The Many Faces of Information Disclosure

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In this article we ask: what kind of information and how much of it should firms voluntarily disclose? Three types of disclosures are considered. One is information that complements the information available only to informed investors (to-be-processed complementary information). The second is information that is orthogonal to that which any investor can acquire and thus complements the information available to *all* investors (preprocessed complementary information). And the third is information that substitutes for the information of the informed investors in that it reveals to all what was previously known only by the informed (substitute information). Our main results are as follows. First, in equilibrium, all types of firms voluntarily disclose all three types of information. Second, in contrast to the existing literature, complementary information disclosure by firms strengthens investors' private incentives to acquire information. Substitute information disclosure weakens private information acquisition incentives. Third, while complementary information disclosure has an ambiguous effect on financial innovation incentives, substitute information disclosure weakens those incentives.

Suppose you are the Chief Executive Officer (CEO) of a firm and must decide whether to disclose to investors some information you have about the firm's future prospects. Let us say the information is about a major investment in research and development. Would you disclose it? Would your decision change if the information is about the renewal of a major contract with your principal customer? Or what if the information relates to an end-of-the-year earnings forecast that is based partly on information already communicated to analysts during quarterly meetings?

One would think intuitively that your decision may differ across these three disclosures because each refers to a different *kind* of information. This intuition comes in part from the fact that it is not only the firm's managers who have information about the firm, it is also being produced by some investors in the market. Thus whatever you disclose could, besides its direct effect on your firm's stock price, also affect the price indirectly by influencing the incentives of investors to collect information about the firm. And the way

Anjan Thakor gratefully acknowledges the financial support of the William Davidson Institute at the Michigan Business School. Arnoud Boot thanks the Stockholm School of Economics (Sweden) and the Davidson Institute at the University of Michigan Business School for their hospitality. We also thank an anonymous referee, Sheridan Titman, Emre Ergungor, participants at the Davidson Institute 1997 seminar on emerging economies, and especially Anand Goel and Henk Koster for their helpful comments. Address correspondence to Anjan V. Thakor, University of Michigan Business School, 701 Tappan St., Ann Arbor, MI 48109-1234.

The Review of Financial Studies Winter 2001 Vol. 14, No. 4, pp. 1021–1057

these incentives are affected is likely to depend on the kind of information disclosed. Any voluntary information disclosure decision must therefore take into account these direct and indirect effects and will also depend on the nature of the information being considered for disclosure. The purpose of this article is to formally explore these determinants of a firm's voluntary information disclosure decision.

There has recently been a resurgence of interest in information disclosure. This reflects the burgeoning interest in financial system design, both from a research and a policy standpoint [see, e.g., example, Allen and Gale (1997, 1999), Boot and Thakor (1997)]. As part of designing their financial systems, policymakers in emerging economies are asking about price transparency and information disclosure. The focus is on capital market growth, which is affected by the trading volume of exchange-traded securities as well as the extent of financial innovation, both of which in turn may be influenced by information disclosure in public securities markets. The most compelling question regarding disclosure, and the one we confront in this article, is *what kind of information and how much of it should firms disclose*?

The literature on information disclosure has primarily focused on *insider trading* and *market liquidity*, *spillover effects* (proprietary information), and *private information production incentives* in addressing this question. From the insider trading and market liquidity literature, the general result is that information disclosure is good. Fishman and Hagerty (1992) show that insider trading can discourage "outside" investors to become informed at a cost, so that it follows that disclosure of insider information can benefit market participants. Bhattacharya and Nicodano (1999) argue that disclosure of insider information can improve welfare by reducing payoff uncertainty in interim states that is of value to liquidity-seeking investors who may wish to sell their holdings in those states.

In the literature on spillover effects, the general result is that disclosure might be undesirable for competitive reasons. Bhattacharya and Chiesa (1995) and Yosha (1995) have shown that disclosure to investors also results in information spilling over to the firm's competitors. Thus disclosure should be limited to information that does not have sensitive competitive implications.

The literature on private information production incentives [e.g., Diamond (1985)] says that disclosure can weaken the gain to private information production. Since such information production involves duplication across uncoordinated investors and has no inherent social value in the models in this literature, the implication is that disclosure by firms is desirable.

We address the disclosure question from a different perspective. Ignoring the insider trading and spillover effects, we ask how much information the shareholders of a good (undervalued) firm—one with good news—would like the manager to disclose to the market. At first blush the answer seems obvious: as much as possible. However, when one considers that disclosure has a "crowding out" effect [see Diamond (1985) and Fishman and Hagerty (1992)] in that it may reduce the informational advantage that informed investors have and hence weaken their incentives to become informed at a cost, the answer becomes less obvious. Moreover, to the extent that an important goal of financial innovation is to improve informational transparency [e.g., Boot and Thakor (1993)], disclosure that itself improves transparency could also have a chilling effect on financial innovation, further weakening the case for disclosure. A further complication arises when we consider the incentives of the shareholders of a bad firm, that is, one with bad news to disclose. These broad insights pave the way for a number of (smaller) questions that we want to answer in this article.

(1) Ignoring the insider trading and spillover effects, is greater information disclosure always better for all firms? How does disclosure by firms affect investors' private incentives to acquire information? What difference does it make if the information disclosed complements that of the informed investors as opposed to substituting for it?
(2) Does greater disclosure lead to stronger or weaker financial innovation incentives?
(3) Does the impact of information disclosure differ across developed and emerging markets? And if so, how?
(4) Under what circumstances might (mandatory) disclosure requirements make sense? Would competition among exchanges lead to more stringent or lax disclosure requirements?

To answer these questions, we focus on voluntary disclosure by firms. Each firm's goal is to choose a disclosure policy that maximizes its expected market value. We focus on the effects that disclosure has on trading and information acquisition incentives in the financial market ("trading incentive" effect) and on security design incentives ("security design" effect). In its impact on trading incentives, disclosure produces two counterveiling forces. On the one hand, greater disclosure means more information is impounded in prices ceteris paribus, and this benefits the good firms. On the other hand, greater disclosure could reduce the benefits of information acquisition in financial markets, leading to reduced price transparency and lower expected market values for the good firms. Our analysis captures the tension between these two effects. Although these effects for bad firms are the exact opposite of those for the good firms, it turns out that in equilibrium the bad firms always mimic the good firms, so that we can focus on what the good firms want to do. On the security design effect, we follow Boot and Thakor (1993) and consider security design as financial innovation directed at altering trading incentives by changing the marginal return to investors from acquiring costly information. This is what links the trading incentive and security design effects.

Unlike previous articles, we pay particular attention to the kind of information that has to be disclosed. We distinguish three types of information and link these to the examples cited earlier. The information could be such that it is directly useful only to those (informed) investors who can process it to discover its implications for future cash flows. That is, it complements the information of *some* investors. We call this "to-be-processed complementary information." The idea is that some disclosed information has no value unless it is processed, and an investor must commit resources to this processing. The research and development example could be interpreted in this vein.

The contract renewal disclosure appears to be an apt illustration of the second type of information. We call this "preprocessed complementary information." It involves information that is orthogonal to the information investors can acquire on their own and thus complements the information of *all* investors. It can be digested by all investors without having to invest resources in processing, and it permits them to revise their expectation of the firm's cash flow to arrive at a new conditional expectation. In the contract renewal example, for instance, disclosure that the contract was renewed would lead to a higher conditional expectation of cash flow.

The third type of information that can be disclosed is "substitute information." With this, information is disclosed to all investors that the informed investors would have had anyway. The example of management issuing an earnings forecast for the firm seems to fit this category. Such disclosure decreases the information advantage informed investors have over the uninformed.

With these types of information disclosures, our main results (answers to the four questions raised earlier) are as follows.

- In equilibrium, all three types of information disclosure enhance the expected market values of *good* firms. In the case of both types of complementary information disclosure, private information production incentives are actually strengthened by disclosure, whereas these incentives are weakened by substitute information disclosure. All firms (good and bad) choose to make all three types of disclosure.
- The impact of disclosure on financial innovation (i.e., the security design effect) depends on the type of disclosure. Financial innovation incentives are unambiguously weakened by substitute information disclosure. Both to-be-processed and preprocessed complementary information disclosures have ambiguous effects on financial innovation incentives.
- Information disclosure is likely to elevate price transparency more in developed markets than in emerging markets. However, information disclosure is also likely to have a more unambiguously favorable effect on financial innovation incentives in emerging markets.
- Given the powerful incentives for voluntary disclosure, mandatory disclosure is unnecessary except to address time consistency and agency

problems. That is, managers may have a vested interest in withholding information to preserve personal control rents or to profit from insider trading. This can create a role for disclosure requirements. Moreover, competition among exchanges will lead to greater stringency in disclosure requirements.

An important point emerging from our analysis is the following. While the earlier literature concentrates on how disclosure can *weaken* the gain to private information production, we show that disclosure can actually *increase* this gain either by improving investors' information acquisition process or by altering the benefits of financial innovation.

In addition to the earlier-mentioned articles on disclosure, our article is related to the literature on the market microstructure implications of differences between exchanges in accounting standards and listing requirements. This literature has examined questions such as how do differences in trade disclosure requirements across markets impact order flow migration, liquidity, and trading costs? Madhavan (1995) develops a model of trade disclosure in which investors have different motives for trade and dealers compete for order flow. He shows that the absence of trade disclosure benefits dealers and larger traders who place multiple orders, implying that market fragmentation cannot be eliminated without mandatory trade disclosure. Naik, Neuberger, and Viswanathan (1996) also examine trade disclosure in the context of the welfare implications of price transparency. They find that higher mandatory disclosure lowers investors' ability to hedge endowment risk, although it also decreases the rents to informed investors. They thus argue that lower levels of mandatory trade disclosure may be worthwhile if the hedging of endowment risk is sufficiently important for welfare. Huddart and Hughes (1997) develop a rational expectations trading model to examine the implications of international differences in accounting standards. They show that there are conditions under which exchanges compete for trade volume by increasing disclosure requirements.

The similarity between these articles and ours is that there are plausible conditions under which more disclosure is worthwhile, given a particular objective function. However, with the exception of Huddart and Hughes (1997), these articles focus on disclosure of *trade information* possessed by some investors, whereas we focus on disclosure of information by issuing firms. Also, whereas Huddart and Hughes assume that listing decisions are made by corporate insiders who wish to maximize trading gains based on their private information, we assume that the goal of firms is to maximize their shareholders' wealth. Moreover, unlike all the other articles, our analysis also examines the impact of disclosure on financial innovation.

The rest is organized as follows. In Section 1 we describe the basic model. The analysis is contained in Section 2. Extensions of the analysis, including the implications for interexchange competition, are discussed in Section 3.

Section 4 discusses the implications of the analysis for emerging capital markets. Section 5 concludes. All proofs are in the appendix.

1. The Different Types of Information Disclosure

We first describe the model, including the key assumptions used in the analysis. After that we discuss the kinds of information disclosed by firms to investors and how this information is processed in the market.

