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The Relation among Capital Markets, Financial Disclosure, Production Efficiency, and Insider Trading

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1. *Introduction*

The purpose of this paper is to establish a link among (1) the nature of the capital market from which a firm secures its investment funds, (2) the firm's chosen level of financial disclosure, (3) the firm's cost of capital, (4) the extent of its residual agency problems, and (5) the extent of insider trading in its shares, in a model in which the costs and benefits associated with disclosure are endogenous. The nature of the capital market is characterized in our discussion by the potential liquidity needs of investors from whom capital is raised.

The level of disclosure is determined by trading off a production efficiency effect and a compensation subsidy effect, both of which fall with increased disclosure, against a market illiquidity effect and its effect on the cost of capital, both of which *also* fall with increased disclosure. Production efficiency falls because more disclosure means less information about the manager's action is impounded in price, so that price-based

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performance measures become less efficient, agency problems increase, and output falls. The compensation subsidy falls because more disclosure reduces the manager's insider trading profits, thereby reducing the market subsidy associated with hiring and paying the manager. Market illiquidity and the cost of capital fall because more disclosure encourages investment by individuals who may have future liquidity needs.

We show that as investors' potential liquidity needs increase, the optimal level of disclosure rises, the liquidity of the market increases, the cost of capital decreases, the expected profits of insider trading decrease, and the manager's residual moral hazard problem increases (as measured by the difference between the induced level of output and the first-best level). With respect to the last point, one plausible response to greater agency problems would be the use of complex performance-related compensation plans (e.g., performance bonuses, *SARs*, and stock option awards).[1] Hence, our analysis predicts a direct relationship between the use of such contracts, the market's potential liquidity needs, and the observed level of disclosure.

While any attempt to provide an explanation for cross-national economic differences is confounded by differences in the cultural, legal, and tax institutions of those economies, our results are consistent with anecdotal evidence concerning differences among the U.S., Japan, and Germany in the liquidity of their major sources of capital, the levels of financial disclosure, the extent of insider trading, and the use of complicated performance-related employment contracts.[2] For example, there is anecdotal evidence that in the United States, relative to these other economies, sources of capital are more diffuse and financial markets are more liquid, there is greater financial disclosure, there is less insider trading, and there is greater reliance on performance-related compensation.[3] In addition, the greater diffuseness of the U.S. capital markets and the consequent less profitable opportunities for insider trading by managers may

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[1] Our analysis is based on the use of optimal linear compensation contracts.

[2] Another difficulty is that little data concerning these cross-country differences has been systematically collected and examined.

[3] With respect to the liquidity issue, in Germany and Japan banks and related firms are major shareholders in corporations and the turnover in the investment portfolios of the German and Japanese banks and related firms is less than that for the average U.S. investor. For example, Raghavan and Sesit [1993] note that "Deutsche Bank, Germany's largest, owns a 28% interest in Daimler[-Benz] as well as substantial stakes in other large German companies." In addition, Woodward [1993], the chief economist of the Securities and Exchange Committee, states that "Until recently, the big German banks have handled nearly all the equity and debt-financing for large corporations." Scown [1990] makes a similar point about Japan," . . . in many cases family members of associated business groups hold most of a company's available shares, much as in Japanese keiretsu. . . . The Tokyo Stock Exchange (TSE) is an example. Although it is the second largest market in the world and has a large number of issues, the TSE has long been known as a thin market because cross-holdings are extensive, resulting in low market liquidity. Nearly three fourths of the shares on the TSE are never traded."

provide a partial explanation for the observed higher level of direct compensation received by U.S. *CEO*s.

In our model, an entrepreneur sells shares to raise a fixed amount of capital ($\$K$); we interpret the fraction of the firm's shares that must be sold to raise $\$K$ as the firm's cost of capital. After receiving $\$K$, the entrepreneur hires a manager by offering a compensation contract that is linear in reported earnings and the price at which the firm's shares trade after earnings are reported. The firm's gross cash flow results from the manager's effort and a random production shock. The manager privately observes the cash flow realization. However, an earnings report publicly discloses this cash flow with noise; the precision of the noise represents the firm's level of disclosure. The entrepreneur commits to the level of disclosure before he sells the shares. The financial market reopens after the earnings report is issued, and the firm's shares are traded. The manager trades on his private information about the cash flow realization.

The previously mentioned result that increased disclosure reduces production efficiency complements previous work that also makes this connection. However, in our model the cost of disclosure arises directly from the production process, and not through competition with other firms (as in Darrough and Stoughton [1990], Wagenhofer [1990], and Feltham and Xie [1992]) or exogenously (as in Verrecchia [1983] and Dye [1985]).

As evidence of lesser disclosure in Germany, Woodward [1993] states: "The American [disclosure] rules are the reason that German companies have avoided American capital markets. German companies find the standards hard to swallow. German accounting permits companies to have 'silent reserves,' which are accounts with undisclosed balances. Thus—except for big banks with clout—most German stockholders cannot find out the earnings, net worth, assets or liabilities of the companies in which they have invested."

Further, in Raghavan and Sesit [1993], Gerhard Liener, Daimler-Benz's chief financial officer, "acknowledges that investors get more information under U.S. rules: 'There's a big gap between German accounting standards and U.S. principles. U.S. accounting discloses so much more and tells you what's really happening in a company.' " Czinkota, Rivoli, and Ronkainen [1992] and Givant [1987] provide corroborative annecdotal evidence. Scown [1990] makes a similar point about Japanese disclosure practices.

