(m) + \delta(1 - q_L) \sum_{i=g,b} \min(F_i, X_i)\sigma_i(m) + pq_L - cm \right]. \tag{15}$$

We should again keep in mind that the security price p is determined in period 0. Thus, the large investor in this stage takes the security price p as given.

In the subsequent analysis, we assume that the maximization problem (15) has an interior solution that satisfies the second-order sufficient condition for m to be a local maximum of $R_L(m, \widetilde{F}, q_L)$.[15] Then, the first-order condition for the problem (15) implies a local optimality condition, and is expressed by

$$\delta \sum_{i=g,b} \max(X_i - F_i, 0)\sigma_i'(m) + \delta(1 - q_L) \sum_{i=g,b} \min(F_i, X_i)\sigma_i'(m) - c = 0. \tag{16}$$

Note that although the large investor pays the full cost of monitoring, she enjoys only a part of the benefits of the monitoring because the monitoring also affects the claims on the outsiders' holdings of the security. Thus, the monitoring level is always less than ex post efficient, which is achieved if the large investor is the sole owner of the security.

In fact, (16) is not easily tractable. To obtain a more manageable form, let us distinguish the following four cases by exploiting the monotonicity condition (2): (A) $F_b \leq F_g \leq X_b < X_g$ or $F_b \leq X_b \leq F_g \leq X_g$, (B) $F_b \leq X_b < X_g \leq F_g$, (C) $X_b \leq F_b \leq F_g \leq X_g$, and (D) $X_b \leq F_b \leq X_g \leq F_g$ or $X_b < X_g \leq F_b \leq F_g$. Furthermore, given the limited liability condition (1), the four possible cases of $\widetilde{F}$ introduced above are reduced to the following four possible sets $\widetilde{F}$ (see Figure 2): $\Delta(A) \equiv \{(F_g, F_b) \mid F_b \leq F_g \leq X_g \text{ and } 0 \leq F_b \leq X_b\}$, $\Delta(B) \equiv \{(F_g, F_b)$

[15] The second-order sufficient condition for m to be a local maximum of $R_L(m, \widetilde{F}, q_L)$ is automatically satisfied if we also assume another monotonicity condition, that the residual claims $X_s - F_s$ are nondecreasing in X_s.

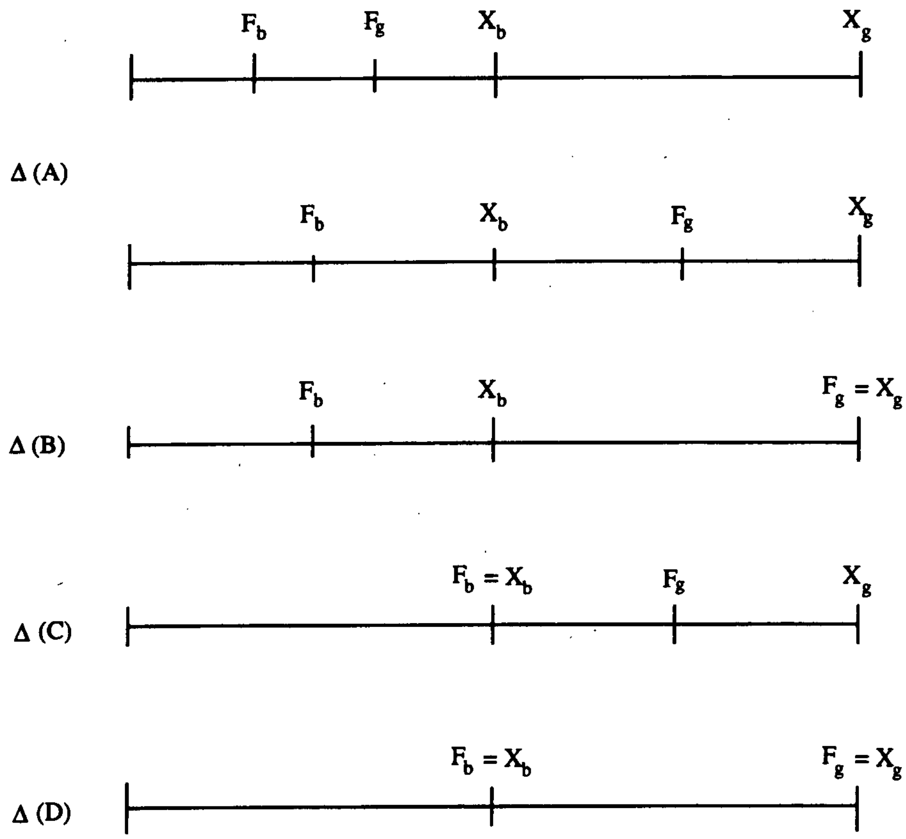

Figure 2. Four possible cases of $\widetilde{F}$.

$| \ 0 \leq F_b \leq X_b < X_g = F_g\}$, $\Delta(C) \equiv \{(F_g, F_b) \mid X_b = F_b \leq F_g \leq X_g\}$, and $\Delta(D) \equiv \{(F_g, F_b) \mid X_b = F_b < X_g = F_g\}$. Note that $\Delta(A)$ is identical to the set $\widetilde{F}$, $\{(F_g, F_b) \mid F_b \leq F_g \leq X_b < X_g$ or $F_b \leq X_b \leq F_g \leq X_g\}$, under conditions (1) and (2). Similarly, $\Delta(D)$ is identical with the set $\widetilde{F}$, $\{(F_g, F_b) \mid X_b \leq F_b \leq X_g \leq F_g$ or $X_b < X_g \leq F_b \leq F_g\}$, under conditions (1) and (2). From now on, we divide the space $\widetilde{F}$ into $\Delta(A)$, $\Delta(B)$, $\Delta(C)$, and $\Delta(D)$. For each division of the space of $\widetilde{F}$, the first-order condition for an interior solution to the monitoring problem is specified in the Appendix. In Subsection 3.3 and Section 4, the optimality condition will be fully exploited.