1.1 The model

1.1.1 Information structure, firm types and preferences. We consider a five-date model. At date $t = 0$, a firm seeks access to the capital market to issue securities that sell off its rights to all its cash flows. Each firm is interested in obtaining the maximum price it can for the securities. We assume that the firm sells a single unit of any particular security. Cash flows are realized at the final date $t = 4$. The firm can be one of two types: high quality (good) and low quality (bad). The date 4 cash flow (value) of the good (G) firm is $\tilde{x}$ and that of the bad (B) firm is $\tilde{y}$. Both $\tilde{x}$ and $\tilde{y}$ are random variables. We assume $\tilde{x}$ equals $x - a$ with probability (w.p.) 0.5 and $x + a$ w.p. 0.5, where $a > 0$ and $x > 0$; $\tilde{y}$ equals $y - a$ w.p. 0.5 and $y + a$ w.p. 0.5, with $0 < y < x$. At $t = 0$, the firm knows its own type but no one else does. The commonly known prior probability is $q \in (0, 1)$ that the firm is G. At $t = 0$ the firm also designs the securities with which to raise capital as well as its information disclosure policy; the latter is a public announcement of the kind of information the firm plans to disclose at a later date. We assume that even though no investor knows what information will be disclosed by the firm, any investor can look at the firm's announced disclosure policy and determine how the nature of the information of various informed investors will change when the disclosure actually occurs.[1] At $t = 1$, some investors decide to become informed about the issuing firm at a cost, whereas the rest remain uninformed; this will be explained in greater detail in a moment. At $t = 2$, the firm discloses information to the market in accordance with its earlier-announced policy. Let ϕ denote this disclosure. At $t = 3$, all investors submit their orders for the firm's securities to a market maker who then sets a price to clear the market at that time. At $t = 4$, the "true" value of the firm's securities becomes known to everybody and investors are paid off. Figure 1 depicts the sequence of events. There is no discounting in this model and everybody is risk neutral.

[1] This assumption allows investors in our model to calculate how a particular disclosure policy affects their expected profit before they discover what information is disclosed under that policy.

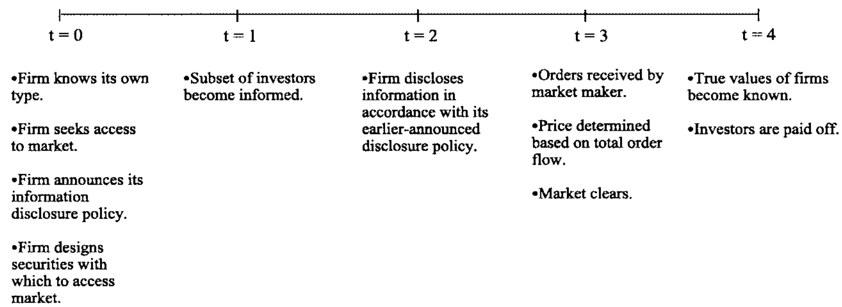

Figure 1
Sequence of events

1.1.2 Types of investors, market structure, and clearing. There are three types of investors in this market: liquidity/noise investors, uninformed discretionary investors (UDIs), and informed investors. The aggregate demand, ℓ, of the liquidity investors is random and exogenously given by the continuously differentiable probability density function $f(\ell)$ which has a support of $(0, \infty)$, with $f'(\ell) < 0$ and $f(\ell)$ being log concave, that is, $\log f(\ell)$ is concave. We specify ℓ in terms of the number of dollars the liquidity investors wish to invest in the security. Like the liquidity investors, the UDIs are a priori unaware of the type of firm whose securities they are buying. However, they condition their aggregate demand on their observation of the sum of the demands of the other two groups of investors. Each UDI can choose to either remain uninformed or acquire/process information at a cost $M_i \in \mathbf{M}$, for investor i. We assume that M_i varies cross-sectionally across investors. Investing that way in information transforms the UDI into an informed investor who knows precisely at $t = 3$ whether the security he is buying is issued by a G or a B firm. This information pertains to aggregate (mean) firm value. Let D_I be the aggregate dollar demand from the informed investors.

The capital market is competitive in that, for the marginal informed investor, the *expected* net gain from buying a security is zero in equilibrium, net of the information cost M_i. Moreover, we assume that there is a competitive market-clearing mechanism called a "market maker" who receives market orders from the informed and liquidity investors. After observing the total demand from these two groups of investors, the market maker communicates it to the UDIs, who absorb the net trade in the security. The market clearing price is one that produces zero expected profit for the UDIs. For simplicity, all traders other than UDIs are constrained to be unable to short sell.[2]

[2] As shown in Boot and Thakor (1993), this assumption is pretty harmless. Limited short sales can be readily accommodated.

Let τ be the UDIs' demand (in terms of number of units) for the security, and let D be the aggregate dollar demand from the liquidity and informed investors, that is, $D = D_I + \ell$. If P is the price of the security, then the number of units of the security purchased by the UDIs is given by

$$\tau = 1 - [D/P],$$

since the supply of the security is one unit. For the UDIs, the end-of-period value of the security is a random variable $\tilde{z} \in \{\tilde{x}, \tilde{y}\}$. Then the market-clearing price of the security, P^e, is

$$P^e = E(\tilde{z} \mid \tau). \tag{1}$$

Since prices are set by a risk-neutral and competitive market maker, and the riskless interest rate is zero, the equilibrium price is simply the expected value of the security, conditional on all the information contained in the order flow.

All individual investors are atomistic and appear observationally identical to the UDIs (and market maker). Thus there is a continuum of investors of each type and the demand-relevant measure of each is zero. Security demand is positive only when integrated over a set of positive measure investors.

1.1.3 Informational and wealth endowments of investors. Each potentially informed investor has $M_i + 1$ units of wealth, so that \$1 can be invested by each in the security after investing $\$M_i$ in information.

Upon investing M_i in information acquisition, each (informed) investor receives a signal θ that reveals the type of the firm issuing the security. Each informed investor receives the same signal. We permit θ to be noisy. The distribution of θ is given by

$$\Pr(\theta = G|G) = \Pr(\theta = B|B) = u \in (0.5, 1)$$
$$\text{and } \Pr(\theta = G|B) = \Pr(\theta = B|G) = 1 - u. \tag{2}$$

Assume for the moment that each firm issues a composite security that is a claim against its total $t = 4$ cash flow. Since each investor is risk neutral and θ is informative about the issuer's type, each informed investor's individual demand d_I will be as follows as long as he anticipates that the equilibrium price will only noisily reveal his information:

$$d_I = d_I(\theta) = \begin{cases} 1 & \text{if } \theta = G \\ 0 & \text{if } \theta = B, \end{cases} \tag{3}$$

where d_I is in dollars.

Let Ω be the measure of those who become informed. Then

$$D_I = D_I(\Omega, \theta) = \Omega d_I(\theta).$$

In the subsequent analysis, the equilibrium Ω is endogenously determined.

1.1.4 Remarks on the model. Our specification that each firm seeks to sell off rights to all its cash flows precludes good firms attempting to signal their type by choosing the size of the fractional claims to future cash flows that they sell. If this were possible, it could be a credible signal because claims to good firms' cash flows are inherently more costly for their initial owners to give up.

Also, the setup of the model makes it look like we are dealing with an initial public offering (IPO). This is primarily because in our formal analysis investors are submitting only buy order for securities. The entire supply of any security is coming from the issuing firm. However, the analysis is clearly intended to cover IPOs as well as seasoned offerings. It is conceptually not difficult to include both buy and sell orders by investors, but it adds a lot of algebra without changing the results qualitatively.

For IPOs, we interpret information disclosure as that revealed in the prospectus. For seasoned offerings, there would be an existing market price, which in our model is the price of the firm prior to information disclosure and security design. Information disclosure would take a variety of forms, including 8-K and 10-K reports filed with the Securities and Exchange Commission (SEC), communication with analysts, annual reports, and so on.

1.2 What are the different faces of disclosure?

Firms disclose different types of payoff-germane information. We thus need to make precise the nature of the information that is disclosed and how this disclosure interacts with what informed investors do.

There are basically two assumptions we can make about the disclosure ϕ and how it compares to the signal θ that informed investors generate. Under Assumption 1 (complementary), the information that is disclosed is complementary to the information that the informed investors receive in the sense that the informed would not have had this information had it not been disclosed. This means that the disclosure does not undermine the value of the information that the informed could obtain. Within this class of disclosures, we examine two types of disclosures. One (case 1) improves the information processing done by informed investors. It thus increases the precision of the signal θ received by these investors. The other (case 2) improves the precision of the information available to *all* investors. The alternative assumption, Assumption 2 (substitute), means that the information that is disclosed is a substitute for the information that informed investors could have obtained themselves. This is case 3. In each of these cases, our goal is to examine the impact of disclosure requirements on the trading incentive and security design effects.

2. Analysis

2.1 The equilibrium measure of informed and definition of equilibrium

The condition determining the equilibrium measure of informed investors, Ω^*, says that for the marginal informed investor the *expected* net gain from becoming informed is zero. Let V be the investor's expected net gain to being informed, $P^e(\phi, D(\theta, \ell))$ the equilibrium price of the security as set by the market maker when the noisy signal ϕ about the firm's type is disclosed (and total demand $D(\theta, \ell)$ is observed), and $P(\theta)$ the value of the security privately known to the informed investor who receives signal θ. An informed investor will submit a buy order (choose $d_I = 1$) only when his signal reveals $\theta = G$, in which case $D(\theta, \ell) = \Omega + \ell$. For investor i we have (we suppress ϕ to avoid notational clutter)

$$V = -M_i + qu \int_0^\infty \{[0.5[x-a]+0.5[x+a]-P^e(\Omega+\ell)][P^e(\Omega+\ell)]^{-1}\} \times f(\ell)d\ell - [1-q][1-u]\int_0^\infty \{[P^e(\Omega+\ell)-0.5[y-a]-0.5[y+a]] \times [P^e(\Omega+\ell)]^{-1}\} f(\ell)d\ell, \quad (4)$$

where we have substituted $D(\theta, \ell) = \Omega + \ell$ for $\theta = G$, and $[P^e(\phi, \Omega + \ell)]^{-1}$ is the number of units demanded.

Observe that although θ is noisy, the informed investor's information is a finer partition of the information available to the UDIs because the latter only observe $D(\theta, \ell)$, which provides a noisy assessment of θ. In Equation (4), the informed investor submits a buy order when $\theta = G$. Conditional on having found a type G firm, the probability is u that an informed investor sees $\theta = G$. The investor's expected gain is then $x - P^e(\Omega + \ell)$, and the joint probability of this event is qu. The investor also submits a buy order when the security is truly type B (the probability of this is $1 - q$) and the signal reveals type G (with conditional probability $1 - u$). In this case the investor's loss is $P^e(\Omega + \ell) - y$ and the joint probability of this event is $[1 - q][1 - u]$. The equilibrium value of Ω^* is determined by the following marginal condition:

$$V(\Omega^* \mid q, \phi, x, y, a, M(\Omega^*), f(\ell)) = 0, \quad (5)$$

where $M(\Omega^*)$ is the information acquisition cost of the marginal investor. Thus V is zero for the marginal investor with information acquisition cost $M(\Omega^*)$, but positive for inframarginal investors with costs $M_i < M(\Omega^*)$.

2.1.1 Definition of equilibrium. A (noisy) rational expectations Nash equilibrium is

(1) A measure of informed investors, Ω^*, satisfying Equation (5), in which each informed investor takes as given the disclosure policy of firms and the equilibrium strategies of the other informed investors and the UDIs, but assumes that the impact of his own trade on the price is negligible.
(2) An aggregate security demand from informed and uninformed liquidity investors equal to $D^*(\theta, \ell) = \Omega^* d_I(\theta) + \ell$, with $d_I(\theta)$ given by Equation (3).
(3) A market-clearing price P^e given by Equation (1), which is determined by the market maker (UDIs) to equate supply and demand and to yield a zero expected net profit to a priori uninformed security purchasers, conditional on the information contained in the order flow, $D^*(\theta, \ell)$, and (if applicable) the signal ϕ.
(4) An information disclosure policy and security design by the issuing firm which, taking as given the above behavior by traders and the UDIs, maximize the issuer's total expected market value.

This Nash equilibrium is a strategic game in which the informed issuer moves first by announcing a disclosure policy and determining its security design, followed by the decision of some investors to become informed, after which information disclosure occurs, and then finally trading occurs with the UDIs responding with a price after observing total demand.

2.2 Analysis of case 1: to-be-processed complementary information

This is the case in which disclosure leads to the release of complementary information that improves the precision of the information (the signal θ) that informed investors have. The practical situation this seems to fit best is the one in which informed investors are processing publicly available information at a personal cost. This processing enables them to learn something about firm value that uninformed investors don't know even though the information *processed* by the informed was available to them as well. We call this disclosure of *to-be-processed complementary information*.