The very nature of insider trading makes it difficult to measure. However, it does appear that in the United States, there are more prohibitions against insider trading and these prohibitions are more frequently enforced than in other countries. For example, the first conviction for insider trading in Germany occurred in 1995 (see Reuters [1995]). Further, in discussing the takeover of Triangle Industries by the French firm of Pechiney, Cohen [1993] states, "Although the case amounted to the biggest insider-trading scandal ever in France, it ended by demonstrating that the crime is viewed far less severely here than in the United States." See also, Protzman [1993; 1994], Conlon [1991], Fisher [1990], Whitney [1993], Scown [1990], and Woodward [1993] for additional anecdotal evidence supporting the assertion that insider trading is less prevalent in the U.S. than in Europe and Japan.

Finally, with respect to the use of complicated performance-related compensation plans, Kaplan [1994] provides some systematic evidence that the use of stock options, *SAR*s, etc. is more prevalent in the U.S. than in Japan.

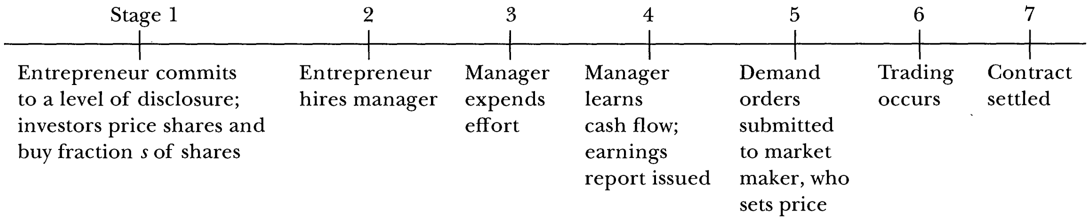

FIG 1.—Time line.

In our analysis, the effect of disclosure on production and liquidity is mediated by its effect on insider trading. Our analysis extends the insider-trading literature (e.g., Manne [1966], Carlton and Fischel [1983], Ausubel [1990], Leland [1990], Fishman and Hagerty [1992], Fischer [1992], Bradley, Khanna, and Slezak [1992], and Khanna, Slezak, and Bradley [1994]) in that we focus on a manager-insider who makes a productive decision, is subject to moral hazard, is compensated with an optimal linear contract, and trades in a rational market in which his trades affect market price.

Our finding of an inverse relation between market liquidity and production efficiency complements work by Bhide [1993]. In Bhide [1993], greater market liquidity reduces the incentives of shareholders to monitor and control managers. In our analysis, the inverse relation between liquidity and production efficiency follows because, given rational pricing of shares, the former increases in disclosure while the latter decreases. The result that increased disclosure reduces the cost of capital also adds to previous work (e.g., Diamond and Verrecchia [1991]) in that we introduce an agency problem.

In section 2 of the paper we describe more fully our model. In section 3 we establish the cost of capital by determining the firm's expected net cash flow conditioned on the optimal level of disclosure and study the effect of the chosen level of disclosure on liquidity, the compensation subsidy arising from the manager's insider trading, and managerial efficiency. In section 4 we relate the chosen level of disclosure, managerial efficiency, and the extent of insider trading to the liquidity needs of investors. In section 5 we discuss the relation between the optimal level of disclosure and the risk aversion of the manager. Summary observations are offered in the final section.

2. *The Model*

The model to be studied is similar to that in Baiman and Verrecchia [1995] and consists of a single-period setting with an entrepreneur, shareholders, a manager, liquidity-motivated traders, and a market maker. The time line for the model is shown in figure 1.

The risk-neutral entrepreneur possesses a stochastic production process (i.e., the firm) whose characteristics are common knowledge. To implement the production process, the entrepreneur must acquire $\$K$ of capital by issuing shares and hire a manager.[4] At the first stage, the entrepreneur commits to a level of financial disclosure,[5] potential risk-neutral shareholders (hereafter referred to as the "original shareholders") price the shares, and the entrepreneur issues that fraction of his firm's shares that raises $\$K$. In pricing the shares, the original shareholders anticipate that at stage 5, before the cash flow is realized and distributed, they may have a liquidity shock that requires them to buy or sell shares at the then-current market price. The shareholders also anticipate both the contract that the entrepreneur will offer the manager and the possibility that the manager will engage in insider trading.

At the second stage the entrepreneur hires a risk-averse manager and designs a compensation contract. The design of the contract is affected by the manager's anticipated insider trading in two ways. First, his expected trading profit provides compensation that does not have to be paid by the firm. The entrepreneur views this expected trading profit as a *subsidy*. Second, the manager's ability to trade potentially loosens the connection between his consumption and the compensation paid by the firm.

At the third stage, the manager expends unobserved effort that stochastically affects the firm's gross cash flow. At the fourth stage, the manager learns the firm's gross cash flow, and the firm issues an earnings report that consists of the cash flow plus noise. This level of noise (i.e., the precision of the earnings reporting process) is the one to which the entrepreneur previously committed.

At the fifth stage, the manager and liquidity-motivated traders, including some of the original shareholders, submit market orders (stated as a fraction of the firm's shares) to the market maker. The demand orders of the liquidity-motivated traders are independent of the earnings report or other information. The demand order submitted by the manager is chosen rationally and is *not* observable.[6] At the sixth stage, a risk-neutral market maker sets the market price equal to the expected cash flow conditional on all information available to him. At the last stage, the firm's cash flow, net of the manager's compensation, is paid to the current shareholders.