Finally, we investigate the case of $E \min(\widetilde{F}, \widetilde{X}) \geq p$, where q_L must be equal to 1 from (11). Then, it is immediately seen from (3) and $q_L = 1$ that the objective function of (5) is described by

$$R_L(m, \widetilde{F}, 1) = \delta E \max(\widetilde{X} - \widetilde{F}, 0) + P(1; \widetilde{F}) - cm.$$

Because of $E\min(\widetilde{F},\ \widetilde{X}) \geq p$ for $p \in P(1;\ \widetilde{F})$ from (11), we have $E\min(\widetilde{F},\ \widetilde{X}) \geq \sup\ P(1;\ \widetilde{F})$. Thus, using the definitions of $\widetilde{X}$ and $\widetilde{F}$, we find

$$\max_{m \geq \underline{m}} R_L(m,\ \widetilde{F},\ 1) = \max_{m \geq \underline{m}} \left[\delta \sum_{i=g,b} \max(X_i - F_i,\ 0)\sigma_i(m) + P(1;\ \widetilde{F}) - cm \right]$$

$$\leq \max_{m \geq \underline{m}} \left[\delta \sum_{i=g,b} \max(X_i - F_i,\ 0)\sigma_i(m) + \sum_{i=g,b} \min(F_i,\ X_i)\sigma_i(m) - cm \right]$$

$$= \lim_{q_L \to 1} \max_{m \geq \underline{m}} R_L(m,\ \widetilde{F},\ q_L). \tag{17}$$

Here, the inequality in (17) is derived from $E\min(\widetilde{F},\ \widetilde{X}) \geq \sup\ P(1;\ \widetilde{F})$, and the final equality in (17) is obtained from the limit of the right-hand side of (15) with $E\min(\widetilde{F},\ \widetilde{X}) = p$, as q_L converges to unity.

The arguments of the three cases examined above suggest the following. First, we can rule out the case of $E\min(\widetilde{F},\ \widetilde{X}) < p$. In this case, we cannot examine the problem of the security issue because the large investor holds all the issued security ($q_L = 0$). Second, we can substitute the case of $E\min(\widetilde{F},\ \widetilde{X}) = p$ for the case of $E\min(\widetilde{F},\ \widetilde{X}) > p$ because the latter is included in the former as q_L converges to unity. We will, therefore, focus on the case of both $E\min(\widetilde{F},\ \widetilde{X}) = p$ and $q_L > 0$ in the subsequent analysis.

3.3. THE PROBLEM FACED BY THE LARGE INVESTOR OF ISSUING THE SECURITY

We are now in a position to discuss the optimization problem of issuing the security, (6), faced by the large investor in period 0. To do so, we first solve the problem (6) with the restriction in which $\widetilde{F} = (F_g,\ F_b)$ belongs to one of the four sets defined in the preceding subsection: (A) $\widetilde{F} \in \Delta(A)$, (B) $\widetilde{F} \in \Delta(B)$, (C) $\widetilde{F} \in \Delta(C)$, and (D) $\widetilde{F} \in \Delta(D)$. Then, we compute the optimal value for the problem (6) under each of the four possible restrictions, and choose the maximal value among the optimal values of the four possible cases. The corresponding solution gives an optimal security design $\widetilde{F}^\circ = (F_g^\circ,\ F_b^\circ)$ and an optimal level of the sold fraction q_L° to the problem (6). In contrast to the analysis of the monitoring problem, the large investor must consider the effect of a change in her strategy on the security price. A detailed analysis of the optimizing conditions to the problem (6) is provided by (A5)–(A8) in the Appendix.

The most notable feature of these optimality conditions is that changes in the design of the security, $(F_g,\ F_b)$, or in the issued amount of security, q_L, has both a direct effect on the monitoring level and an indirect effect through a change in the security price. If the large investor did not take into account the effect of a change in

(F_g, F_b) or q_L on sales revenues, the optimal strategy would be given by $F_g = X_g$, $F_b = X_b$, and $q_L = 1$ in all possible cases, unless the security market breaks down. However, this implies that the large investor would securitize all the project returns and sell all of the security. Thus, the monitoring level would be minimized, which might cause a collapse of the security market: outside investors would rationally anticipate the strategy of the large investor and participate in the security market only if the security price is low enough.

On the basis of the optimality conditions (A5)–(A8) given in the Appendix, we now have the following proposition on the optimal strategy of the large investor for each possible set of $\widetilde{F}$. The detailed proof is presented in the Appendix.

PROPOSITION 1. (i) If $\widetilde{F}$ is restricted to $\Delta(A)$ or $\Delta(C)$, the optimal solution to the constrained maximization problem, $(m^*,\ F_g^*,\ F_b^*,\ q_L^*)$, is characterized by

$$\delta[X_g - X_b - q_L^*(F_g^* - X_b)]\sigma_g{}'(m^*) = c, \tag{18a}$$

$$F_g^* = \min\left(X_b - (1-\delta)\sigma_g(m^*)\left[\sigma_g'(m^*)\frac{\partial m^*}{\partial F_g^*}\right]^{-1},\ X_g\right), \tag{18b}$$

$$F_b^* = X_b, \tag{18c}$$

$$(1-\delta)[F_g^*\sigma_g(m^*) + X_b\sigma_b(m^*)] + q_L^*(F_g^* - X_b)\sigma_g'(m^*)\frac{\partial m^*}{\partial q_L^*} = 0. \tag{18d}$$

The large investor's payoff is then

$$\begin{aligned}\Pi_{L0}^A \;=\; \Pi_{L0}^C &= \delta[X_g\sigma_g(m^*) + X_b\sigma_b(m^*)] \\ &\quad + q_L^*(1-\delta)[F_g^*\sigma_g(m^*) + X_b\sigma_b(m^*)] - cm^*.\end{aligned} \tag{18e}$$

(ii) If $\widetilde{F}$ is restricted to $\Delta(B)$ or $\Delta(D)$, the optimal solution to the constrained maximization problem, $(m^{**},\ F_g^{**},\ F_b^{**},\ q_L^{**})$, is represented by

$$\delta(1 - q_L^{**})(X_g - X_b)\sigma_g'(m^{**}) = c, \tag{19a}$$

$$F_g^{**} = X_g, \tag{19b}$$

$$F_b^{**} = X_b, \tag{19c}$$

$$(1-\delta)[X_g\sigma_g(m^{**}) + X_b\sigma_b(m^{**})] + q_L^{**}(X_g - X_b)\sigma_g'(m^{**})\frac{\partial m^{**}}{\partial q_L^{**}} = 0. \tag{19d}$$

The large investor's payoff is then

$$\Pi_{L0}^B = \Pi_{L0}^D = [\delta + q_L^{**}(1-\delta)][X_g\sigma_g(m^{**}) + X_b\sigma_b(m^{**})] - cm^{**}. \tag{19e}$$

Proposition 1 shows that, if $\widetilde{F}$ is restricted to $\Delta(A)$ or $\Delta(C)$, the optimal security can be a debt-like security with $F_g^* < X_g$ and $F_b^* = X_b$. One interpretation of this kind of security is standard debt with default such as that analyzed in DeMarzo and Duffie (1999) and von Thadden (1995): F_g^* can be viewed as the face value, and F_b^* as the default payment of debt. Another interpretation is debt with call options (convertible bond or debt with warrant): $X_g - F_g^*$ can then be interpreted as the option premium. Proposition 1 also indicates that if $\widetilde{F}$ is restricted to $\Delta(B)$ or $\Delta(D)$, the optimal security is equity whose claim fully reflects the project returns.