The idea is that there is some information that is useless unless processed. For example, a company might disclose its projected R&D spending by product line over the next few years. Alternatively, a company may announce the adoption of an incentive compensation plan for upper and middle management, say one linked to economic value added. While information of this sort is made available to all investors, its implications for future cash flows and firm value will need to be discovered through a processing of that information. Some investors—those we call informed—will have invested the resources to acquire the information infrastructure or skills needed for this processing, whereas the rest will be unable to use the disclosed information to revise their estimates of firm value. Thus we assume that disclosure raises the quality of what the informed investors know.

We will model this by assuming that the signal θ about firm type is noisy and that disclosure improves the precision of θ. Following the specification of the noisy signal θ given in Equation (2), an increase in the precision of θ is represented by an increase in u. Thus, $\phi = \Delta u$. Recall that $\{x-a, x+a\}$ and $\{y-a, y+a\}$ are the sets of possible realizations of x and y, respectively (the values of the type G and type B firms). We set $a = 0$ because it plays no role here.

2.2.1 Unlevered (composite) security and no disclosure. We now analyze the investor's incentive to acquire information and the type G issuer's expected market value. We continue to assume that all informed investors receive the same noisy signal θ on a given security. The aggregate demand for a security is given by $D = D(\theta, \ell)$. The investor's net gain from being informed is given by Equation (4) with $a = 0$.

The equilibrium value of Ω, call it Ω^*, is determined by the following marginal condition:

$$V(\Omega^* \mid q, \phi = \Delta u, x, y,\ M(\Omega^*), f(\ell), u) = 0. \tag{6}$$

We can also define the market price of the firm's only security as

$$P^e(D(\theta, \ell)) = \Pr(G|D(\theta, \ell)) \times [x - y] + y, \tag{7}$$

where $\Pr(G|D(\theta, \ell))$ is the probability that the true type is G, conditional on an aggregate demand of D. The type G issuing firm's expected market value (revenues) is

$$R = u \int_0^\infty \Pr(G|D = \Omega + \ell)[x - y] f(\ell)\, d\ell + [1 - u] \int_0^\infty \Pr(G|D = \ell)[x - y] f(\ell)\, d\ell + y. \tag{8}$$

The specification in Equation (8) takes into account the fact that there is a probability $[1 - u]$ that a type G issuer does not face informed demand. We next consider the impact of to-be-processed complementary information disclosure (case 1).

2.2.2 Unlevered security with information disclosure. It is relatively straightforward to establish that disclosure makes the type G firm better off when this disclosure is interpreted as increasing u.

Proposition 1. *Disclosure increases the equilibrium measure of informed investors, Ω^*, and the expected market value of the type G issuer.*

The intuition for the positive trading incentive effect is that the presence of noise in the informed investor's signal diminishes the expected gain to being informed, ceteris paribus [see Equation (4)]. Thus the measure of informed investors is smaller, which in turn leads to a lower expected market value for the type G issuer because of lower price transparency. Disclosure reverses this by reducing the noise in the informed investor's signal.

This result stands in contrast to the findings of Diamond (1985) and Fishman and Hagerty (1992) that information disclosure by firms "crowds out" that by investors, thereby weakening private information acquisition incentives. Here disclosure makes these incentives stronger. The reason is that, unlike the earlier articles, the information disclosed by firms *complements* that of investors rather than substituting for it. We now turn to the interaction between disclosure and security design.

2.2.3 Security design with no disclosure. Following Boot and Thakor (1993), we will model security design as splitting up the unlevered security into two securities: a senior security S, which is not information sensitive, and a junior security J, which is more information sensitive than the composite security. The firm issues one unit of each security. Information sensitivity is defined as the percentage divergence between the "true" value of the security and its value based on the *prior* beliefs of the UDIs. S promises a sure date 4 payoff of y, whereas J is a claim against all of the issuing firm's residual value after S is paid off. Since either type of issuer can pay off y, the date 4 payoff to S is y with probability one. However, J will pay off $x - y$ if issued by the type G firm (with probability q), and zero if issued by the type B firm (with probability $1 - q$).

Although ℓ is exogenous in our model, it is reasonable to posit that the creation of a more information-sensitive security will cause some liquidity demand to migrate away from J [see, e.g., Gorton and Pennacchi (1990)]. Suppose that a fraction $\alpha \in (0, 1)$ of liquidity demand will migrate from J to S. Thus the new liquidity demand for J is now given by the density $f_n(\cdot)$, and a realization ℓ^o of liquidity demand for the composite security (when it is the only security offered) "corresponds" to a realization of $[1 - \alpha]\ell^o$ of liquidity demand for J (when both S and J are offered in lieu of the composite security), that is, $f_n([1 - \alpha]\ell^o) = f(\ell^o)[1 - \alpha]^{-1}\,\forall\,\ell^o$.

With this, it follows readily from Boot and Thakor (1993) that as long as some liquidity demand remains in security J, the total equilibrium expected market value of the type G firm is higher and that of the type B firm is lower by issuing securities S and J than by issuing only the (composite) unlevered security. However, in equilibrium, both the type G and type B firms issue securities S and J.

The intuition is as follows. By stripping away S from the unlevered security, the issuer separates out a component of firm value about which there is no informational asymmetry, and thereby concentrates informational sensitivity in J. The informed investor can now invest *all* of his wealth in J, rather than being implicitly compelled to invest some of it in S, as in the unlevered security case. This informational leveraging up of the informed investor's wealth position leads to a greater expected profit for the informed ceteris paribus, and hence to a larger equilibrium measure of informed investors.[3] Since both types of firms obtain the first-best price for S, the increase in the equilibrium measure of informed for J leads to greater price revelation, and a higher total expected market value for the type G firm than if only a single unlevered security is issued. Of course, by the same token, the type B firm suffers an expected market value decline, but it is forced to follow the lead of the type G firm in equilibrium because otherwise it would be unambiguously identified as a type B firm.

It may seem somewhat simplistic to think of security design merely as a switch from all-equity (composite security) finance to issuing debt (security S) and equity (security J), particularly since private debt typically precedes public equity, so that most firms with publicly traded equity also have debt. Our interpretation of debt and equity as security design is clearly allegorical. The idea is that the intent of security design is to create more information-sensitive claims. Examples of such claims are options [see, e.g., Back (1993)], as well as the use of securities that hedge some portion of the firm's cash flow so as to increase the sensitivity of these cash flows to factors that the firm controls and investors are producing information about. The creation of more informationally sensitive securities in this manner increases the marginal return to an investor from becoming informed about the firm and hence increases the measure of informed investors. This means that it is in the interest of the type G (undervalued) firm to keep searching for securities with ever-increasing informational leverage. But by doing this, an ever-increasing fraction of liquidity demand is likely to migrate away. This is not a problem as long as some liquidity demand remains so that incentives to become informed still exist for some investors. Hence, from this perspective, the firm should seek to keep increasing information leverage until it drives out so much liquidity demand that further increases would not make it profitable for any investors to become informed.

2.2.4 Information disclosure and security design. We will once again consider the cash flow partitioning made possible by creating securities S and J, and the associated migration of liquidity demand from J to S. The expected

[3] More precisely, in the absence of the migration of liquidity investors, the equilibrium measure of informed investors will exceed that in the case of the unlevered security, as stated in the text. Migration of liquidity investors will reduce the measure of informed investors, but increase price transparency. Hence in all cases *more* information will be revealed in prices with security splitting than with the unlevered security. Hence security splitting will always lead to higher expected revenues for the type G firm.

profit of an informed investor who invests only in security J is given by

$$V_J = -M(\Omega) + qu \int_0^{\infty} \left\{ \frac{x - y - P_J^e(\Omega + \ell^o)}{P_J^e(\Omega + \ell^o)} \right\} f_n(\ell^o)\, d\ell^o \\ - [1-q][1-u] \int_o^{\infty} f_n(\ell^o)\, d\ell^o. \quad (9)$$

This expression is similar to Equation (4). The main difference is the last term. When an informed investor mistakenly invests in security J issued by a type B firm, he buys a worthless security, so that his \$1 investment is completely lost. With information disclosure $\phi = \Delta u$ and the signal precision of informed investors (after information acquisition) increases from u to $u + \Delta u$.

As in the no-disclosure case, the informed investors put all their investable wealth in security J. We now have the following result.

Proposition 2. *With to-be-processed complementary information disclosure, as long as some liquidity demand remains in security J, the total equilibrium expected market value of the type G firm is higher and that of the type B firm is lower by issuing securities S and J than by issuing only the unlevered security. Moreover, the type G firm is always better off and the type B firm always worse off with disclosure than without. In a universally divine sequential equilibrium [Banks and Sobel (1987)], both types of firms offer securities S and J and choose to disclose information. The off-equilibrium path belief of the UDIs in this equilibrium is that any firm choosing not to disclose or issuing the unlevered security is type B with probability one.*

Let's consider the intuition. As explained following Proposition 1, disclosure increases the measure of informed investors. We have also seen that the information leveraging due to security design has a similar effect. The joining of disclosure and security design thus leads to the largest measure of informed investors and hence the highest expected market value for the type G firm. This type of firm thus takes the lead on both counts and compels the type B firm to follow suit in equilibrium to preclude its unambiguous discovery.

Next we ask whether disclosure strengthens or weakens security design incentives. We first show that disclosure can strengthen security design incentives.

Lemma 1. *There are exogenous parameter values such that security design incentives are strengthened by to-be-processed complementary information disclosure.*

It is easy to see the intuition behind why disclosure improves security design incentives, but a general result seems beyond reach. To understand the intuition, suppose u is sufficiently low (just above 0.5) and the lowest M_i is sufficiently high so that nobody becomes informed even with security design. Now suppose disclosure raises u enough to generate a positive measure of informed investors with security design but not without. Then it will be true that security design incentives are strengthened by disclosure.

An example illustrates this point.

Example. Suppose $x = 10$, $y = 1$, and $q = 0.6$. We let liquidity demand follow the exponential density $f(\ell) = [1/6]\exp(-\ell/6)$.

With this specification, it can be shown that, with the unlevered (composite) security, the minimum u for which informed trading becomes profitable is $\underline{u} = 0.5 + 1.4815M$. With security design, informed trading is more effective and the minimum u satisfies $\underline{u}_{SD} = 0.5 + 1.25M$. We abstain from migration of liquidity demand. Suppose that information acquisition costs are homogeneous across investors with $M = 0.20$ and $u = 0.74$. From $\underline{u}$ and $\underline{u}_{SD}$ it follows immediately that no investor becomes informed (with or without security design). This means that for any positive cost C of security design, there is no security design in equilibrium. The equilibrium revenues to the good firm then equal its prior value, that is, $P_G = 0.6(10) + 0.4(1) = 6.4$. Now consider a disclosure $\phi = \Delta u = 0.02$. At the new $u = 0.76$, informed trading is attractive *only* in case of security design. In that case, the expected equilibrium revenues to the good firm equal $R = 6.4266$. Note that $R > P_G$. Thus with a cost of security design $C < 0.0266$, disclosure induces security design.

What this shows is that, starting out from a situation in which informed trading is prohibitively expensive—either because of a high information acquisition costs M_i or excessive noise in the informed signals—disclosure may facilitate informed trading by helping to overcome the cost of becoming informed and thus induce financial innovation (security design). Moreover, market efficiency will be enhanced, due to both the direct impact of the disclosure on price efficiency and the indirect impact that comes from how disclosure positively affects informed trading.