In the U.S., the existence of strict prohibitions on insider trading and stringent reporting requirements for all insider transactions (even for those not involving inside information) would seem to call into question

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[4] We assume that $\$K$ is small enough relative to the firm's expected net cash flow that the fraction of total shares to be issued is less than one.

[5] We assume the entrepreneur chooses the firm's level of financial disclosure. We model a situation in which the choice of financial disclosure is publicly observed, as is the case, for example, with respect to the choice of the major financial accounting principles. When the choice of disclosure is observed, delegating the choice to management and retaining the choice by the entrepreneur are equivalent.

[6] In contrast, Dye [1984] assumes that the manager's trades are observable and contractible.

our assumption that the manager can execute unobservable trades based on inside information. Nonetheless, this assumption can be defended as follows. First, restrictions/prohibitions on insider trading are less frequent and less well enforced in other countries.[7] This suggests that our assumption is at least appropriate for these economies. Second, the number of insider trading cases brought and won by the *S.E.C.* each year indicates that insider trading does exist in the U.S., despite the restrictions.[8] Finally, even if insider trading is effectively prohibited, we show in section 4 that the results of our analysis extend to the case in which the person trading on private information is *outside* the firm. In other words, a key requirement in our model is that some trader be privately informed and trade on that information; it is not necessary that the privately informed trader be the manager.

The firm's production process is represented by $\tilde{u} = e + \tilde{x}$, where $\tilde{u}$ is the firm's cash flow gross of the manager's compensation, e is the effort taken by the manager at stage 3, and $\tilde{x}$ is a noise term that is normally distributed, with mean zero and precision h, and independent of the manager's effort.

The publicly disseminated earnings report is $\tilde{r} = \tilde{u} + \tilde{\delta}$, where $\tilde{r}$ is the report and $\tilde{\delta}$ is a normally distributed noise term with mean zero and precision n. The parameter n characterizes the level of disclosure committed to by the entrepreneur in stage 1. $\tilde{\delta}$ is unaffected by the manager's action. Thus, the earnings report is an unbiased estimate of the firm's gross cash flow.

The manager's utility function is assumed to be $-\exp\{-\tau(c + \tilde{D}_M(\tilde{u} - \tilde{P}) - V(e))\}$. τ is the manager's coefficient of risk aversion, c is his compensation, and $\tilde{D}_M$ is his demand order. $\tilde{P}$ is the market value of the firm set by the market maker and $V(e) = \frac{e^2}{2}$ is the manager's disutility from choosing effort e. $\tilde{D}_M(\tilde{u} - \tilde{P})$ is the manager's trading profit at stage 5.[9]

We assume that the manager's contract is based only on the earnings report and the market price at stage 5; the firm's gross cash flow is not contractible. For reasons of tractability, we restrict the contract to be linear in the two contractible variables.[10] The contract offered to the manager is thus $\alpha\tilde{r} + \beta\tilde{P} + \gamma$, where α, β, and γ are the linear compensation

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[7] See the earlier discussion in n. 2.

[8] Two recent U.S. court cases in which individuals were convicted of insider trading are discussed in the *New York Times* (see "Insider-Trading Cases . . . " [1995] and Bloomberg Business News [1995]).

[9] Without loss of generality, we assume that the manager holds no shares in the firm prior to trading. In addition, we assume that the manager is allowed to sell short. Alternatively, we could assume that the manager is endowed with a sufficient number of shares such that any sale of shares would be covered by his endowment.

[10] See Bushman and Indjejikian [1993], Kim and Suh [1993], Paul [1992], and Baiman and Verrecchia [1995] for other work that makes this assumption. Also see Holmstrom and Milgrom [1987] for a similar model in which the optimal contract is linear.

coefficients and $\tilde{P}$ is the stage 5 market price, gross of the manager's compensation.

After the manager expends his effort and observes the firm's gross cash flow, the earnings report is disseminated and the market opens with three types of traders: the manager who trades on his private knowledge of the firm's gross cash flow; liquidity-motivated traders whose demands are independent of the earnings report; and the market maker. Liquidity traders include both some of the original shareholders and possibly others (the latter are referred to as investors). The total market demand for all liquidity-motivated traders is $\tilde{N}$, and that for just the original shareholders is $\tilde{z}$. $\tilde{N}$ and $\tilde{z}$ are normally distributed, each with mean zero and precisions η and Δ, respectively, where $\Delta \geq \eta$. The liquidity shocks of the two types of liquidity-motivated traders are independent; that is, $\tilde{N} - \tilde{z}$ and $\tilde{z}$ are independent. Δ and η are exogenous. The market order for the manager is $\tilde{D}_M$ and total demand is $\tilde{D}_T = \tilde{D}_M + \tilde{N}$.

We assume a Kyle [1985] type market equilibrium process. The informed manager and the liquidity-motivated traders simultaneously submit orders to a market maker who sets price equal to the firm's expected gross cash flow, conditional on all public information. In addition, the market maker buys the excess shares, if net demand is negative, and shorts the stock, if net demand is positive.[11]

The conditioning information used by the market maker in setting price includes the earnings report, total net demand, and a public but noncontractible signal that could cause the market maker to revise his conjecture about the manager's action choice.[12] That is, we assume there is information about the manager's effort choice that is public, hence impounded in price, but not contractible.[13] We discuss this assumption next.