It is instructive to explore the implications of equations (18) and (19). Let us begin with (18a). Given the security price determined in period 0, an increase in the monitoring effort in period 1 affects the ex ante payoff of the large investor through two routes. One effect increases the expected project returns, thereby further increasing not only the discounted residual returns to be received by the large investor, that is, $\delta(X_g - F_g^* - X_b + F_b^*)\sigma_g'(m^*)$, but also the discounted security returns for the unsold portion to be received by the large investor, that is, $\delta(1-q_L^*)(F_g^*-F_b^*)\sigma_g'(m^*)$. The combined effects *increase* the ex ante payoff of the large investor, expressed by the left-hand side of (18a). The other effect increases the total monitoring cost, c, thus *decreasing* the ex ante payoff of the large investor. This cost effect is represented by the right-hand side of (18a). The monitoring level is then chosen to balance the former benefit against the latter cost.

Before proceeding to (18b) and (18c), we discuss the implications of (18d) because it is then more straightforward to understand (18b) and (18c). An increase in the sold fraction has two potentially conflicting effects on the ex ante payoff of the large investor. One effect causes the large investor to receive higher revenues from the sale of the security. This effect enables the large investor to satisfy any desire to obtain as much revenue as possible at date 0 rather than at date 1 thus directly *increasing* her ex ante payoff, expressed by $(1-\delta)p^* = (1-\delta)[F_g^*\sigma_g(m^*) + X_b\sigma_b(m^*)]$. The other effect of an increase in q_L reduces the correlation between the ex post project returns and the ex post payoff of the large investor because she obtains the more deterministic sales revenues at period 0. Since this effect leads to a lower monitoring level, outside investors rationally anticipate a lower intensity of monitoring. This expectation reduces the security price, thus indirectly *decreasing* the large investor's revenues from the sale of the security, represented by $q_L^*(F_g^* - X_b)\sigma_g'(m^*)[\partial m^*/\partial q_L^*]$. The former direct benefit cancels out the latter indirect cost at the optimal level of the sold fraction.

We can now examine the implications of (18b) and (18c), and show how the design of the security affects the ex ante payoff of the large investor. If $F_g^* < X_g$, we multiply both sides of (18b) by q_L^* and rewrite it:

$$-q_L^*\delta\sigma_g(m^*) + q_L^*\sigma_g(m^*) + q_L^*(F_g^* - X_b)\sigma_g'(m^*)\frac{\partial m^*}{\partial F_g^*} = 0. \tag{20}$$

Given (20), an increase in F_g brings two direct effects to the ex ante payoff of the large investor. The first increases the discounted good state security returns to be received by the large investor, expressed by $\delta(1-q_L^*)\sigma_g(m^*)$. The second direct effect in turn decreases the discounted good state residual returns to be obtained by the large investor, represented by $-\delta\sigma_g(m^*)$. The combined two direct effects are then summarized by $-q_L^*\delta\sigma_g(m^*)$, which is *negative* and is shown by the first term in the left-hand side of (20). An increase in F_g also leads to two indirect effects on the ex ante payoff of the large investor due to a change in the security price. Due to an increase in the security returns at the good state, one indirect effect raises the security price. This effect results in an increase in the large investor's revenues from the sale of the security, represented by $q_L^*\sigma_g(m^*)$, which is *positive* and is indicated by the middle term in the left-hand side of (20). The other indirect effect of an increase in F_g reduces the incentive for the large investor to attain the good state because the combined two direct effects represented by the first term in the left-hand side of (20) decrease her discounted good state returns. This indirect effect causes the large investor to choose a lower monitoring level. Since outside investors anticipate this, the security price and the large investor's revenues from the sale of the security *decrease*. This effect is captured by the final term in the left-hand side of (20). The claim at the good state, F_g, is thus determined by considering all of these effects.

In contrast, the claim at the bad state, F_b, is found to be on the boundary of $F_b \leq X_b$, since the total effect of an increase in F_b on the ex ante payoff of the large investor, $q_L^*(1-\delta)\sigma_b(m^*) + q_L^*(F_g^* - X_b)\sigma_g'(m^*)\frac{\partial m^*}{\partial F_b^*}$, becomes positive. The reason for $F_b^* = X_b$ mainly depends on these facts: (i) that an increase in F_b further motivates the large investor to attain the good state because its direct effects decrease her discounted bad state returns mainly through a decline in the discounted bad state residual returns to be received by the large investor, and (ii) that its positive indirect effects dominate its negative direct effects.

In a similar manner, we can investigate the implications of (19) by substituting X_g for F_g.

Using Proposition 1, an optimal solution to the sequential optimization problem faced by the large investor, $(m^\circ,\ F_g^\circ,\ F_b^\circ,\ q_L^\circ)$, is represented by

$$(m^\circ,\ F_g^\circ,\ F_b^\circ,\ q_L^\circ)\begin{cases} = (m^*,\ F_g^*,\ F_b^*,\ q_L^*) & \text{if } \Pi_{L0}^A > \Pi_{L0}^B, \\ = (m^{**},\ F_g^{**},\ F_b^{**},\ q_L^{**}) & \text{if } \Pi_{L0}^A \leq \Pi_{L0}^B. \end{cases} \tag{21}$$

Here, Π_{L0}^A and Π_{L0}^B are determined by (18e) and (19e), respectively.

Comparing Π_{L0}^A with Π_{L0}^B, we now obtain the following proposition that characterizes the optimal security design. The detailed proof is provided in the Appendix.

PROPOSITION 2. (i) In the presence of the monitoring problem, the optimal security is standard debt with default or debt with call options ($F_g^* < X_g$ and $F_b^* = X_b$). (ii) In the absence of the monitoring problem, the optimal security is equity.

One crucial implication of this proposition is that it is not optimal to issue risk-free debt such as $F_g^* = F_b^*$ because risk-free debt prevents the large investor from satisfying the desire to obtain the revenues as much as possible at date 0 rather than at date 1. Another important implication of this proposition is that in the presence of the monitoring problem, it is not optimal to issue equity.