The other extreme—when informed trading is already very high (e.g., due to a low M and high u)—is also interesting. What is the benefit of disclosure in this case? Because disclosure improves the precision of the information available to informed investors, it encourages informed demand and will bring security prices even closer to their intrinsic values. In general, in this case disclosure also augments the value of security design by further improving its information leveraging effect. It can be shown in the example above that the extra value created by security design is maximized when u approaches one. This result, however, does *not* hold in general. Different assumptions about the liquidity demand density and the homogeneity of information acquisition costs in combination with migration of liquidity demand (in case of security design) could lead to positive and/or negative effects of disclosure on security design.[4]

Thus disclosure and security design can be *complements* or *substitutes*. What we can say is that in *underdeveloped* financial markets, the first extreme—with a prohibitive cost of becoming informed—is most relevant. In that situation, the disclosure of to-be-processed complementary information unambiguously improves financial innovation incentives and market efficiency.

2.3 Analysis of case 2: preprocessed complementary information

In case 1 we considered disclosure of information that benefited only *some* investors (the informed). In case 2 we now consider information disclosure that potentially benefits *all* investors, and involves information that can be costlessly processed by all investors. We first consider disclosure of information that would otherwise have *not* been available to anybody, and thus complements what investors know. We call this preprocessed complementary information disclosure.

The idea is that such disclosure increases the precision of investors' information. In an extreme characterization of this idea, we assume that the signal ϕ provided by the disclosure reveals a new conditional expectation of the firm's cash flows that takes the form of informing *all* investors about whether the "additional" cash flow a for the firm has a plus or a minus sign, without revealing the firm's type. That is, prior to the disclosure, investors believe that the type G firm's cash flow is either $x - a$ or $x + a$ with equal probability, and the type B firm's cash flow is $y - a$ or $y + a$ with equal probability. After the disclosure, *all* investors know the precise cash flow of each type of firm. We now set $u = 1$, which means that θ is noiseless. This implies that, subsequent to disclosure, informed investors know the type of firm they have encountered as well as its precise cash flow, whereas uninformed investors know only the precise cash flow of each type of firm but not the type of the firm they are dealing with.

This case deals with disclosure of information that is *orthogonal* to the kind of information investors can acquire on their own. There are many examples of this kind of disclosure. There may be some firms for whom there is a single uncertainty whose resolution would significantly impact investors' cash flow estimates. For instance, it could be whether a major contract will be awarded or renewed, as in the case of Enron's power generation contract with a state government in India, or Whirlpool Corporation's contract renewal

[4] For example, if we change the homogeneous information acquisition cost M in this example into a *strongly* convex function $M(\Omega)$, disclosure would *reduce* the incremental value of security design. This is because disclosure has a positive impact on Ω, and at this higher level of Ω, security design (that further elevates Ω) has a bigger impact on the cost $M(\Omega)$ because of convexity. Thus disclosure makes security design more costly for informed traders, reducing its net benefits. In other words, disclosure diminishes the positive effect of security design on the measure of informed traders Ω because of its effect on the information acquisition costs faced by the marginal investor.

to supply home appliances to Sears, or Boeing being awarded a contract for the latest-series 737 jets by KLM. Alternatively it could be related to the outcome of a pending legal battle, as in a class-action lawsuit against a tobacco firm. Investors know that if the outcome goes this way, the cash flow is such and such, and if it goes the other way, it is something else. However, because this information is very idiosyncratic to the firm, it will always become available to the firm before investors receive it. As soon as the firm makes its disclosure, the uncertainty gets resolved and the cash flow estimate, conditional on the type of the firm, becomes unambiguously fixed.

2.3.1 Unlevered security with and without disclosure. As in the previous case, informed investors seek to avoid type B firms and invest only in type G firms. Since $u = 1$, they can now identify type G firms without error.

We now have the following expected profit for an informed investor i who buys the unlevered security in the absence of disclosure [see also Equation (4)],

$$V = -M_i + q \int_0^\infty \left\{ \frac{x - P^e(\Omega + \ell)}{P^e(\Omega + \ell)} \right\} f(\ell)\, d\ell. \tag{10}$$

With all firms adopting the same disclosure policy, disclosure perfectly reveals each firm's type-dependent cash flow. An investor i who is considering becoming informed will calculate his expected profit as

$$\widehat{V} = -M_i + q \left\{ 0.5 \int_0^\infty \left[\frac{x - a}{P_e^{(-)}} - 1 \right] f(\ell)\, d\ell + 0.5 \int_0^\infty \left[\frac{x + a}{P_e^{(+)}} - 1 \right] f(\ell)\, d\ell \right\}, \tag{11}$$

where $P_e^{(-)}$ and $P_e^{(+)}$ are equilibrium market prices defined as follows. Whenever disclosure reveals adverse information, namely a cash flow of $x - a$ or $y - a$, the equilibrium market price of the firm's unlevered security is denoted $P_e^{(-)}$. Similarly, when the disclosure reveals favorable information, namely a cash flow of $x + a$ or $y + a$, the equilibrium market price is $P_e^{(+)}$.

The equilibrium measure of informed investors, Ω^*, sets Equation (11) equal to zero.[5] Comparing Equations (10) and (11), we can now derive a result similar to Proposition 1.

Proposition 3. *Disclosure of preprocessed complementary information increases the equilibrium measure of informed investors, Ω^*, and the expected market value of the type G issuer.*

[5] To avoid notational clutter, we again use the symbol Ω^* to characterize the equilibrium measure of informed traders. Obviously this level of Ω^* is different from the equilibrium level in case 1 (see Proposition 1).

The intuition for this result is as follows. The equilibrium value of the unlevered security *without* disclosure, $P^e(\Omega, \ell)$, is some sort of an average of $P_e^{(-)}$ and $P_e^{(+)}$. Since V is a convex function of P^e, and $\widehat{V}$ a convex function $P_e^{(-)}$ and $P_e^{(+)}$, we can see from Jensen's inequality that disclosure enhances the expected revenue of the type G firm, that is, $\widehat{V} > V$.[6] This also implies that the equilibrium measure of informed investors will be higher with disclosure than without. The reason why disclosure has this effect is that informed investors can buy more securities on average at the (postdisclosure) state-contingent price than at the (average) no-disclosure price. That is, the average of $(1/P_e^{(-)})$ and $(1/P_e^{(+)})$ exceeds $1/P^e$, which yields the informed investors a larger benefit from getting informed.

So once again we see that disclosure improves private information acquisition incentives, in contrast to the existing literature. The intuition for this is the same as that for case 1; the disclosure is complementary to that which investors can acquire on their own, not a substitute.

2.3.2 Impact of disclosure on security design. Limiting ourselves to debt and equity security design, the question is how should security S be designed? It is clear that if S is to be riskless and independent of firm type, then it should promise to pay $y-a$. Then J promises to pay the difference between the actual cash flow and $y-a$.

With no disclosure, the expected profit of an informed investor i who buys only J is given by

$$V_J = -M_i + q\int_0^{\infty}\left\{\frac{x-y+a-P_J^e(\Omega_J+\ell^o)}{P_J^e(\Omega_J+\ell^o)}\right\}f_n(\ell^o)\,d\ell^o. \qquad (12)$$

Now if *all* firms announce a disclosure policy that reveals the cash flow associated with each type of firm—and all firms adopt the same disclosure policy in equilibrium—then an investor i who is considering becoming informed will calculate his expected profit from investing in J as

$$\widehat{V}_J = -M_i + q\left\{\begin{array}{l} 0.5\displaystyle\int_0^{\infty}\left[\frac{x-y}{P_e^{J(-)}}-1\right]f_n(\ell^o)\,d\ell^o \\ \quad +0.5\displaystyle\int_0^{\infty}\left[\frac{x-y+2a}{P_e^{J(+)}}-1\right]f_n(\ell^o)\,d\ell^o \end{array}\right\}, \qquad (13)$$

where $P_e^{J(-)}$ is the price of J when the actual disclosure reveals the cash flow to be $x-a$ or $y-a$, and $P_e^{J(+)}$ is the price of J when the disclosure reveals $x+a$ or $y+a$. As in the unlevered security case, whether information will be disclosed or not clearly impacts V_J [note the difference between

[6] The fact that $\widehat{V} > V$ is not obvious because the numerators in Equation (11) differ from those in Equation (10). With a few steps, however, it can be shown that $0.5[\{x-a\}/P_e^{(-)}]+0.5[\{x+a\}/P_e^{(+)}] > x/[0.5P_e^{(-)}+0.5P_e^{(+)}]$. Also note that, at any level of Ω, $P_e^{(+)} = P_e^{(-)} + 2a$.

Equations (12) and (13)] and hence Ω_J and the expected market value of the type G firm. We can now prove the following result.

Proposition 4. *When firms announce the adoption of preprocessed complementary information disclosure along with the issuance of securities S and J, the adoption of this disclosure policy increases the equilibrium expected market value of the type G firm. In a universally divine sequential equilibrium, all firms choose to disclose and issue securities S and J. Any firm that deviates from the equilibrium is viewed as type B with probability one.*

The reason why disclosure increases the expected market value of the type G firm is similar to the intuition provided following Proposition 3. Moreover, as with case 1, the largest measure of informed investors is obtained with having both disclosure and security design. As for the effect of disclosure on the added value of security design, while there exist exogenous parameter values for which security design incentives are strengthened by disclosure (as in Lemma 1), the general effect is ambiguous. If nobody chooses to become informed, disclosure may make security design valuable, whereas if there is already a high level of informed trading, disclosure may discourage security design innovation.

2.4 Analysis of case 3: substitute information disclosure

This is the case in which disclosure requirements result in the release of information to *all* investors that would otherwise have been available only to the informed investors. Thus disclosure provides information that is a substitute for the information possessed by informed investors. A good example of this could be an earnings forecast. Because informed investors—such as security analysts—are in regular touch with the firm's management and also cognizant of relevant industry developments, they have a better idea of what the annual earnings of the firm will be *before* year end than uninformed investors do. Management's own earnings expectations may already be known to these informed investors. If the firm's management now discloses all this information publicly, it will release to uninformed investors information that only the informed may have had otherwise. Another example may be an Internet firm like Amazon.com. Current estimates that it is likely to earn positive profits by 2001 are known to all. But over time, these estimates may change. Informed investors are likely to be better informed than the general public about when Amazon.com's profits will first become positive. So if the CEO of Amazon.com releases information that helps everybody revise these estimates, he has made a substitute information disclosure and diminished the information advantage of informed investors.

We model this type of disclosure as follows. We assume that disclosure leads to a signal ϕ about firm type. The signal either reveals firm type perfectly or is uninformative, and at the time that the signal is received, investors know whether it is perfectly revealing or uninformative. That is, ϕ is ϕ^* with probability $r \in (0, 1)$ and ϕ^o with probability $1-r$, where ϕ^* is the perfectly revealing signal and ϕ^o the uninformative signal. This means

$$\Pr(G \mid \phi^* = G) = \Pr(B \mid \phi^* = B) = 1.$$

For simplicity, we will assume that $a = 0$ because it plays no role in the analysis of this case.

Our plan in this subsection is as follows. First, we will analyze the equilibrium, including the expected revenue of the issuing firm, *without* the information disclosure that generates ϕ. We will then compare this equilibrium to the disclosure equilibrium in which the UDIs obtain ϕ. In each case, we will also compute the benefits of security design to the issuing firm. We will show that, as long as we hold security design fixed, this type of information disclosure increases expected revenues. However, it lowers the expected benefits of security design.

2.4.1 Unlevered security with and without disclosure. Again informed investors avoid type B firms and invest only in type G firms. With disclosure, there is a probability r that the type of the firm will be revealed. In that case, the informed investors cannot make any profits. We can write the expected profit of an informed investor i as

$$V = -M_i + q[1-r] \int_0^\infty \left[\frac{x - P^e(\Omega + \ell)}{P^e(\Omega + \ell)} \right] f(\ell)\, d\ell. \qquad (14)$$

We let $P^e(\Omega + \ell)$ now refer to the value of the firm in the case that uninformed investors and the market maker receive the uninformative signal $\phi = \phi^o$, so that their belief revision about firm type is based solely on the observed order flow. The no-disclosure case is a special case of Equation (14), with $r = 0$. The expected revenue of the type G firm can now be calculated as

$$R = rx + [1-r] \int_0^\infty P^e(\Omega + \ell) f(\ell)\, d\ell. \qquad (15)$$

With this in hand, we can establish the following result about the trading incentive effects of disclosure in this case.