In general, price is used in contracting because it contains information that cannot be directly incorporated into the contracts themselves, perhaps because of cost. For example, many bond agreements include accounting-based covenants that do not adjust for management's observable choices of accounting methods. The alleged lag between stock price declines and top management's employment status provides indirect evidence consistent with such incomplete compensation contracts. In these instances, investors apparently impound the effects of inappropriate managerial actions into stock price well before this information is reflected in management's compensation or employment status. Thus, we believe our assumption of a public but noncontractible signal about the

[11] In this way, no problem arises if the net demand exceeds the supply of shares.

[12] For example, assume that the manager chooses his action from the set $\{a, b, c\}$. If there were publicly observable but noncontractible signals $\{y_a, y_b, y_c\}$, where y_i implied *not* action i, then observing such a signal would cause the market maker to adjust his conjecture about the manager's action choice.

[13] A similar assumption is made in Bebchuk and Fershtman [1994].

manager's action is descriptively valid and allows us to study the effect of contract incompleteness.

As a simplifying assumption, we assume the signal observed by the market maker is the action taken by the manager. However, we emphasize that the analysis holds even if the signal is imperfect, as long as it could cause the market maker to revise his conjecture about the action chosen by the manager. This informational assumption allows us to model the game between the manager and the market maker as a Stackelberg game, with the manager moving first. Previous work has used the Nash equilibrium concept (e.g., Holmstrom and Tirole [1993]). We discuss the effect of this difference in equilibrium concept in section 3.

3. Results

At the first stage, the entrepreneur raises $\$K$ by selling a fraction of the firm's shares, s, determined such that the risk-neutral original shareholders are indifferent between receiving this fractional ownership (and thus, possibly subjecting themselves to liquidity shocks in the future) and an amount $\$K$. That is, s is chosen to satisfy:

$$(1-q)E[s(\tilde{u}-c(\cdot))] + qE[-(\tilde{z}-s)\tilde{P}^N + \tilde{z}(\tilde{u}-c(\cdot))] = K \qquad (1)$$

where q is the fraction of the shareholders who will receive a liquidity shock at stage 5 and therefore engage in a trade at the net-of-compensation price $\tilde{P}^N$ $(=\tilde{P}-c(\cdot))$, $\tilde{z}$ is the after-trade shareholdings (as a fraction of the firm's shares) of the original shareholders who receive a liquidity shock, and $c(\cdot)$ is the compensation to be paid to the manager.[14]

The market maker sets price, $\tilde{P}$, equal to expected gross cash flow conditional on the earnings report, total net demand, and e.[15] As is standard, we restrict our attention to equilibrium pricing rules that are linear in the observables. Lemma 1 characterizes the optimal linear pricing rule and demand function.[16]

LEMMA 1. The optimal linear pricing rule and the manager's demand function are:

$$P = E[\tilde{u}\,|\tilde{r}=r, \tilde{D}_T = D_T, e] = \left[\frac{n}{n+h}\right] r + \lambda D_T + \left[\frac{h}{n+h}\right] e - \lambda\beta$$

and:

$$D_M(\tilde{u}=u, \tilde{r}=r) = ([h+n]\,Q)^{-1}(h[u-e]-n[r-u]) + \beta$$

[14] We assume that $100q\%$ of the original shareholders will receive a liquidity shock for certain, although which ones actually receive the shock is uncertain. The parameter q is exogenously given.

[15] We let P represent the price for the gross cash flow of the firm rather than the cash flow net of compensation, for notational convenience. This does not qualitatively affect the analysis or results.

[16] All proofs are in Appendix A.

where $Q = 2\lambda + \lambda^2\tau\eta^{-1}$ and λ is the unique strictly positive solution to $F(\lambda) = (h + n)\lambda Q^2 - \eta(Q - \lambda) = 0$.

λ is a measure of the market's liquidity. As λ increases, the market becomes less liquid and price becomes more sensitive to changes in total demand. Note that the choice of n, the reporting precision, affects both λ and the manager's trading opportunities.

We next establish the manager's optimal compensation scheme.

LEMMA 2. The optimal α, β, e, and γ are:

$$\alpha = \frac{-\tau nh}{(h+\tau)\,Q(h+n)^2 + \tau h^2}$$

$$\beta = \frac{(h+n)\,(\tau h + Qh(h+n))}{(h+\tau)\,Q(h+n)^2 + \tau h^2}$$

$$e = \frac{\tau h^2 + Qh(h+n)^2}{(h+\tau)\,Q(h+n)^2 + \tau h^2}$$

where $1 > e > 0$ and γ is chosen to satisfy the manager's individual rationality constraint.

It can be easily shown that the entrepreneur's objective function at this stage (stage 2) is strictly concave in α, β, and e. Therefore, the chosen α, β, and e will be interior solutions. These choices are *not* independent of the precision of the liquidity-motivated trading process, η, and market liquidity, λ, so that the entrepreneur chooses them anticipating the manager's future trading opportunities.

Solving (1) for the fraction of shares to be sold in stage 1 gives $s = \dfrac{K + q\lambda\Delta^{-1}}{E[\tilde{u} - c(\cdot)]}$. The term $q\lambda\Delta^{-1}$ represents the premium demanded by the original shareholders for the possibility of having to engage in liquidity-motivated trades. The parameter q captures the likelihood of the original shareholders becoming liquidity traders, while $\lambda\Delta^{-1}$, the correlation between liquidity trades and price, captures the cost to the original shareholders from trading in a market in which their trades affect price.