A natural intuition is that risk-free debt would be an optimal security if we neglected the large investor's desire to receive the revenues as much as possible at date 0 rather than at date 1. This is because the large investor would receive the full margin benefit from monitoring as well as bearing the full marginal cost of monitoring. However, in the present case, the large investor can sell some portion of the security and receive the revenues from the sale of the security. Since the discount factor δ is less than one, the sales revenues received in period 0 are higher than the residual claims received in period 2. Hence, unless the monitoring level decreases through a change in security payments, the large investor is motivated to increase the sales revenues received in period 0. This implies that, in the absence of monitoring considerations, the large investor is motivated to set security claims at each state to increase by the maximum amount that the firm can pay. If the security claims need not be constrained by monitoring considerations, then the optimal security becomes equity because $F_g^* = X_g$ and $F_b^* = X_b$. On the other hand, if the security claims are constrained by monitoring considerations to some extent, the large investor needs to enhance her monitoring activity by increasing the residual revenues received at the good state in period 2. The large investor would therefore face the possibility that the optimal security becomes standard debt with default because she must set F_g^* less than X_g while keeping $F_b^* = X_b$.

More specifically, in the presence of monitoring considerations, the large investor needs to consider the trade-off between a decline in F_g from X_g and a rise in q_L. In other words, she needs to balance the costs of securitizing a smaller portion of the project returns against the costs of selling a smaller portion of the issued security.[16] Since the total effects of a decrease in F_g from X_g and an increase in q_L on the ex ante payoff of the large investor per issued amount are positive, the optimal security involves debt-like types such as standard debt with default or debt with call options.

Several remarks about this proposition are in order. First, we should notice that the result of this proposition depends on the simplifying assumptions such as two possible outcomes and so on. Second, Admati, Pfleiderer, and Zechner (1994) discuss the monitoring activity of the large investor when only equity can be issued. However, Proposition 2 implies that the optimal security becomes debt-like in the presence of the monitoring problem, although our framework is restricted. This suggests that the security design problem needs to be analyzed endogenously in the study of the monitoring of the large investor.

[16] We should keep in mind that securitizing a larger portion of the project returns is not a perfect substitute for selling a larger portion of the issued security. This mainly depends on the assumption that a change in F_g can affect the payoff of the large investor in a different way from a change in q_L. See note 7.

4. Normative Analysis of the Financial Market Equilibrium

In this section, we compare the financial market equilibrium in the preceding section with several benchmark cases: the competitive equilibrium allocation, the passive equilibrium allocation, and the constrained social surplus maximizing allocation.

The competitive equilibrium allocation deals with the situation in which the large investor does not take account of the effect of the issued amount of security on her sales revenues. The passive equilibrium allocation arises from the situation in which the large investor chooses the minimum monitoring level. The constrained social surplus maximizing allocation corresponds to the constrained Pareto optimal allocation such that the social planner maximizes the social surplus subject to several information constraints. In the analysis that follows, we show that the financial market equilibrium in the preceding section is constrained Pareto optimal, whereas the competitive and passive equilibrium allocations are not. With regard to the competitive and passive equilibrium allocations, we suggest that they are identical.

PROPOSITION 3. If the large investor does not take account of the effect of the issued amount of security on her sales revenues, the optimal allocation, $(\widehat{m}, \widehat{F}_g, \widehat{F}_b, \widehat{q_L})$, would be given such that the monitoring level of the large investor, $\widehat{m}$, is minimized: more specifically, $\widehat{m} = \underline{m}$, $\widehat{F}_g = X_g$, $\widehat{F}_b = X_b$, and $\widehat{q_L} = 1$.

Proof. If the large investor does not take into account the effect of the issued amount of security on her sales revenues, the optimality conditions for the problem (6) provided by (A5)–(A8) in the Appendix show that her optimal strategy is given by $\widehat{m} = \underline{m}$, $\widehat{F}_g = X_g$, $\widehat{F}_b = X_b$, and $\widehat{q_L} = 1$ in all possible cases, provided the security market does not collapse.

The intuitive explanation for Proposition 3 is clarified as follows. If the large investor does not consider the effect of the issued amount of security on her sales revenues, it is optimal for the large investor to securitize all the project returns and sell all of the security, because she evaluates the sales revenues received in period 0 more than the residual claims received in period 2. Since the large investor need not take account of the monitoring problem, she can minimize the monitoring level. However, this might cause the collapse of the security market because outside investors would rationally anticipate the large investor's strategy and participate in the security market only if the security price is low enough.

Proposition 2 indicates that in the presence of the monitoring problem, the optimal security is a debt-like security if the large investor takes account of the effect of the amount sold on the revenues received. On the other hand, Proposition 3 suggests that even in the presence of the monitoring problem, the optimal security is equity if the large investor does not take account of the effect of the amount of security issued on her sales revenues, that is, if she chooses the minimum monitoring level. The result of Proposition 3 depends on the assumption that the large investor cannot be committed to any prior levels of monitoring until she designs and issues the security.

We next examine the relation between the financial market equilibrium and constrained social surplus maximizing allocations, defined such that the social planner maximizes the social surplus subject to the constraints: (i) that the large investor initially owns the risky project,[17] (ii) that her monitoring level is unobservable to outside investors, and (iii) that she cannot be committed to any specific levels of monitoring before she designs and issues the security.

Let $S(m, \widetilde{F}, q)$ be the social surplus defined by

$$S(m, \widetilde{F}, q) = \delta E\widetilde{X} + q(1-\delta)E\min(\widetilde{F}, \widetilde{X}) - cm, \tag{23}$$

where the first term represents the project returns, the second term expresses the liquidity benefits of the large investor, and the third term indicates the monitoring cost.

Then, the constrained social surplus maximizing allocation is formally characterized by the following sequential maximization problem:

Constrained social surplus maximizing allocation. In period 1, the social planner chooses a monitoring level m such that

$$S^1(\widetilde{F}, q) = \max_{m \geq \underline{m}} S(m, \widetilde{F}, q). \tag{24}$$

In period 0, the social planner chooses a design $\widetilde{F}$ and a fraction q of security sold to outside investors such that

$$S^0 = \max_{\widetilde{F}\in\Delta,\, q\in[0,1]} S^1(\widetilde{F}, q). \tag{25}$$

Given (A1) and (A3) with $E\min(\widetilde{F}, \widetilde{X}) = p$ in the Appendix, it can be seen immediately from (23) that the constrained social surplus maximization problem is equivalent to the sequential optimization problem of the large investor at financial market equilibrium. Thus, we obtain the following proposition:

PROPOSITION 4. If the large investor takes account of the effect of the amount sold on the revenues received, the financial market equilibrium characterized in the preceding section is constrained Pareto optimal in the sense that it attains the constrained social surplus maximizing allocation.

In view of Propositions 2–4, we see that the competitive equilibrium allocation is not constrained Pareto optimal. Thus, the large investor must take into account the effect of the issued amount of security on her sales revenues to attain the

[17] See note 5.

constrained social surplus maximizing allocation. This finding is reminiscent of the results of Allen and Gale (1991) in a different context. The intuition behind this proposition is that the social surplus can be transformed into the surplus of the large investor as a result of the price adjustment at financial market equilibrium. This finding mainly depends on both the price-making behavior of the large investor and the risk neutrality of the large investor and outside investors.