Proposition 5. *The equilibrium measure of informed investors for the type G firm with an unlevered security is lower with the substitute information disclosure ϕ than without.*

This proposition tells us that this type of disclosure decreases the measure of informed investors. The intuition is that the disclosed information substitutes for what the informed would know anyway. It thus weakens their incentive to acquire information privately, as in the existing literature.

Despite this, such disclosure could benefit the firm because the direct effect of improved price transparency generally offsets the indirect effect of less-informed trading.

Next, we wish to examine the impact of information disclosure on the expected revenue of the type G firm. There are two opposing effects at work here. On the one hand, disclosure directly causes more information to be impounded into prices by making additional information available to everybody; this increases the type G firm's revenues. On the other hand, it reduces the information advantage of informed investors, causing the measure of informed investors to decline and resulting in less information to work its way into prices; this decreases the type G firm's revenues. What the next result establishes is that the first effect dominates.

Proposition 6. *Suppose $\psi(P;\Omega)$ is the density function of the security price P conditional on a measure of informed investors Ω. Then, if $\psi(P;\widehat{\Omega})/\psi(P;\Omega)$ is decreasing in P for $\widehat{\Omega}<\Omega$ (monotone likelihood ratio property), the equilibrium expected revenue of the type G firm is higher with substitute information disclosure than without.*

Lemma 2. *Let $f(\ell)$ follow a truncated normal distribution with $f(\ell)=c\cdot\exp(-\ell^2/2\sigma^2)\,\forall\,\ell\geq 0$ and $f(\ell)=0\,\forall\,\ell<0$ and $c>0$ and $\sigma^2>0$ are constants. Then $\psi(P;\widehat{\Omega})/\psi(P;\Omega)$ is decreasing in P for $\widehat{\Omega}<\Omega$.*

We suspect that the result in Proposition 6 is true even without the restriction identified in the proposition. If disclosure were to decrease expected revenue for the firm, then it must become more profitable for investors to become informed. This would increase the measure of informed investors and the firm's expected revenue.

We will show next that such disclosure can adversely affect security design incentives.

2.4.2 Security design with disclosure. We now consider a security design similar to that in case 1 where a senior security S promising y and a junior security with risky payoff $x-y$ are created.

Proposition 7. *While security design elevates the type G firm's expected revenue also with substitute information disclosure, the increase in expected revenue due to security design is smaller with substitute information disclosure than without. Thus if security design imposes on the issuer a fixed cost, say $C>0$, then it is possible for substitute information disclosure to eliminate security design even though it was optimal in the absence of that disclosure.*

This result is intuitive. Increasing information disclosure improves price informativeness and expected revenues for type G firms even without security design. On average then we have a high level of price informativeness, and the enhancement in expected revenue due to security design is smaller. Since security design in practice could involve costs [see, e.g., Boot and Thakor (1997)], it is possible that the benefits of security design to the type G firm exceed the costs without disclosure but fail to do so with disclosure. In this case, information disclosure retards financial innovation.

To see how disclosure may make a firm abstain from security design, let R be the expected revenue of a type G firm in the unlevered security equilibrium *without* disclosure and R_S the expected revenue with security design but without disclosure. Let C the cost of security design, so that the firm engages in security design if $R_S - R > C$. Using hats to indicate the relevant values with disclosure, we see that Proposition 5 tells us that the difference $\widehat{R}_S - \widehat{R}$, although positive, is smaller than $R_S - R$. Suppose $\widehat{R}_S - \widehat{R} < C$, so that there is no security design with disclosure.

Despite this, the firm is always better off with disclosure. To see this, note that when there is disclosure the firm's net revenues are $\widehat{R}_S - C$ with security design and $\widehat{R}$ without. Since disclosure always increases revenue, we have $\widehat{R}_S > R_S$. Thus $\widehat{R}_S - C > R_S - C$. Now, for the firm to be worse off with disclosure (when it abstains from security design) than without disclosure (when it engages in security design), we must have $\widehat{R} < R_S - C$. Combining these two inequalities gives us $\widehat{R}_S - C > R_S - C > \widehat{R}$. But this contradicts the assumption that $\widehat{R}_S - \widehat{R} < C$. So it must be the case that the firm is never worse off with disclosure, even when this disclosure discourages security design.

For the diminished security design incentives due to disclosure to lead to the firm being worse off with disclosure, there has to be some externality. For example, if there is cross-sectionally less financial innovation due to disclosure and this increases the cost of innovation for each firm, then it is possible for disclosure to make firms worse off. The reason is that adoption externalities may mean that it takes sufficiently many firms to introduce an innovation for it to succeed.

3. Additional Considerations

In this section we will deal with two issues not considered in the previous section. The first has to do with insider trading, and the second with competition among multiple exchanges.

3.1 Insider trading and disclosure requirements

We have focused on voluntary disclosures and shown that firms have powerful incentives to disclose many types of information without being required to do so.[7] However, if insiders could profitably trade on their private information, they may choose not to disclose information to others. That is, the private gains to insider trading may exceed the private gains to insiders from maximizing firm value through disclosure. Disclosure *requirements* may then be needed to limit the ability of corporate insiders to profit on their inside information. Indeed, in many instances, rampant insider trading is the motivation for disclosure requirements.

But this distorted private trade-off cannot be a compelling justification for mandating disclosure. The justification must come from social welfare considerations. On this there are two points of view. One is that insider trading improves welfare. As Bhattacharya and Nicodano (1999) note, this happens in two cases: when information revelation through prices guides interim investment choices, and when it creates additional incentives for effort choices by managers.

The other point of view is that insider trading reduces welfare. This point has been argued on many different grounds, perhaps most forcefully on information revelation grounds by Fishman and Hagerty (1992). Their point is that, while it is commonly believed that insider trading can improve the information content of prices by causing more of the insiders' information to be reflected in prices, it can also discourage informed traders who are competitively disadvantaged relative to corporate insiders [see also Hu and Noe (1997)]. The net effect could be less informative prices and lower social welfare. Disclosure requirements could then be justified as a way to limit insider trading and increase the information content of prices.

If insider trading were standing in the way of voluntary disclosure, then the above justification for disclosure requirements would have benefits to the initial shareholders of firms in our model. This can be seen most clearly in the context of our model in connection with to-be-processed and preprocessed disclosures. Both types of disclosure not only makes the type G firm better off, but also increase the measure of informed investors. The effect on financial innovation incentives is ambiguous, but expected net revenues are unambiguously higher. Thus in the absence of mandatory disclosure, insider trading could (i) decrease the information content of prices by sufficiently reducing the measure of informed investors, (ii) make the higher-quality firms worse off, and (iii) possibly slow down financial innovation.

3.2 Competition among exchanges or securities regulators

If, due to managerial agency problems or insider trading, it is socially useful to have disclosure requirements, it is natural to wonder about the implications for competing regulators. U.S. firms do not have a choice—the SEC regulates

[7] We have ignored the "two-audience signaling" problem that in disclosing information to investors, the firm faces the costs of inadvertently signaling proprietary information to product-market competitors. The desirability of disclosure regulation has recently been analyzed by Admati and Pfleiderer (2000).

securities markets and dictates disclosure requirements. Such a monopoly regulator is the norm in many countries. Romano (1998) has recently suggested, however, that it may be better to give firms a choice between the SEC and other securities regulators (states or even foreign countries). The idea is that this would introduce competition among regulators that would benefit firms. Is such competition good for firms?

The knee-jerk reaction to this is that it would lead to a deterioration in the quality of disclosure, since regulators would compete by lightening the disclosure burden they impose on firms [see, e.g., *The Economist* (1998)]. However, consistent with Romano's conjecture, our analysis implies the opposite. Since the high-quality firms are the ones that benefit from greater stringency in disclosure requirements for certain forms of information, regulators and/or exchanges will have to compete for these firms by *increasing* the stringency of their disclosure requirements. This means that the regulatory objective function would be the one we have assumed—maximizing expected revenues for high-quality firms. Such an objective function would be a natural outcome of competition among exchanges/regulators for the best issuers.

If, however, managers as corporate insiders benefit from not disclosing information, as argued in the previous subsection, then they may have an incentive to block even high-quality firms from listing with exchanges with the most stringent disclosure requirements. But to the extent that shareholders are better off with more disclosure, managers, faced with corporate control pressures, may have no choice but to list with the exchange that requires the most disclosure. Of course, if disclosure was purely voluntary, they might ex ante precommit to high levels of disclosure but then renege ex post. Having disclosure mandated by an exchange would then be a way to solve this time-consistency problem.

4. Implications for Disclosure Requirements in Emerging Economies

To understand the implications of our analysis for emerging markets, we begin by noting that there is likely to be greater heterogeneity in investors' information acquisition costs in emerging markets than in developed markets. As a financial market develops, we would expect the less-efficient (higher-cost) investors to be weeded out through a Darwinian survival process, leading to lower heterogeneity among investors.

The main implications of heterogeneity in information acquisition costs are summarized in the next proposition.

Proposition 8. *Heterogeneity in investors' information acquisition costs lessens the positive impact of to-be-processed and preprocessed information disclosures and increases the positive impact of substitute information disclosure on the type G firm's value.*

Information disclosure, regardless of type, is beneficial to the (type G) firm in both emerging and developed markets. Proposition 8 asserts the following.

Since to-be-processed and preprocessed information disclosures encourage informed trading, heterogeneity lessens the extent to which such disclosures increase informed trading and hence the positive impact of these disclosures on firm value. By contrast, substitute information disclosure reduces informed trading even though it increases firm value, because the direct impact of disclosure on firm value exceeds its indirect impact through informed trading. Heterogeneity lowers the information acquisition cost of the marginal investor and thereby helps decrease the impact of disclosure on the measure of informed investors. Thus the indirect (negative) effect of disclosure on firm value in the case of substitute information disclosure is smaller and the overall effect of heterogeneity is to increase the positive impact of substitute information disclosure on firm value.

Of course, not all forms of disclosure are as relevant in emerging markets as they are in developed markets. One would expect to-be-processed and preprocessed complementary disclosure to be of greater relevance than substitute information disclosure in emerging markets. The reason is that in emerging markets, even informed investors are likely to be relatively less informed, so that any information that is disclosed is likely to be complementary, rather than substituting for what the informed already know.[8] Moreover, the costs of investors' information acquisition and the fraction of bad firms are also likely to be high in emerging markets. The idea is that information is not as well documented, is harder to find, and suffers from reliability problems. So, becoming informed simply consumes more resources. Similarly, there are relatively more bad firms in the population because they have not yet been effectively sorted out. The implications of all this are summarized as follows.

Proposition 9. *(1) Assuming that to-be-processed and preprocessed complementary information disclosures are more relevant than substitute information disclosure for emerging markets and that investors' information acquisition costs are much higher in emerging markets than in developed markets, information disclosure will elevate the values of type G firms and strengthen financial innovation incentives in emerging markets. (2) If the fraction of type B firms in the population is larger in emerging markets than in developed markets, then price transparency will on average be lower in emerging markets and (complementary) information disclosure will lead to stronger incentives for financial innovation (with a sufficiently high fraction of type B firms).*

The intuition is straightforward. Disclosure always improves good firms' values, so complementary information disclosure will do that in emerging markets as well. If investors' information acquisition costs are sufficiently high, there may be little or no informed trading. From our analysis in

[8] Remember we are assuming that informed investors are "outsiders" who become informed at a cost. Insider trading, which is likely to be greater in emerging markets, is not considered here.