The entrepreneur chooses the optimal level of disclosure, n, at stage 1 so as to maximize the value of his claim $(1 - s)$ to the expected residual cash flow of the firm $E[\tilde{u} - c(\cdot)]$. Thus, the entrepreneur solves the following problem: $\max_n E[(1 - s)\ (\tilde{u} - c(\cdot))]$. Using the earlier solution for s and substituting in the solution for the optimal contract from Lemma 1 provides the result given in Proposition 1.

PROPOSITION 1. The entrepreneur's maximization problem at stage 2 is $\max_n \left[\frac{e}{2} - q\lambda\Delta^{-1} - \frac{L}{2} + \frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]\right]$, where $\frac{L}{2}$ represents the manager's exogenously specified outside opportunity utility.

From Proposition 1, the choice of n affects the entrepreneur's utility in three ways: production efficiency, $\frac{e}{2}$, liquidity, $-q\lambda\Delta^{-1}$, and subsidy $\frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]$.[17] The expression $\frac{e}{2}$ represents the production efficiency effect because e is the manager's induced action choice. The expression $-q\lambda\Delta^{-1}$, the liquidity effect, was discussed earlier. The expression $\frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]$ is the subsidy effect because it is derived from the compensation constant, γ, chosen to satisfy the manager's Individual Rationality constraint. Next we discuss how changing the disclosure level affects each of these.

We start with the liquidity effect. In pricing the shares of the firm at stage 1, the original shareholders factor in the possibility of becoming liquidity traders at stage 5. Clearly, in the event of the liquidity shock, these shareholders prefer to trade in a more liquid market. The choice of disclosure level affects the liquidity of the market, λ, at stage 5, which in turn influences share prices at stage 1, and hence the firm's cost of capital. This effect is summarized in Corollary 1 (whose proof is straightforward and not offered).

COROLLARY 1.

(*a*) Market liquidity increases in the precision of disclosure, i.e., $\frac{d\lambda}{dn} < 0$.

(*b*) The liquidity effect component of the entrepreneur's objective function increases in the precision of disclosure, i.e., $\frac{d(-q\lambda\Delta^{-1})}{dn} > 0$.

The intuition for this result is that more disclosure reduces the information asymmetry between the informed manager and the market maker. Hence, there is less information for the market maker to extract from the total net demand, thereby reducing the sensitivity of price to the total net demand order. This implies that λ decreases and the market becomes more liquid. Because the original shareholders value future liquidity, the firm's cost of capital falls with more disclosure.

Next, consider the effect of changing n on the entrepreneur's objective function through its effect on the subsidy, $\frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]$. The subsidy effect arises from the manager's trading profits, which can be used by the entrepreneur to reduce the manager's direct compensation from the firm. Corollary 2 (whose proof is straightforward and not offered) establishes that more disclosure reduces the subsidy.

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[17] We ignore $\frac{L}{2}$ in the subsequent discussion because it is fixed and exogenously determined by the manager's outside opportunities, which are assumed to be independent of the events in this model.

COROLLARY 2. The subsidy effect component of the entrepreneur's objective function decreases in the precision of disclosure, i.e.:

$$\frac{d\left[\frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]\right]}{dn} < 0.$$

As we show later, as disclosure increases, the manager's informational advantage (and his information rent) decreases. However, his outside opportunity utility must still be satisfied. Therefore, the expected value of the compensation contract must increase to adjust for the decrease in the manager's expected trading profits.

Finally, recall that $\frac{e}{2}$ is the expected cash flow to the firm after compensating the manager, ignoring any reduction in his compensation from the subsidy effect. The expression $\frac{e}{2}$ represents the efficiency effect and captures the moral hazard problem inherent in the entrepreneur contracting with the manager. Corollary 3 (whose proof is straightforward and not offered) establishes the efficiency effect of disclosure.

COROLLARY 3. The production efficiency effect component of the entrepreneur's objective function decreases in the precision of disclosure, i.e., $\frac{de}{dn} < 0$.

The intuition underlying this result is as follows. By assumption, the market maker knows the manager's level of effort.[18] To set the price, the market maker uses this effort information, together with reported earnings, to extract the manager's private information about the realized firm cash flow from the total net demand order, D_T.[19] With more disclosure, reported earnings become more informative about firm cash flow, so the market maker relies more on reported earnings and less on total net demand in specifying price. As a result, when disclosure increases, the market maker has less need to use his knowledge of the manager's effort level to extract the manager's private information from D_T. Consequently, more disclosure means *there is less information about the manager's chosen effort contained in price* (i.e., the $\frac{h}{h+n}e$ term in the pricing equation decreases as n increases). Even though the entrepreneur remains interested in price (as a measure of effort, not as a measure of cash flow information), the efficiency of price as a contracting variable declines with an increase in disclosure, and, as demonstrated in Corollary 3, this decline is not offset by the improvement in reported earnings.

Two points should be emphasized here. First, although increased disclosure makes price and reported earnings inferior joint measures of the manager's effort level because price impounds less effort information, it makes them better joint measures of cash flow (i.e., the variance of $\tilde{u}$ con-

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[18] In contrast, the entrepreneur can only conjecture the manager's chosen effort level.

[19] The use of the effort information is manifest in the $\frac{h}{h+n}e$ term in the expression for price in Lemma 1.

ditional on P and r decreases with more disclosure). Second, if the market maker did not observe the manager's effort, but (like the entrepreneur) had to conjecture the manager's effort in specifying price, neither price nor reported earnings would contain information about the manager's effort not already contained in cash flow.[20] Further, because price is constructed to be the minimum variance estimation of firm cash flow, it is a sufficient statistic for price and reported earnings with respect to cash flow. As a result, if the market maker did not observe the manager's effort, the entrepreneur would contract only on price, rather than on price and reported earnings.