5. Conclusion

This paper has developed a framework for analyzing a problem of security design in the presence of monitoring done by a large investor to discipline the management of a firm. Since the large investor enjoys only a part of the benefits brought about by her monitoring activities but incurs all the associated costs, she needs to structure the problem of security design to motivate herself to make an efficient level of monitoring if she cannot be committed to any prior levels of monitoring before she designs and issues the security. In fact, it is costly to design and issue the security to attain an efficient level of monitoring because of both the direct effect on the ex ante payoff of the large investor and the indirect effect on her ex ante payoff through a change in the security price.

By assuming that the large investor takes account of the effect on her sales revenues of the amount of security issued, we have shown that the optimal security is a debt-like security such as standard debt with a positive probability of default, or debt with call options in the presence of the monitoring problem. This result suggests that it is not necessarily optimal to issue a security with zero default probability such as risk-free debt, and that the monitoring model of Admati, Pfleiderer, and Zechner (1994) is restricted in the sense that only equity is permitted to be issued. We have also proved that the financial market equilibrium is constrained Pareto optimal. In contrast, if the large investor does not take into account the effect of the amount of security issued on her sales revenues, the competitive equilibrium allocation is not constrained Pareto optimal or the market collapses. Furthermore, unless the market breaks down, the optimal security in this case is always equity; and the monitoring level of the large investor is minimized.

As suggested in DeMarzo and Duffie (1999), the model rather closely fits into the context of the design of corporated securities that are sold by an informed underwriter who retains some fraction of the security of issuing firms. In Germany and Japan, the recent trend in the financing patterns of nonfinancial firms away from (indirect) bank borrowing and toward (direct) bond financing has been affecting their corporate governance systems. However, since German house banks and Japanese main banks usually retain the security of their borrowing firms, our result indicates that these intermediaries may still discipline the management of firms by designing a debt-like security for their borrowing firms and retaining some portion of the security.

Within our framework, many issues remain to be investigated. Among other things, the problem of multi-security design is an important question that we hope to pursue in future research. Furthermore, the spanning issue caused by the risk averting actions of investors should also be examined. Finally, as has been recently studied under the incomplete contract model, the bankruptcy and liquidation problem is an important topic of corporate governance (see Hart and Moore (1989), Bolton and Scharfstein (1990), Aghion and Bolton (1992), Berglöf and von Thadden (1994), and Dewatripont and Tirole (1994)). It will be very interesting to explore how the design of securities can resolve the bankruptcy and liquidation problem at financial market equilibrium.

Appendix

5.1. FIRST-ORDER CONDITION (16) FOR EACH DIVISION OF THE SPACE $\widetilde{F}$:

For each possible set of $\widetilde{F}$, we obtain the corresponding value of the objective function of (5) and the corresponding expression for the first-order condition (16):
Objective function of (5) in the case of $E\min(\widetilde{F}, \widetilde{X}) = p$:

(A) $\widetilde{F} \in \Delta(A)$:

$$R_L(m, \widetilde{F}, q_L) = \delta[(X_g - F_g)\sigma_g(m) + (X_b - F_b)\sigma_b(m)] + \delta(1 - q_L)[F_g\sigma_g(m) + F_b\sigma_b(m)] + pq_L - cm, \quad \text{(A1A)}$$

(B) $\widetilde{F} \in \Delta(B)$:

$$R_L(m, \widetilde{F}, q_L) = \delta(X_b - F_b)\sigma_b(m) + \delta(1 - q_L)[X_g\sigma_g(m) + F_b\sigma_b(m)] + pq_L - cm, \quad \text{(A1B)}$$

(C) $\widetilde{F} \in \Delta(C)$:

$$R_L(m, \widetilde{F}, q_L) = \delta(X_g - F_g)\sigma_g(m) + \delta(1 - q_L)[F_g\sigma_g(m) + X_b\sigma_b(m)] + pq_L - cm, \quad \text{(A1C)}$$

(D) $\widetilde{F} \in \Delta(D)$:

$$R_L(m, \widetilde{F}, q_L) = \delta(1 - q_L)[X_g\sigma_g(m) + X_b\sigma_b(m)] + pq_L - cm. \quad \text{(A1D)}$$

First-order condition (16):

(A) $\widetilde{F} \in \Delta(A)$:

$$\delta[X_g - X_b - q_L(F_g - F_b)]\sigma_g'(m) = c, \quad \text{(A2A)}$$

(B) $\widetilde{F} \in \Delta(B)$:

$$\delta[X_g - X_b - q_L(X_g - F_b)]\sigma_g'(m) = c, \tag{A2B}$$

(C) $\widetilde{F} \in \Delta(C)$:

$$\delta[X_g - X_b - q_L(F_g - X_b)]\sigma_g'(m) = c, \tag{A2C}$$

(D) $\widetilde{F} \in \Delta(D)$:

$$\delta(1 - q_L)(X_g - X_b)\sigma_g'(m) = c. \tag{A2D}$$

We should again notice that the large investor takes the security price as given when solving the monitoring problem in period 1.

In Subsection 3.3, we will use (A1) and (A2) to solve the problem (6) faced by the large investor in period 0.

5.2. OPTIMIZING CONDITIONS FOR THE PROBLEM (6):

For this analysis, we need to respecify the objective function $\Pi_{L1}(\widetilde{F}, q_L)$ of the problem (6) for each possible case generated from the restriction of $\widetilde{F}$. Substituting $E\min(\widetilde{F}, \widetilde{X})$ for p in (A1A)–(A1D) yields:

(A) $\widetilde{F} \in \Delta(A)$:

$$\Pi_{L1}^{A}(\widetilde{F}, q_L) = \delta[X_g\sigma_g(m_A) + X_b\sigma_b(m_A)] + q_L(1 - \delta)[F_g\sigma_g(m_A) + F_b\sigma_b(m_A)] - cm_A, \tag{A3A}$$

(B) $\widetilde{F} \in \Delta(B)$:

$$\Pi_{L1}^{B}(\widetilde{F}, q_L) = \delta[X_g\sigma_g(m_B) + X_b\sigma_b(m_B)] + q_L(1 - \delta)[X_g\sigma_g(m_B) + F_b\sigma_b(m_B)] - cm_B, \tag{A3B}$$

(C) $\widetilde{F} \in \Delta(C)$:

$$\Pi_{L1}^{C}(\widetilde{F}, q_L) = \delta[X_g\sigma_g(m_C) + X_b\sigma_b(m_C)] + q_L(1 - \delta)[F_g\sigma_g(m_C) + X_b\sigma_b(m_C)] - cm_C, \tag{A3C}$$

(D) $\widetilde{F} \in \Delta(D)$:

$$\Pi_{L1}^{D}(\widetilde{F}, q_L) = [\delta + q_L(1 - \delta)][X_g\sigma_g(m_D) + X_b\sigma_b(m_D)] - cm_D, \tag{A3D}$$

where m_A, m_B, m_C, and m_D denote the monitoring levels that satisfy the optimality conditions (A2A), (A2B), (A2C), and (A2D), respectively.