Section 2, we know that in this case disclosure of either to-be-processed or preprocessed complementary information strengthens incentives for financial innovation.

If the fraction of type B firms is higher in emerging markets than in developed markets, then emerging markets will have a lower measure of informed investors. The reason is that informed investors benefit only from locating good firms, so that if the probability of finding a good firm declines, so does the benefit of becoming informed. This means lower price transparency. And, as explained above, when the measure of informed investors is very small, disclosure improves financial innovation incentives.

Taken together, Propositions 8 and 9 suggest that, while disclosure of all types of information is valuable in both emerging and developed markets, one may make an even stronger case for disclosure in emerging markets. Although disclosure may not enhance price transparency as much in emerging markets as in developed markets, what is important is that price transparency *does* improve due to disclosure. Moreover, unlike developed markets, disclosure also strengthens incentives for financial innovation in emerging markets.

5. Conclusion

We have examined the incentives of firms to disclose information of various sorts. Our analysis explores the impact of various types of information disclosure on the market values of firms and on their incentives to engage in financial innovation that increases investors' private incentives to acquire information.

We have distinguished information disclosure on the basis of whether it is orthogonal to the information that investors would have acquired on their own and thus *complements* their information or it *substitutes* for it. When complementary information is disclosed, we distinguish between (to-be-processed) information about firms that is useful to a *subset* of investors (the informed) and (preprocessed) information about firms that is useful to *all* investors. In both cases, we find that complementary information disclosure increases the private information acquisition incentives of investors, in contrast to the existing literature. Moreover, financial innovation incentives may be strengthened or weakened with both types of complementary information disclosure. All types of firms prefer to make both types of complementary information disclosures in equilibrium.

We find that substitute information disclosure has the usual "crowding out" effect that diminishes the number of investors who become informed as well as the incentives for financial innovation. Despite this, the expected revenues of good firms are enhanced by such disclosure, and all firms make this disclosure in equilibrium.

Our article makes a very strong case for *voluntary* information disclosure by firms. Such disclosure always benefits the shareholders of good firms, and those who have bad news have no choice but to follow suit in equilibrium. However, agency and time-consistency problems could open up a wedge between the interests of managers and shareholders and create a role for disclosure requirements. In this case, competition between exchanges will lead to more stringent disclosure requirements.

Our analysis also has implications for information disclosure in emerging markets. We interpret emerging markets as having greater cross-sectional heterogeneity in information acquisition costs and a relatively high fraction of bad firms. We show that this *reduces* the positive impact of disclosure on price transparency. But it could lead to a more unambiguous positive impact of disclosure on financial innovation incentives.

The thesis that forms the backbone of this article is that financial disclosure and financial innovation share the common feature that both affect the private incentives of investors to gather information that in turn affect price transparency and firms' market values. Moreover, firms' financial innovation incentives are influenced by what information firms disclose to investors. Future research may be able to develop this thesis further by tackling interesting questions about differences in the attributes of traded securities and their price dynamics across different financial markets.

Appendix

Proof of Proposition 1. First some preliminaries. Note that Equation (6) can be written as

$$V = -M(\Omega)-\{qu+[1-q][1-u]\}+\{qux+[1-q][1-u]y\} \times \int_0^{\infty}[P^e(\Omega+\ell)]^{-1}f(\ell)d\ell. \tag{A.1}$$

Moreover, we know that

$$\Pr(G \mid D(\tilde{\theta},\ell)) = \frac{\{uf(D-\Omega)+[1-u]f(D)\}q}{\{uf(D-\Omega)+[1-u]f(D)\}q+\{uf(D)+[1-u]f(D-\Omega)\}[1-q]}. \tag{A.2}$$

Substitution of Equation (A.2) in Equation (7) gives

$$[P^e(\Omega+\ell)]^{-1} = \frac{q\{uf(\ell)+[1-u]f(\ell+\Omega)\}+[1-q]\{[uf(\ell+\Omega)+[1-u]f(\ell)]\}}{q\{uf(\ell)+[1-u]f(\ell+\Omega)\}x+[1-q]\{[uf(\ell+\Omega)+[1-u]f(\ell)]\}y}. \tag{A.3}$$

We will now show that $\partial V/\partial u > 0 \,\forall\, \Omega > 0$. It is sufficient to show that the profits V to the informed in Equation (A.1) evaluated at $u = 1$ strictly exceed those evaluated at $u < 1$, and that the difference is decreasing in u. Substituting Equation (A.3) in Equation (A.1), we see that Equation (A.1) evaluated at $u = 1$ exceeds that evaluated at $u < 1$ if

$$qx\left\{\frac{qf(\ell)+[1-q]f(\ell+\Omega)}{qf(\ell)x+[1-q]f(\ell+\Omega)y}\right\}-q > -qu-[1-q][1-u]+\{qux+[1-q][1-u]y\}\Gamma \,\forall\, \ell, \tag{A.4}$$

where

$$\Gamma \equiv \frac{q\{uf(\ell) + [1-u]f(\ell+\Omega)\} + [1-q]\{uf(\ell+\Omega) + [1-u]f(\ell)\}}{q\{uf(\ell) + [1-u]f(l+\Omega)\}x + [1-q]\{uf(\ell+\Omega) + [1-u]f(\ell)\}y}.$$

Tedious algebra involving premultiplication by

$$C \equiv q\{uf(\ell) + [1-u]f(\ell+\Omega)\}x + [1-q]\{uf(\ell+\Omega) + [1-u]f(\ell)\}y > 0$$

gives

$$[1-u]\{[qf(\ell) + [1-q]f(\ell+\Omega)][qx + [1-q]y]\tau - [2q-1][qx + [1-q]y]\} > 0 \quad \text{(A.5)}$$

where

$$\tau \equiv 1 - \frac{qx[f(\ell) - f(\ell+\Omega)]}{[1-q]f(\ell+\Omega)y + qf(\ell)x}.$$

A little algebra shows that the left-hand side of Equation (A.5) is indeed strictly positive. Observe that the quantity on the left-hand side of Equation (A.5) is strictly decreasing in u. Since the premultiplication involved C, with $\partial C/\partial u > 0$, it follows that $\partial V/\partial u > 0$.

Now, from Equation (6) we know that Ω^* solves

$$V(\Omega^* \mid q, \phi = \Delta u, x, y, M(\Omega^*), f(\ell)) = 0. \quad \text{(A.6)}$$

Given $\partial V/\partial u > 0$ and $\partial V/\partial \Omega < 0$ [see Equation (A.1)], it follows that $\partial \Omega^*/\partial u > 0$, that is, a higher value of u increases the expected revenue of the informed investors, and hence encourages informed trading. This proves the first part of the proposition. Recall that the type G issuing firm's expected market value is given by Equation (8).

If the total demand $D(\tilde{\theta}, \ell)$ turns out to be less than Ω, then the absence of informed demand is perfectly revealed to the market maker. The proof involves showing that, holding Ω fixed, R is increasing in u. Since $f(\ell)$ is log concave, we know that R is increasing in Ω. And since Ω^* is increasing in u, an increase in u will impact Ω in such a way as to further accentuate the increase in R. These details are not included here, but are available upon request. ■

Proof of Proposition 2. Define P_J^e as the equilibrium price of security J and $P_J(\theta)$ as the value of security J that is privately known to the informed trader who receives signal θ. The informed trader can gain nothing by purchasing security S, whereas there is possibly a positive expected profit from purchasing security J; we focus throughout on the case where investors' information acquisition costs are sufficiently low so that some investors choose to become informed. Thus an informed trader's optimal strategy is to invest his entire wealth endowment in security J. When security J is offered, the informed trader's expected net gain from being informed is (note that $f_n(\bullet)$ is the density function of liquidity demand in security J):

$$\begin{aligned} V_J &= -M(\Omega_j) + qu \int_0^\infty \left\{ \frac{[x-y] - P_J^e(\ell^o + \Omega_J)}{P_J^e(\ell^o + \Omega_J)} \right\} f_n(\ell)^o d\ell^o \\ &\quad - [1-q][1-u] \int_0^\infty f_n(\ell^o)\, d\ell^o \\ &= -M(\Omega_J) - \{qu + [1-q][1-u]\} \\ &\quad + qu[x-y] \int_0^\infty [p_J^e(\ell^o + \Omega_J)]^{-1} f_n(\ell^o)\, d\ell^o, \end{aligned} \quad \text{(A.7)}$$

where Ω_J is the measure of the set of traders who become informed, and $M(\Omega_J)$ is the cost of becoming informed for the marginally informed investor when the measure of informed traders equals Ω_J. In writing Equation (A.7), we have used the fact that the informed trader will submit an order for security J only when $\theta = G$, and in that case the privately known (intrinsic) value of that security is $x - y$ with probability u. For a realization $D^J = D^J(\theta, \ell^o)$ of aggregate demand in security J, the market maker will set

$$P_J^e(D^J(\theta, \ell^o)) = \Pr(\theta = G | D^J(\theta, \ell^o))[x - y]. \tag{A.8}$$

Using Bayes' rule, we have

$$\Pr(\theta = G | D^J(\theta, \ell)) = \frac{\{uf_n(D^J - \Omega_J) + [1-u]f_n(D^J)\}q}{\left\{\begin{array}{l} [uf_n(D^J - \Omega_J) + [1-u]f_n(D^J)]q \\ \quad +[1-q][f_n(D^J - \Omega_J)[1-u] + uf_n(D^J)] \end{array}\right\}} \tag{A.9}$$

and

$$[P_J^e(\Omega_J + \ell^o)]^{-1} = \frac{\left[\begin{array}{l} q\{[uf_n(\ell^o) + [1-u]f_n(\ell^o + \Omega_J)]\} \\ \quad +[1-q]\{[uf_n(\ell^o + \Omega_J) + [1-u]f_n(\ell^o)]\} \end{array}\right]}{q[uf_n(\ell^o) + [1-u]f_n(\ell^o + \Omega_J)[x - y]}. \tag{A.10}$$

Letting Ω_J^* be the equilibrium value of Ω_J, we have Ω_J^*, being determined by the marginal condition,

$$V_J(\Omega_J^* \mid q, x, y, M(\Omega_J^*), f_n(\ell^o), u) = 0. \tag{A.11}$$

We now wish to compare Ω_J^* to Ω^*. To do this, substitute Equations (A.7) and (A.10) in Equation (A.11) and simplify to

$$\begin{aligned} 0 = &-M(\Omega_J^*) - [1-q][1-u] + [1-q]u \\ &\times \int_0^\infty \left\{\frac{[uf_n(\ell^o + \Omega_J^*) + [1-u]f_n(\ell^o)]}{[uf_n(\ell^o) + [1-u]f_n(\ell^o + \Omega_J^*)]}\right\} f_n(\ell^o)\, d\ell^o. \end{aligned} \tag{A.12}$$

We need to compare the Ω_J^* in Equation (A.12) to Ω^* given by

$$0 = -M(\Omega^*) + qu\int_0^\infty \left[\frac{x - P^e}{P^e}\right] f(\ell)\, d\ell - [1-q][1-u]\int_0^\infty \left[\frac{P^e - y}{P^e}\right] f(\ell)\, d\ell \tag{A.13}$$

which, after appropriate substitutions can be written as

$$\begin{aligned} 0 = &-M(\Omega^*) - [1-q][1-u] - qu + [qux + \{1-q\}\{1-u\}y] \\ &\times \int_0^\infty \frac{\left\{\begin{array}{l} q[uf(\ell) + [1-u]f(\ell + \Omega^*)] \\ \quad +[1-q][uf(\ell + \Omega^*) + [1-u]f(\ell)] \end{array}\right\}}{\left\{\begin{array}{l} q[uf(\ell) + [1-u]f(\ell + \Omega^*)]x \\ \quad +[1-q][uf(\ell + \Omega^*) + [1-u]f(\ell)]y \end{array}\right\}} f(\ell)\, d\ell. \end{aligned} \tag{A.14}$$

We now need to compare Equations (A.12) and (A.14). As stated in the text, $f_n([1-\alpha]\ell^o) = f(\ell^o)[1-\alpha]^{-1}\,\forall\,\ell^o$. Thus a liquidity demand ℓ^o in security J corresponds to a demand $\ell = \{\ell^o/[1-\alpha]\}$ in the composite security. Now evaluate Equation (A.7) at $\overline{\Omega}_J = [1-\alpha]\Omega^*$. Even ignoring $M(\overline{\Omega}_J) < M(\Omega^*)$, we observe that informed trading in J is strictly profitable at $\Omega_J = \overline{\Omega}_J$. Therefore we have established $\Omega_J^* > [1-\alpha]\Omega^*$.