In summary, increased disclosure reduces both the production efficiency and subsidy effects, and increases the liquidity effect. The result that a change in n has countervailing effects on the entrepreneur's objective function suggests that, in general, partial disclosure ($0 < n < \infty$) is optimal.[21] However, we have found examples (available from the authors) where either no disclosure or full disclosure is optimal. In the next section we discuss more fully the determinants of the optimal choice of the level of disclosure.

4. *Determinants of the Optimal Level of Disclosure and Insider Trading*

In this section we address the relations discussed in the introduction: the liquidity needs of the original investors, the optimal level of disclosure, residual agency problems, and the extent of insider trading. The liquidity needs of the original shareholders are characterized by the fraction of original shareholders who become liquidity traders, q, and the precision of the process generating their liquidity trades, Δ. Let n^* be the level of disclosure that maximizes the entrepreneur's stage 1 objective function as determined in Proposition 1.

PROPOSITION 2. Assuming partial disclosure is optimal:

(a) The optimal level of disclosure increases in the fraction of original shareholders who become liquidity traders, i.e., $\frac{dn^*}{dq} > 0$.

(b) Holding η fixed, the optimal level of disclosure increases in the variance (i.e., the inverse of the precision) of the original shareholders' liquidity shock, i.e., $\frac{dn^*}{d\Delta^{-1}} > 0$.

Both parts of the proposition follow from the result that liquidity increases in n. The intuition for part (a) is that as q increases, the demand for liquidity increases. To meet this increased demand, the entrepreneur increases the level of disclosure. To interpret part (b), note that the total

[20] In this circumstance the manager and market maker play a Nash game. See the discussion in Baiman and Verrecchia [1995] for further details.

[21] An example for which this is the case has the following parameter values: $h = \eta = \Delta = .15$, $\tau = 5$, $K = 10$, $q = .5$.

noise associated with liquidity trading, η, is constant, so that the information in the total demand order observed by the market maker is also held constant, and so is the informativeness of price. As Δ increases, the variance of the original shareholders' liquidity shock decreases. This implies a decrease in the magnitude of the liquidity shock, thereby decreasing the original shareholders' demand for liquidity. Thus, the entrepreneur can reduce n and thereby increase production efficiency.

The fact that the optimal level of disclosure n^* is increasing in both q and Δ^{-1} suggests that if the original shareholders were the only liquidity-motivated shareholders ($\Delta = \eta$) and all were certain to receive a liquidity shock at stage 5 ($q = 1$), then full disclosure would be optimal. However, this is not always so.[22] Even in this case, less than full disclosure and, hence, some illiquidity may be optimal. The only reason for the entrepreneur to induce an illiquid market (choose n so that $\lambda > 0$) is to make price a better contracting variable. Thus, moral hazard concerns alone can induce the original shareholders to accept some illiquidity, even when they know for certain they will receive liquidity shocks. Finally, the existence of liquidity traders, other than the original shareholders, is not crucial to the analysis, because partial disclosure can be optimal even in the absence of nonoriginal shareholder liquidity needs.

Next, combining Corollary 3 and Proposition 2 directly implies Corollary 4 (which is offered without proof), which addresses the relation between the nature of the capital market and residual agency problems.

COROLLARY 4. If partial disclosure is optimal, productive efficiency decreases (and agency costs increase) as the fraction of the original shareholders who become liquidity traders and/or the variance of the original shareholders' liquidity shock increases, i.e., $\frac{de}{dq} < 0$ and $\frac{de}{d\Delta^{-1}} < 0$, holding η fixed.

Our final analysis concerns the relation between the nature of the capital market and the extent of insider trading. We measure the extent of insider trading as the expected profit from insider trading, $E[\tilde{D}_M(\tilde{u} - \tilde{P})]$. Assuming partial disclosure is optimal, it is straightforward to establish the intermediate result that the extent of insider trading decreases in the precision of disclosure, i.e., $\frac{dE[\tilde{D}_M(\tilde{u} - \tilde{P})]}{dn} < 0$.

To interpret this result, it is useful to think of the expected profit from insider trading as a function of the trader's aggressiveness (i.e., the size of his trade) and his informational advantage. We measure the aggressiveness of the manager's trading by $E[\,|\tilde{D}_M - \beta|\,]$, which is the expected level of managerial insider trading over and above that required to unravel his stock-price-based compensation. The accuracy of price as an estimator of cash flow is represented by $E[(\tilde{u} - \tilde{P})^2]$. It is straightforward to establish that the aggressiveness of the insider's trades increases in the

[22] When $h = 4$, $\eta = \Delta = 18$, $\tau = 18$, $K = 10$, and $q = 1$, no disclosure is optimal ($n^* = 0$).

disclosure precision ($\frac{dE[|\tilde{D}_M\tilde{u}-\beta|]}{dn} > 0$), while the trader's informational advantage decreases in the disclosure precision ($\frac{dE[(\tilde{u}-\tilde{P})^2]}{dn} > 0$). As disclosure increases, λ decreases, which means that the effect of the manager's trades on market price is decreasing. This allows the manager to increase the size (i.e., aggressiveness) of his trade without affecting market price. However, increased disclosure makes price a better estimator of cash flow and reduces the manager's informational advantage. Thus, while increasing disclosure has countervailing effects on the manager's total expected profit from insider trading, the net effect is always to decrease his expected trading profit. We can combine Proposition 2 and the intermediate result that the expected profit from insider trading decreases in n to establish the relation between the nature of the market and the extent of insider trading.