Now, for each possible set of $\widetilde{F}$, we solve the following constrained maximization problem:

$$\Pi^i_{L0} = \max_{\widetilde{F}\in\Delta(i),\, q_L\in[0,1]} \Pi^i_{L1}(\widetilde{F}, q_L), \qquad i = A, B, C, D. \tag{A4}$$

Using the envelope theorem and (A2A)–(A2D), the first-order conditions for each constrained maximization problem are described as follows:

(A) $\widetilde{F} \in \Delta(A)$:

$$q_L\left[(1-\delta)\sigma_g(m_A) + (F_g - F_b)\sigma_g'(m_A)\frac{\partial m_A}{\partial F_g}\right] + \eta_{g0} - \eta_{g1} = 0, \tag{A5a}$$

$$q_L\left[(1-\delta)\sigma_b(m_A) + (F_g - F_b)\sigma_g'(m_A)\frac{\partial m_A}{\partial F_b}\right] - \eta_{g0} + \eta_{b0} - \eta_{b1} = 0, \tag{A5b}$$

$$(1-\delta)[F_g\sigma_g(m_A) + F_b\sigma_b(m_A)] + q_L(F_g - F_b)\sigma_g'(m_A)\frac{\partial m_A}{\partial q_L} - \varsigma = 0, \tag{A5c}$$

where η_{g0}, η_{g1}, η_{b0}, η_{b1}, and ς are the nonnegative multipliers associated with $F_g \geq F_b$, $X_g \geq F_g$, $F_b \geq 0$, $X_b \geq F_b$, and $1 \geq q_L$, respectively. The partial derivatives $\partial m_A/\partial F_g$, $\partial m_A/\partial F_b$, and $\partial m_A/\partial q_L$ are derived by totally differentiating (A2A) with respect to m_A, F_g, F_b, and q_L.

(B) $\widetilde{F} \in \Delta(B)$:

$$q_L\left[(1-\delta)\sigma_b(m_B) + (X_g - F_b)\sigma_g'(m_B)\frac{\partial m_B}{\partial F_b}\right] + \eta_{b0} - \eta_{b1} = 0, \tag{A6a}$$

$$(1-\delta)[X_g\sigma_g(m_B) + F_b\sigma_b(m_B)] + q_L(X_g - F_b)\sigma_g'(m_B)\frac{\partial m_B}{\partial q_L} - \varsigma = 0, \tag{A6b}$$

where η_{b0}, η_{b1}, and ς are the nonnegative multipliers associated with $F_b \geq 0$, $X_b \geq F_b$, and $1 \geq q_L$, respectively. The partial derivatives $\partial m_B/\partial F_b$ and $\partial m_B/\partial q_L$ are obtained by totally differentiating (A2B) with respect to m_B, F_b, and q_L. Note that F_g is equal to X_g in this parameter constellation.

(C) $\widetilde{F} \in \Delta(C)$:

$$q_L\left[(1-\delta)\sigma_g(m_C) + (F_g - X_b)\sigma_g'(m_C)\frac{\partial m_C}{\partial F_g}\right] + \eta_{g0} - \eta_{g1} = 0, \tag{A7a}$$

$$(1-\delta)[F_g\sigma_g(m_C) + X_b\sigma_b(m_C)] + q_L(F_g - X_b)\sigma_g'(m_C)\frac{\partial m_C}{\partial q_L} - \varsigma = 0, \tag{A7b}$$

where η_{g0}, η_{g1}, and ς are the nonnegative multipliers associated with $F_g \geq X_b$, $X_g \geq F_g$, and $1 \geq q_L$, respectively. The partial derivatives $\partial m_C/\partial F_g$ and $\partial m_C/\partial q_L$ are constructed by totally differentiating (A2C) with respect to m_C, F_g, and q_L. Note that F_b is equal to X_b in this case.

(D) $\widetilde{F} \in \Delta(D)$:

$$(1-\delta)[X_g\sigma_g(m_D) + X_b\sigma_b(m_D)] + q_L(X_g - X_b)\sigma_g'(m_D)\frac{\partial m_D}{\partial q_L} - \varsigma = 0, \quad \text{(A8)}$$

where ς is the nonnegative multiplier associated with $1 \geq q_L$. The partial derivative $\partial m_D/\partial q_L$ is derived by totally differentiating (A2D) with respect to m_D and q_L. Note that $F_g = X_g$ and $F_b = X_b$ in this case.

Proof of Proposition 1. We begin by evaluating the first-order conditions for $\widetilde{F}$ and q_L, assuming $\widetilde{F} \in \Delta(A)$, that is, (A5a)–(A5c). To do so, we first need to specify $\partial m_A/\partial F_g$, $\partial m_A/\partial F_b$, and $\partial m_A/\partial q_L$, which are obtained from (A2A). Totally differentiating (A2A) with respect to m_A, F_g, F_b, and q_L yields

$$\frac{\partial m_A}{\partial F_g} = \frac{\delta q_L \sigma_g'(m_A)}{\Lambda_A} < 0, \quad \text{(A9)}$$

$$\frac{\partial m_A}{\partial F_b} = -\frac{\delta q_L \sigma_g'(m_A)}{\Lambda_A} > 0, \quad \text{(A10)}$$

$$\frac{\partial m_A}{\partial q_L} = \frac{\delta(F_g - F_b)\sigma_g'(m_A)}{\Lambda_A} \leq 0, \quad \text{(A11)}$$