We show next that $\Omega_J^* > [1-\alpha]\Omega^*$ implies a strictly higher total expected revenue for a type G issuer selling securities J and S. Define R_{JS} as the total expected outcome of the type G issuer from selling securities J and S. Then we have

$$R_{JS} = y + E(P_J^e) = y + uE[P_J^e(\Omega_J + \ell^o)] + [1-u]E[P_J^e(\ell^o)]. \tag{A.15}$$

It is straightforward to show that, given $f_n'(\ell + \Omega_J) < 0$ and log concavity of $f_n(\cdot)$, we have $\partial E[P_J^e(\Omega_J + \ell^o)]/\partial\Omega_J > 0$. This means that the expected price fetched by the junior security is increasing in Ω_J conditional on the signal $\theta = G$. On the other hand, the expected price decreases in Ω_J conditional on the signal $\theta = B$. Since the signal is more likely to be good for a good firm ($u > 0.5$), the expected revenue also increases in Ω_J, that is, $\partial R_{JS}/\partial\Omega_J > 0$.

This latter (sub) result can be proved as follows. It can be shown using some algebra that the ex ante expected price of the junior security is the same as the cross-sectional average of the junior security's value

$$\{qu + [1-q](1-u)\}E[P_J^e(\Omega_J + \ell^o)] + \{q[1-u] + [1-q]u\}E[P_J^e(\ell^o)]$$
$$= q[x-y].$$

Therefore,

$$E[P_J^e(\ell^o)] = \frac{q[x-y]}{q[1-u]+[1-q]u} - \frac{E[P_J^e(\Omega_J+\ell^o)]\{qu+[1-q][1-u]\}}{q[1-u]+[1-q]u}.$$

Substituting in Equation (A.15),

$$R_{JS} = y + \frac{q[1-u][x-y]}{q[1-u]+[1-q]u} + [1-u]\left\{\frac{u}{1-u} - \frac{qu+[1-q][1-u]}{q[1-u]+[1-q]u}\right\}$$
$$\times E[P_J^e(\Omega_J+\ell^o)].$$

The coefficient of $E[P_J^e(\Omega_J + \ell^o)]$ is positive in the above equation so R_{JS} is increasing in $E[P_J^e(\Omega_J + \ell^o)]$ which in turn is increasing in Ω_J.

We now compare this to the expected revenue, R, with the (composite) unlevered security. For the unlevered security [see Equation (A.3)], we now have

$$R = y + E(P^e) = y + uE[P^e(\Omega+\ell)] + [1-u]E[P^e(\ell)]. \tag{A.16}$$

Use $f_n([1-\alpha]\ell^o) = f(\ell^o)[1-\alpha]^{-1}\,\forall\,\ell^o$ and compare Equations (A.3) and (A.10) to see that at $\Omega_J = [1-\alpha]\Omega$ we have $P^e(D) = P_J^e([1-\alpha]D) + y$. This implies that $R_{JS} = R$ at $\Omega_J = [1-\alpha]\Omega$. However, we have established that $\widehat{\Omega}_J^* > [1-\alpha]\Omega^*$. Hence, since $\partial R_{JS}/\partial\Omega_J > 0$, splitting the unlevered security enhances the type G's expected revenue.

Similar steps can be used to show that the type B issuer's expected revenue declines when it splits the unlevered security. However, if it follows the conjectured equilibrium strategy of splitting the security, its total expected revenue (defined as $\overline{R}_{JS}$) is

$$\overline{R}_{JS} = y + E_B(\overline{P}_J^e)$$

where $E_B(\overline{P}_J^e)$ is the expected equilibrium price of security J for the type B issuer. If it chooses not to split the unlevered security, its expected total revenue is y, since the market maker believes with probability one that the defecting firm is of type B. It can be easily checked that the Kreps and Wilson (1982) requirement that the equilibrium strategies and beliefs represent a "consistent assessment" is satisfied here. Thus with this out-of-equilibrium (o.o.e.) belief, the equilibrium in which both firms choose to split their securities is a sequential equilibrium. Note that this o.o.e. belief survives the universal divinity refinement of Banks and Sobel (1987). To see this, let p be the probability belief of the market maker that the defecting issuer is of type G. We will assume that the market maker prices the security to break even, conditional on his beliefs, even outside the equilibrium, that is, his best response is fixed by his belief. Let p_G be the critical value of this probability such that $R_{JS} = R(p_G)$, where $R(p_G)$ is the type G issuer's expected revenue if it defects from the equilibrium by issuing a composite security and the market maker believes with probability (w.p.) p_G that the defector is of type G. Clearly, $R_{JS} < R(p)$ for $p > p_G$ and $R_{JS} > R(p)$ for $p < p_G$, that is, $R(p)$ is increasing in p. Similarly, define p_B through the equality $\overline{R}_{JS} = R(p_B)$. Since $\overline{R}_{JS} < R_{JS}$, it is clear that $R(p_G) > R(p_B)$. Hence, $[p_G, 1] \subset [p_B, 1]$, which means that, according to the universal divinity criterion, the market maker must attach zero probability to the defector being of type G. Since $E_B(\overline{P}_J^e) > 0 \, \forall \, \ell^o \in (0, \infty)$, it is privately optimal for the type B issuer to split the security. ∎

Proof of Lemma 1. From Propositions 1 and 2 we know that the incentive to become informed is strictly increasing in disclosure (higher u), but security design also elevates the incentives to become informed.

From Equations (A.7) and (A.1), we can now see that if the lowest M_i is sufficiently high (i.e., the information acquisition cost of the lowest-cost investor is high) for a given u, no informed trading will occur with or without security design. However, the incentives to become informed are still stronger with security design than without. But since the net benefits to becoming informed are negative, there is no security design. Increasing u (by disclosure) can help since it improves the incentives to become informed. Since the incentives to become informed are stronger with security design, a sufficiently large increase in u will make the incentives to become informed positive first with security design. Once this happens, security design becomes profitable. Hence we have proved that this disclosure may strengthen security design incentives. ∎

Proof of Proposition 3. The proof follows from a comparison of Equations (10) and (11). Let $\overline{\Omega}$ be the measure of informed investors that sets V in Equation (10) equal to zero. We will show that, at this level of Ω, $\widehat{V}$ in Equation (11) is strictly positive. It will then follow that the Ω that leads to $\widehat{V} = 0$ should be strictly greater than $\overline{\Omega}$.

Observe from Equations (10) and (11) that all we need to show is that

$$0.5\left[\frac{x-a}{p_e^{(-)}}\right] + 0.5\left[\frac{x+a}{p_e^{(+)}}\right] > \frac{x}{0.5P_e^{(-)} + 0.5P_e^{(+)}}$$

Since $p_e^{(-)} = p_e^{(+)} - 2a$ we need to show that

$$\frac{x-a}{p_e^{(-)}} + \frac{x+a}{p_e^{(-)} + 2a} > \frac{2x}{p_e^{(-)} + a}.$$

After some algebra, it can be shown that this holds if $p_e^{(-)} < x - a$. This always holds since $\sup_\ell \{p_e^{(-)}\} = x - a$. ∎

Proof of Proposition 4. The proof follows from a comparison of Equations (12) and (13). Let $\overline{\Omega}_J$ be the measure of informed investors that sets V_J in Equation (12) equal to zero, and let $\widehat{\Omega}_J$ be the measure of informed investors such that $\widehat{V}_J$ in Equation (13) is zero. Now, write $\widehat{V}_J(\Omega_J)$ to express $\widehat{V}_J(\cdot)$ as a function of Ω_J. Clearly, $\widehat{V}_J(\widehat{\Omega}_J) = 0$. Evaluate $\widehat{V}_J$ at $\overline{\Omega}_J$, that is, $\widehat{V}_J(\overline{\Omega}_J)$. For any realization ℓ^o, we know that

$$P_e^J(\overline{\Omega}_J + \ell^o) = 0.5P_e^{J(-)}(\overline{\Omega}_J + \ell^o) = 0.5P_e^{J(+)}(\overline{\Omega}_J + \ell^o).$$

And since V_J is a convex function of P_J^e, we see from Equations (11) and (12) that $\widehat{V}_J(\overline{\Omega}_J + \ell_o) > V_J(\overline{\Omega}_J + \ell_o) = 0$. This means that $\widehat{\Omega}_J > \overline{\Omega}_J$. The rest of the proof follows the lines of the proof of Proposition 2. ∎

Proof of Proposition 5. Let Ω^* be the equilibrium measure of informed traders without disclosure, with

$$V(\Omega^* \mid q, r, y, a, \phi, M(\Omega^*), f(\ell)) = 0. \tag{A.17}$$

Now the total derivative $dV^*/dr = 0$ in equilibrium. Hence [see Equation (14)],

$$\partial\left\{\int_0^\infty \frac{[x - P^e(\Omega^* + \ell)]}{P^e(\Omega^* + \ell)} f(\ell)\, d\ell\right\}\Big/\partial r > 0.$$

Given $f'(\ell) < 0\,\forall\,\ell$, this holds if $\partial\Omega^*/\partial r < 0$. This proves the proposition. ■

Proof of Proposition 6. We now prove that substitute information disclosure will increase the expected revenue of the good firm. Let hats delineate all the relevant variables with disclosure and the absence of hats indicate the no-disclosure case. We first assume a homogeneous information cost M across informed investors. An informed investor's expected trading profit with disclosure is given by

$$\widehat{V} = -M + q[1-r]\int_0^\infty \frac{[x - \widehat{P}^e(\widehat{\Omega}) + \ell]}{\widehat{P}^e(\widehat{\Omega} + \ell)} f(\ell)\, d\ell,$$

and without disclosure it is given by

$$V = -M + q\int_0^\infty \frac{[x - P^e(\Omega + \ell)]}{P^e(\Omega + \ell)} f(\ell)\, d\ell.$$

In equilibrium we know that $\widehat{V} = V = 0$, which means

$$q\left[\int_0^\infty \left\{\frac{[1-r][x - \widehat{P}^e(\widehat{\Omega} + \ell)]}{\widehat{P}^e(\widehat{\Omega} + \ell)} - \frac{[x - P^e(\Omega + \ell)]}{P^e(\Omega + \ell)}\right\} f(\ell)\, d\ell\right] = 0. \qquad \text{(A.18)}$$

From Equation (A.18) it follows immediately that $\widehat{\Omega} < \Omega$. We now proceed as follows. Let R and $\widehat{R}$ be the (random) revenues of the good firm without, respectively, with disclosure,

$$R = P(\ell + \Omega)$$

$$\widehat{R} = \begin{cases} \widehat{P}(\ell + \widehat{\Omega}) & \text{with probability } (1-r) \\ x & \text{with probability } r \end{cases}$$

Define H and G as the cumulative distribution functions of and $\frac{1}{R}$ and $\frac{1}{\widehat{R}}$, respectively.