COROLLARY 5. Assuming partial disclosure is optimal:

(a) The extent of insider trading decreases in the fraction of the original shareholders who become liquidity traders, i.e.,
$$\frac{dE[\tilde{D}_M(\tilde{u}-\tilde{P})]}{dq} < 0.$$

(b) Holding η fixed, the extent of insider trading decreases in the variance of the original shareholders' liquidity shock, i.e.,
$$\frac{dE[\tilde{D}_M(\tilde{u}-\tilde{P})]}{d\Delta^{-1}} < 0.$$

It is important to note that the results discussed above depend on the existence of an informed trader, but this person need not be the manager. To see this, suppose the manager is unable to trade, but another individual in the economy privately observes gross cash flow, $\tilde{u}$, at stage 4 and trades on that information at stage 5. In this case, there is no subsidy effect (because the manager has no trading profits), but the choice of n still involves a trade-off between a production efficiency effect and a liquidity effect. In particular, it can be shown that the manager's optimal induced effort, market illiquity, and the cost of capital all still decrease in n. Thus, the inverse relation between production efficiency and disclosure is caused by the existence of some privately informed trader, not necessarily the manager.

Separating the roles of manager and informed trader allows us to address another point. As discussed earlier, the aggressiveness of trading based on private information is influenced by the level of disclosure. This implies that a potentially important determinant of the optimal level of disclosure is the aggressiveness of privately informed trading. In our model the less risk-averse the privately informed individual, the more aggressively he trades. However, when the privately informed trader is also the manager, changing his risk coefficient affects disclosure in several different ways.

To study the effect of aggressive trading by a privately informed individual, we assume that the manager and trader are different people. Let the (nontrading) manager's utility function be $-\exp\{-\tau(\alpha\tilde{r} + \beta\tilde{P} + \gamma - V(e))\}$. If the privately informed trader is risk-neutral, we can show that partial disclosure is always dominated by full disclosure. To see this, assume otherwise, that is, that the original disclosure level is n^*, where n^* is an interior solution and therefore satisfies the first-order condition. The entrepreneur's objective function is $F(n) = \frac{1}{2}\{\frac{h(2h+n)}{h(2h+n)+\tau(h+n)}\} - q\lambda\Delta^{-1} - \frac{L}{2} - \frac{1}{\sqrt{2}}$. The first-order condition for a local maximum of $F(n)$ with respect to n is $A^4\eta\, q^2 = 4\,\tau^2\,\Delta^2\,h^4\,(h+n)^3$, where $A = h(2h+n) + \tau(h+n)$. Consequently, if there exists a global maximum, n^*, which is also in the interior, it must be the case that $F(n^*) > \lim_{n\to\infty} F(n) = \frac{1}{2}\{\frac{h}{h+\tau}\}$. However, substituting the first-order condition into the previous inequality and rearranging terms implies that $0 > hn + \tau(h+n)$, which is a contradiction. Therefore, partial disclosure is dominated by full disclosure when the informed trader is risk-neutral.

This result holds regardless of the other exogenous parameters (such as q and Δ). Of course, no disclosure might be optimal for this problem, because either $q = 0$ or $\Delta^{-1} = 0$ is sufficient to eliminate liquidity as a concern in choosing a level of disclosure. Thus, with a risk-neutral privately informed trader who is not a manager, the optimal level of disclosure will either be none or full.

5. *Disclosure and Managerial Risk Aversion*

In the previous section we demonstrated that the risk aversion of the informed trader and hence the aggressiveness of his trading affect the entrepreneur's optimal choice of financial disclosure. In this section we pursue the role of the *manager's* risk aversion in the choice of the level of disclosure.

Returning to the basic model in which the manager is the only informed trader, it appears that changing in the manager's risk coefficient, τ, has an ambiguous effect on the optimal level of disclosure. However, some insight can be gained by decomposing the comparative static of a change in τ on n^* (the optimal level of disclosure) into the liquidity, subsidy, and production efficiency effects discussed earlier.[23] Throughout this section we assume that partial disclosure is optimal.

[23] Let $OBJ\,(n, \tau)$ be the entrepreneur's stage 1 objective function. Earlier we divided it into its three components: liquidity ($LIQ(n,\tau)$), subsidy ($SUB(n,\tau)$), and productive efficiency ($PROD(n,\tau)$). We can show that:

$$\text{Sign}\left\{\frac{dn^*}{d\tau}\right\} = \text{Sign}\left\{\frac{d}{d\tau}\left[\frac{dOBJ(n,\tau)}{dn}\right]\right\} = \text{Sign}\left\{\frac{d}{d\tau}\left[\frac{dLIQ(n,\tau)}{dn} + \frac{dSUB(n,\tau)}{dn} + \frac{dPROD(n,\tau)}{dn}\right]\right\}.$$

Proposition 3 separately evaluates $\text{Sign}\left\{\frac{d}{d\tau}\left[\frac{dLIQ(n,\tau)}{dn}\right]\right\}$, $\text{Sign}\left\{\frac{d}{d\tau}\left[\frac{dSUB(n,\tau)}{dn}\right]\right\}$, and $\text{Sign}\left\{\frac{d}{d\tau}\left[\frac{dPROD(n,\tau)}{dn}\right]\right\}$.