where $\Lambda_A = \delta[X_g - X_b - q_L(F_g - F_b)]\sigma_g''(m_A) < 0$. Note that Λ_A is negative because the second-order condition must be satisfied. The signs of (A9)–(A11) then follow from (2), $0 < q_L \leq 1$, and $\sigma_g'(m) > 0$. Since η_{g0}, η_{b0}, and η_{b1} are the nonnegative multipliers associated with $F_g \geq F_b$, $F_b \geq 0$, and $X_b \geq F_b$, (A5b) and (A10) show that $\eta_{g0} > 0$ or $\eta_{b1} > 0$ or both, that is, $F_g = F_b$ or $X_b = F_b$ or $F_g = F_b = X_b$. If $\eta_{g0} > 0$ so that $F_g = F_b$, it is seen from (A5a) that $\eta_{g1} > 0$, which means $X_g = F_g = F_b$. This contradicts $F_b \leq X_b < X_g$ for $\widetilde{F} \in \Delta(A)$. Thus, we must have $\eta_{b1} > 0$ and $F_b = X_b$. Furthermore, if $F_g = F_b = X_b$, it again follows from (A5a) that $\eta_{g1} > 0$, which implies $X_g = F_g$. However, this contradicts $F_g = F_b = X_b < X_g$. Therefore, we must have $X_b = F_b < F_g$ and $\eta_{g1} = 0$. Given $\partial m_A/\partial F_g < 0$ from (A9) and $\partial m_A/\partial q_L < 0$ from (A11) with $X_b = F_b < F_g$, we can assume that F_g and q_L are determined as an interior solution by (A5a) and (A5c). Thus, rearranging (A2A), (A5a), and (A5c) with $X_b = F_b$ and $\eta_{g0} = \eta_{g1} = \varsigma = 0$, we obtain (18a)–(18e) if $\widetilde{F} \in \Delta(A)$.

We next discuss the first-order conditions for $\widetilde{F}$ and q_L, assuming $\widetilde{F} \in \Delta(B)$, that is, (A6a) and (A6b). To specify $\partial m_B/\partial F_b$ and $\partial m_B/\partial q_L$, we totally differentiate (A2B) with respect to m_B, F_b, and q_L:

$$\frac{\partial m_B}{\partial F_b} = -\frac{\delta q_L \sigma_g'(m_B)}{\Lambda_B} > 0, \tag{A12}$$

$$\frac{\partial m_B}{\partial q_L} = \frac{\delta (X_g - F_b)\sigma_g'(m_B)}{\Lambda_B} \leq 0, \tag{A13}$$

where $\Lambda_B = \delta[X_g - X_b - q_L(X_g - F_b)]\sigma_g''(m_B) < 0$, which is negative from the second-order condition. It then follows from (A6a) and (A12) that $\eta_{b1} > 0$, that is, $X_b = F_b$. Given $\partial m_B/\partial q_L < 0$ from (A13) and $F_b = X_b < X_g$, we can assume that q_L is determined as an interior solution by (A6b). Thus, rearranging (A2B) and (A6b) with $\varsigma = 0$ and $(F_b, F_g) = (X_b, X_g)$ from $F_b = X_b$ and $\widetilde{F} \in \Delta(B)$, we have (19a)–(19e) if $\widetilde{F} \in \Delta(B)$.

To examine the first-order conditions for $\widetilde{F}$ and q_L when $\widetilde{F} \in \Delta(C)$, that is, (A7a) and (A7b), we totally differentiate (A2C) with respect to m_C, F_g, and q_L:

$$\frac{\partial m_C}{\partial F_g} = \frac{\delta q_L \sigma_g'(m_C)}{\Lambda_C} < 0, \tag{A14}$$

$$\frac{\partial m_C}{\partial q_L} = \frac{\delta (F_g - X_b)\sigma_g'(m_C)}{\Lambda_C} \leq 0, \tag{A15}$$

where $\Lambda_C = \delta[X_g - X_b - q_L(F_g - X_b)]\sigma_g''(m_C) < 0$, which is negative from the second-order condition. Suppose that $X_b = F_b = F_g$. Then, it is found from (A7a) that $\eta_{g1} > 0$, that is, $X_g = F_g$. Since this contradicts $F_g = X_b$, we must have $X_b = F_b < F_g$ for $\widetilde{F} \in \Delta(C)$. Given $\partial m_C/\partial F_g < 0$ from (A14) and $\partial m_C/\partial q_L < 0$ from (A15) with $F_g > X_b$, we can assume that F_g and q_L are determined as an interior solution by (A7a) and (A7b). Thus, rearranging (A2C), (A7a), and (A7b) with $X_b = F_b$ and $\eta_{g0} = \eta_{g1} = \varsigma = 0$, we have (18a)–(18e) if $\widetilde{F} \in \Delta(C)$.

Finally, we investigate the first-order condition for q_L when $\widetilde{F} \in \Delta(D)$, that is, (A8). We totally differentiate (A2D) with respect to m_D and q_L, and see

$$\frac{\partial m_D}{\partial q_L} = \frac{\delta (X_g - X_b)\sigma_g'(m_D)}{\Lambda_D} < 0. \tag{A16}$$

Here, $\Lambda_D = \delta(1 - q_L)(X_g - X_b)\sigma_g''(m_D) < 0$, which is negative due to the second-order condition. Given $\partial m_D/\partial q_L < 0$ from (A16), we can assume that q_L is determined as an interior solution by (A8). Thus, rearranging (A2D) and (A8) with $X_b = F_b$, $X_g = F_g$, and $\varsigma = 0$, we obtain (19a)–(19e) if $\widetilde{F} \in \Delta(D)$.

Proof of Proposition 2. Since $(\widetilde{F}^{**}, q_L^{**})$ is feasible in the problem (6) even if $\widetilde{F}$ is restricted to the set $\Delta(A) \cup \Delta(C)$, we should notice that $\Pi_{L1}(\widetilde{F}^{*}, q_L^{*}) \geq \Pi_{L1}(\widetilde{F}^{**}, q_L^{**})$. Thus, the remaining problem is to check whether or not a solution with $F_g^* < X_g$ is really optimal.

In the absence of the monitoring problem, $\sigma_g(m)$ is independent of m so that $\sigma_g^{'}(m) = 0$. Thus, the problem (6) has no interior solution with respect to F_g if $\widetilde{F}$ is restricted to the set $\Delta(A) \cup \Delta(C)$. More specifically, it follows from (A5a) and (A7a) that $\eta_{g1} > 0$ in this case. Thus, we see $F_g^* = X_g$ even if $\widetilde{F}$ is restricted by the set $\Delta(A) \cup \Delta(C)$. This finding implies that the optimal security is equity.