In equilibrium, the measure of informed investors is determined competitively so that

$$\begin{aligned} M &= qE\left[\frac{x}{P(\ell + \Omega)} - 1\right] \\ &= q(1-r)E\left[\frac{x}{\widehat{P}(\ell + \widehat{\Omega})} - 1\right] \\ \Rightarrow E\left[\frac{x}{P(\ell + \Omega)}\right] &= \frac{r}{x} + (1-r)E\left[\frac{1}{\widehat{P}(\ell + \widehat{\Omega})}\right] \\ \Rightarrow E\left[\frac{1}{R}\right] &= E\left[\frac{1}{\widehat{R}}\right]. \end{aligned} \qquad \text{(A.19)}$$

Now we are given that if $\psi(P;\widehat{\Omega})/\psi(P;\Omega)$ is decreasing in P for $\widehat{\Omega} < \Omega$. This means that

$$\frac{\text{probability density function (pdf) of } \frac{1}{\widehat{P}(\ell,\widehat{\Omega})} \text{ at } \frac{1}{P}}{\text{pdf of } \frac{1}{P(\ell,\Omega)} \text{ at } \frac{1}{P}} = \frac{P^2 * \text{ pdf of } \widehat{P}(\ell,\widehat{\Omega}) \text{ at } P}{P^2 * \text{ pdf of } P(\ell,\Omega) \text{ at } P}$$

is increasing in $\frac{1}{P}$. In other words, $\frac{dG}{dH}$ is increasing monotonically in $\frac{1}{P}$.

Since dG and dH are probability density functions, $\frac{dG}{dH}$ monotonically increases so there is an s^* such that $dG(s) < dH(s)$ for $s < s^*$ and $dG(s) > dH(s)$ for $s > s^*$. This means $G - H$ is a decreasing function for $s < s^*$ and an increasing function for $s > s^*$. But $G\left(\frac{1}{x}\right) - H\left(\frac{1}{x}\right) = r - 0 = r > 0$. So there is an $\tilde{s}$ such that $G(s) - H(s) > 0$ for $s < \tilde{s}$ and $G(s) - H(s) < 0$ for $s > \tilde{s}$.

Finally, we show that H second-order stochastically dominates G. It is sufficient to show that

$$\int_0^s G(t)dt \geq \int_0^s H(t)\,dt\,\forall\, s.$$

For $s \leq \tilde{s}$, this is obvious as functions $G - H$ is nonnegative for $s < \tilde{s}$. For $s > \tilde{s}$, we shall use the fact that G and H have the same mean [see Equation (A.19)]. This implies for $s > \tilde{s}$,

$$\begin{aligned}\int_0^s G(t)dt - \int_0^s H(t)\,dt &= \int_0^{\frac{1}{qx+(1-q)y}} \{G(t) - H(t)\}\,dt - \int_s^{\frac{1}{qx+(1-q)y}} \{G(t) - H(t)\}\,dt \\ &= -\int_s^{\frac{1}{qx+(1-q)y}} \{G(t) - H(t)\}\,dt \geq 0\end{aligned}$$

because the integrand is nonpositive.

Second-order stochastic dominance means that for any convex function λ, $E[\lambda(\frac{1}{R})] < E[\lambda(\frac{1}{\widehat{R}})]$. The function $\lambda(x) = 1/x$ is convex, so that $E[R] < E[\widehat{R}]$.

Finally, we show that the presence of heterogenous information acquisition costs M_i *strengthens* the above result. Note that [see Equation (A.18)] $\widehat{\Omega} < \Omega$. This means $M(\widehat{\Omega}) < M(\Omega)$. Let $M(\Omega) = M$ at the level where $V = 0$, so that at the original level $\widehat{\Omega}$ we now have $\widehat{V} > V = 0$. This implies that $\widehat{\Omega}$ needs to go up to restore the equilibrium equality of $\widehat{V} = 0$. This means an even greater increase in the good firm's revenues due to disclosure with heterogeneous information acquisition costs than with homogeneous information acquisition costs. ■

Proof of Lemma 2. Given that $f(\ell)$ follows a truncated normal distribution as defined in the lemma, let us find the probability density functions (pdf) of P and $\widehat{P}$

$$\begin{aligned}P(\ell, \Omega) \;=\; P \text{ if } &\frac{qf(\ell)\Omega + (1-q)f(\ell+\Omega)y}{qf(\ell) + (1-q)f(\ell+\Omega)} = P \\ \Rightarrow\; &\frac{f(\ell+\Omega)}{f(\ell)} = \frac{x-P}{P-y} \cdot \frac{q}{1-q} \\ \Rightarrow\; &\frac{e^{-(\ell+\Omega)^2/2\sigma^2}}{e^{-t^2/2\sigma^2}} = \frac{\Omega - P}{P-y} \cdot \frac{q}{1-q} \\ \Rightarrow\; &\ell(P) = \frac{\Omega}{2} - \frac{\sigma^2}{\Omega}\ell n\left\{\frac{(x-P)}{(P-y)}\frac{q}{(1-q)}\right\}.\end{aligned}$$

Therefore, $P(\ell, \Omega) \leq P$ if $\ell \leq \frac{\Omega}{2} - \frac{\sigma^2}{\Omega}\ell n\left\{\frac{(x-P)}{(P-y)}\frac{q}{(1-q)}\right\} \equiv \ell(P)$. Using rules for change of variable, we can get the pdf of $P(\ell, \Omega)$ from the pdf of ℓ.

The pdf of $P(\ell, \Omega)$ at P is

$$\begin{aligned}\psi(P; \Omega) &= f(\ell(P))\left|\frac{\partial \ell(P)}{\partial P}\right|_P \\ &= ce^{-\left\{\frac{\Omega}{2} - \frac{\sigma^2}{\Omega}\ell n\left(\frac{(x-P)}{(P-y)}\frac{u}{(1-u)}\right)\right\}^2/2\sigma^2} \cdot \frac{\sigma^2}{\Omega}\frac{(x-y)}{(x-P)(P-y)}.\end{aligned}$$

Similarly, the pdf of $\widehat{P}(\ell, \widehat{\Omega})$ at P is

$$\psi(P; \widehat{\Omega}) = ce^{-\left\{\frac{\widehat{\Omega}}{2} - \frac{\sigma^2}{\widehat{\Omega}}\ell n\left(\frac{(x-P)}{(P-y)}\frac{q}{(1-q)}\right)\right\}^2/2\sigma^2} \cdot \frac{\sigma^2}{\widehat{\Omega}}\frac{(x-y)}{(x-P)(P-y)}.$$

Now, the ratio of pdf's is

$$= \frac{\psi(P, \widehat{\Omega}) \text{ at } P}{\psi(P, \Omega) \text{ at } P}$$

$$= \underbrace{\frac{\Omega}{\widehat{\Omega}} e^{\frac{\Omega^2 - \widehat{\Omega}^2}{\sigma^2}}}_{\text{Independent of } P} \quad \underbrace{e^{\left(\frac{1}{\Omega^2} - \frac{1}{\widehat{\Omega}^2}\right)\frac{\sigma^2}{2}\left\{\ell n\left(\frac{(x-P)}{(P-y)}\frac{q}{(1-q)}\right)\right\}^2}}_{\text{Decreasing in } P \text{ because } \widehat{\Omega} < \Omega}$$

and $\left\{\ell n\left(\frac{(x-P)}{(P-y)}\frac{q}{(1-q)}\right)\right\}^2$ is increasing in P.

Thus the pdf ratio is decreasing in P. ■

Proof of Proposition 7. This proposition calls for a comparison of the incremental benefits of splitting (security design) *with* disclosure ϕ to those *without* disclosure ϕ. Splitting gives (the analysis is similar to that in Equation (A.7):

$$V = -M(\Omega_J) + q[1-r]E\left\{\frac{x-y}{P_J^e(\Omega_J + \ell^o)}\right\} - q[1-r] \tag{A.20}$$

where

$$P_J^e(\Omega_J + \ell^o) = \frac{[f_n(\ell^o)q][x-y]}{f_n(\ell^o)q + f_n(\Omega_J + \ell^o)[1-q]}. \tag{A.21}$$

At the optimum, $\Omega_J = \Omega_J^*$ is determined such that $V = 0$. The equilibrium revenues are given by

$$R_{JS}^* = y + r[x-y] + [1-r]E(P_J^e(\Omega_J^* + \ell^o))$$

where $E(P_J^e(\Omega_J^* + \ell^o))$ is defined in Equation (A.21). Thus

$$E\left(\frac{1}{\widehat{P}^e}\right) > 0$$

$$R_{JS}^* = rx + [1-r]\left\{y + [x-y]E\left(\frac{f_n(\ell^o)q}{f_n(\ell^o)q + f_n(\Omega_J^* + \ell^o)[1-q]}\right)\right\}. \tag{A.22}$$

Without splitting, in the unlevered case we have

$$R^* = rx + [1-r]\left\{y + [x-y]E\left(\frac{f(\ell)q}{f(\ell)q + f(\Omega^* + \ell)[1-q]}\right)\right\}. \tag{A.23}$$

The benefit to the firm of splitting is $R_{JS}^* - R^*$, and

$$R_{JS}^* - R^* = [1-r][x-y]\left\{E\left(\frac{f_n(\ell^o)q}{f_n(\ell^o)q + f_n(\Omega_J^* + \ell^o)[1-q]}\right) - E\left(\frac{f(\ell)q}{f(\ell)q + f(\Omega^* + \ell)[1-q]}\right)\right\}. \tag{A.24}$$

From Equation (A.24) it follows that $\partial[R_{JS}^* - R^*]/\partial r < 0$. Thus more public disclosure reduces the benefits of splitting (security design); it is easy to formally verify that the second-order effects of r on Ω^* and Ω_J^* are inconsequential. The result in Proposition 7 now follows immediately. Given that the benefits to security design are decreasing in r, we see that there exists a range of fixed costs of security design to the issuing firms such that these firms opt for security design with disclosure but abstain from it without disclosure. ■

Proof of Proposition 8. In the case of to-be-processed complementary information (case 1), note from the proof of Proposition 1 that disclosure increases informed trading. With heterogeneous information acquisition costs, disclosure [see Equation (A.1)] causes the measure of informed investors to increase less, thus reducing the value of such disclosure. As a result, the value of the type G firm is affected less by information disclosure when there is heterogeneity in information acquisition costs.

With the split security (Proposition 2), disclosure will increase the measure of informed investors. But due to the increasing cost of information acquisition for the marginal investor, the informed investor will be discouraged and the expected revenue (value) of a type G firm is lower with heterogeneous information acquisition costs than with homogeneous costs.

In the case of preprocessed complementary information, again the increasing marginal cost of information acquisition will ceteris paribus lower information acquisition incentives and reduce the type G firm's value (see Propositions 3 and 4).

For substitute information disclosure (case 3), we can prove the following. With the unlevered security (Propositions 5 and 6), disclosure reduces Ω^* (note $\partial\Omega^*/\partial r < 0$). With heterogeneous information acquisition costs, heterogeneity will lower the information acquisition cost of the marginal investor, and using Equation (14) and the analysis in the proofs of Propositions 5 and 6, we see that it will reduce the impact of r on Ω^*. Thus heterogeneous information acquisition costs increase informed trading, and hence the value of a type G firm. As in the other two cases, with split securities, heterogeneous information acquisition costs lower the increment in the measure of informed investors that can be attributed to security design, and hence the value of the type G firm. ■

Proof of Proposition 9. Part (1) is straightforward. We have already established in earlier results that disclosure of all types increases the value of the type G firm. By Lemma 1 for case 1 (and its implicit analog for case 2), we know that when the measure of informed investors is zero due to prohibitive information acquisition costs, disclosure of either to-be-processed or preprocessed complementary information will strengthen incentives for financial innovation.

If the fraction of type B firms increases, q decreases. From Equations (4) and (6), it follows immediately that the measure of informed investors, Ω, will decrease. It follows readily from this (e.g., Proposition 1) that price transparency will decline. And we have already shown that with a sufficiently small measure of informed investors, complementary information disclosure strengthens financial innovation incentives. ■

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