We now return to the situation in which $\sigma_g^{'}(m) > 0$. Let us take the solution $(F_g, F_b, q_L) = (F_g^{**}, F_b^{**}, q_L^{**}) = (X_g, X_b, q_L^{**})$ as a starting point. Then, consider a permutation $(F_g^{\diamond}, F_b^{\diamond}, q_L^{\diamond})$ from the solution $(F_g^{**}, F_b^{**}, q_L^{**})$; that is, $(F_g^{\diamond}, F_b^{\diamond}, q_L^{\diamond}) = (X_g - \epsilon, X_b, q_L^{**}(1+\phi))$, where $X_g - X_b > \epsilon > 0$ and $\phi > 0$. Choose $m^{\diamond}$ that satisfies

$$\delta[X_g - X_b - q_L^{\diamond}(F_g^{\diamond} - X_b)]\sigma_g^{'}(m^{\diamond}) = c,$$

which means

$$\delta[X_g - X_b - q_L^{**}(1+\phi)(X_g - \epsilon - X_b)]\sigma_g^{'}(m^{\diamond}) = c. \tag{A17}$$

Since $(F_g^{\diamond}, F_b^{\diamond}) \in \Delta(A) \cap \Delta(C)$, the large investor's payoff is represented by

$$\Pi_{L1}^{A}(\widetilde{F}^{\diamond}, q_L^{\diamond}) = \delta[X_g\sigma_g(m^{\diamond}) + X_b\sigma_b(m^{\diamond})]$$
$$+ q_L^{**}(1+\phi)(1-\delta)[(X_g - \epsilon)\sigma_g(m^{\diamond}) + X_b\sigma_b(m^{\diamond})] - cm^{\diamond}.$$

Now, for Π_{L0}^{B} defined in Proposition 1, construct

$$\Gamma^{\epsilon,\phi} \equiv \Pi_{L1}^{A}(\widetilde{F}^{\diamond}, q_L^{\diamond}) - \Pi_{L0}^{B} = \delta(X_g - X_b)[\sigma_g(m^{\diamond}) - \sigma_g(m^{**})] +$$
$$+ q_L^{**}(1+\phi)(1-\delta)(X_g - \epsilon - X_b)[\sigma_g(m^{\diamond}) - \sigma_g(m^{**})] - c(m^{\diamond} - m^{**})$$
$$+ q_L^{**}\phi(1-\delta)[(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})] - q_L^{**}(1-\delta)\epsilon\sigma_g(m^{**}). \tag{A18}$$

Because of $\sigma_g^{''} < 0$, we find

$$\delta(X_g - X_b)[\sigma_g(m^{\diamond}) - \sigma_g(m^{**})] - \delta q_L^{**}(1+\phi)(X_g - \epsilon - X_b)[\sigma_g(m^{\diamond})$$
$$- \sigma_g(m^{**})] > -\delta[X_g - X_b - q_L^{**}(1+\phi)(X_g - \epsilon - X_b)]\sigma_g^{'}(m^{\diamond})(m^{**} - m^{\diamond}),$$
$$\text{for } m^{**} \neq m^{\diamond}. \tag{A19}$$

Combining (A18) and (A19) yields

$$\begin{aligned}\Gamma^{\epsilon,\phi} > &-\{\delta[X_g - X_b - q_L^{**}(1+\phi)(X_g - \epsilon - X_b)]\sigma_g'(m^{\Diamond}) - c\}(m^{**} - m^{\Diamond})\\ &+ q_L^{**}(1+\phi)(X_g - \epsilon - X_b)[\sigma_g(m^{\Diamond}) - \sigma_g(m^{**})]\\ &+ q_L^{**}\phi(1-\delta)[(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})]\\ &- q_L^{**}(1-\delta)\epsilon\sigma_g(m^{**}), \qquad \text{for } m^{**} \neq m^{\Diamond}.\end{aligned}$$

Since $m^{\Diamond}$ satisfies (A17), this inequality reduces to

$$\begin{aligned}\Gamma^{\epsilon,\phi} > q_L^{**}\{&(1+\phi)(X_g - \epsilon - X_b)[\sigma_g(m^{\Diamond}) - \sigma_g(m^{**})]\\ &+ \phi(1-\delta)[(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})] - (1-\delta)\epsilon\sigma_g(m^{**})\},\end{aligned}$$

$$\text{for } m^{**} \neq m^{\Diamond}. \tag{A20}$$

Now, suppose that we can take a pair $(\epsilon, \phi) \in \{(\epsilon, \phi) \mid X_g - X_b > \epsilon > 0$ and $\phi > 0\}$ which satisfies

$$X_g - X_b - q_L^{**}(1+\phi)(X_g - \epsilon - X_b) \geq X_g - X_b - q_L^{**}(X_g - X_b), \tag{A21}$$

$$\phi[(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})] \geq \epsilon\sigma_g(m^{**}). \tag{A22}$$

Condition (A21) with (19a), (A17), and $\sigma_g'' < 0$ leads to $m^{\Diamond} \geq m^{**}$, thereby ensuring that the first term in the large bracket of the right-hand side of (A20) is nonnegative. Condition (A22) also means that the sum of the remaining two terms in the large bracket of the right-hand side of (A20) are nonnegative. Thus, if (A21) and (A22) hold, the right-hand side of (A20) is nonnegative. Combining (A21) and (A22) under $(\epsilon, \phi) \in \{(\epsilon, \phi) \mid X_g - X_b > \epsilon > 0$ and $\phi > 0\}$, we now have the following sufficient condition for $\Gamma^{\epsilon,\phi} > 0$:

$$\Xi_1 \equiv \frac{\epsilon\sigma_g(m^{**})}{(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})} \leq \phi \leq \frac{\epsilon}{X_g - \epsilon - X_b} \equiv \Xi_2, \tag{A23}$$

where m^{**} is determined with q_L^{**} from (19a) and (19d). Note that $X_g - X_b > \epsilon$ is also fulfilled for any pair of $(\epsilon, \phi) > 0$ that satisfies (A23). Thus, if these exists a pair $(\epsilon, \phi) > 0$ that satisfies (A23), then $\Gamma^{\epsilon,\phi} > 0$ for $(\epsilon, \phi) \in \{(\epsilon, \phi) \mid X_g - X_b > \epsilon > 0$ and $\phi > 0\}$. This finding shows

$$\Pi_{L0}^A \geq \Pi_{L1}^A(\widetilde{F}^{\Diamond}, q_L^{\Diamond}) > \Pi_{L0}^B.$$

The remaining problem is to prove that a pair $(\epsilon, \phi) > 0$ that satisfies (A23) always exists. Given $\sigma_b(m^{**}) = 1 - \sigma_g(m^{**})$, we see

$$\frac{\epsilon\sigma_g(m^{**})}{(X_g - \epsilon)\sigma_g(m^{**}) + X_b\sigma_b(m^{**})} \leq \frac{\epsilon}{X_g - \epsilon - X_b + \frac{X_b}{\sigma_g(m^{**})}} < \frac{\epsilon}{X_g - \epsilon - X_b},$$

for any ϵ such that $X_g - X_b > \epsilon > 0$. This completes the proof of Proposition 2.

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