First, consider the effect of a change in τ on n^* through liquidity. Increasing τ makes the manager more risk-averse, so he trades less aggressively. This makes the market more liquid, which allows the entrepreneur to reduce the level of disclosure, thereby dealing more effectively with the manager's moral hazard problem.

Next, consider the effect of an increase in the manager's risk coefficient through the subsidy effect. One of the costs of increasing n is that it reduces the manager's total trading rent and thereby reduces the subsidy. However, a more risk-averse manager trades less aggressively anyway, earning smaller rents and thereby generating a still smaller subsidy. Therefore, the subsidy cost of increasing n decreases as the manager becomes more risk-averse, allowing the entrepreneur to increase n.

Because the liquidity and subsidy effects of changes in the manager's risk aversion on the optimal level of disclosure go in opposite directions, the overall effect is probably ambiguous. Moreover, as we show next, the production efficiency effect is ambiguous on its own, further reinforcing the chances of an ambiguous comparative static in τ.

Recall that the production efficiency effect is $\frac{e}{2}$. A change in τ has two production efficiency effects. First, increasing τ increases the manager's risk aversion, which, in turn, increases the moral hazard problem. This should result in a compensating decrease in n^*. On the other hand, a decrease in n^* increases λ, and therefore increases $\lambda^2 \eta^{-1}$, which represents the risk borne by the manager associated with his price-based compensation. As the manager becomes more risk-averse, the risk premium associated with decreasing n, and thereby increasing the riskiness of his price-based compensation, increases. This makes decreasing n in response to an increase in τ more costly, the more risk-averse the manager. For small initial τ, the first effect dominates the second; that is, an increase in τ results in a decrease in n^*. Likewise, for sufficiently large initial τ, the second effect dominates the first; that is, an increase in τ results in an increase in n^*. This intuition is supported in the simple case, discussed earlier, in which the manager is not allowed to trade, but there is a risk-neutral privately informed trader who does trade on his private information. For this case, the sign of the production efficiency effect of $\frac{dn^*}{d\tau}$ is the same as the sign of $-h(2h + n) + \tau(h + n)$, which is negative for small τ and positive for large τ.

These results are summarized in Proposition 3.

PROPOSITION 3. Assuming partial disclosure is optimal:

(*a*) Increasing the manager's risk coefficient reduces the optimal level of disclosure through the liquidity effect.

(*b*) Increasing the manager's risk coefficient increases the optimal level of disclosure through the subsidy effect.

(*c*) Increasing the manager's risk coefficient has an ambiguous effect on the optimal level of disclosure through the efficiency effect.

6. *Conclusion*

In this paper we establish a link among the liquidity needs of the capital markets, the optimal level of disclosure, the cost of capital, agency costs, and insider trading. We demonstrate that the firm's optimal choice of financial disclosure policy is affected by the liquidity needs of the capital market and involves a trade-off between productive efficiency and the cost of capital. This trade-off arises endogenously as a result of rational pricing and the presence of insider trading. We show that more disclosure results in less information about the manager's action being impounded in price, so that price-based performance measures become less efficient, agency problems increase, and output falls. More disclosure also reduces the manager's insider-trading profits, and hence the market subsidy associated with hiring and paying the manager. The cost of capital falls with more disclosure because the latter increases market liquidity, which encourages investment by individuals who may have future liquidity needs. Thus, as investors' potential liquidity needs increase, the optimal level of disclosure increases, the liquidity of the market increases, the cost of capital decreases, the expected profits of insider trading decrease, and the manager's residual moral hazard problem increases (leading to decreased efficiency).

This relation between liquidity needs, disclosure, market liquidity, and insider trading is consistent with anecdotal evidence concerning differences among the United States, Japan, and Germany. With respect to the efficiency result, one plausible response to greater agency problems would be the use of complex performance-related compensation plans (e.g., performance bonuses, *SAR*s, and stock option awards). Hence, our analysis predicts a direct relationship between the use of such contracts and the market's potential liquidity needs and the observed level of disclosure.

APPENDIX A
Proofs

Proof of Lemma 1. The proof is the same as that of Propositions 1 and 2 in Baiman and Verrecchia [1995]. D_M is found by substituting the assumed linear pricing rule, $ar + \lambda D_T + k_p$, into the manager's unconditional expected utility:

$$E[-\exp\{-\tau(\alpha r + \beta\tilde{P} + \gamma + D_M(u - \tilde{P}) - V(e))\}|\tilde{u} = u, \tilde{r} = r]$$
$$= -\exp\{-\tau(\alpha r + \beta E[\tilde{P} \mid u, r] + D_M(u - E[\tilde{P} \mid u, r]\ ) + \gamma - \frac{\tau}{2}$$
$$(\beta - D_M)^2 \mathrm{Var}(\tilde{P} \mid u, r) - V(e))\}$$

and then taking the first-order condition of the above with respect to D_M. This gives the manager's demand rule in terms of the pricing parameters, a, λ, and k_P. Next, to find $\tilde{P} = E[\tilde{u} \mid \tilde{r} = r, \tilde{D}_T = D_T]$, we first need to find the covariance matrix for $[u, r, D_T]$. That matrix is:

$$
\begin{array}{cc}
 & \begin{array}{ccc} u & r & D_T \end{array} \\
\begin{array}{c} u \\ r \\ D_T \end{array} & \mathrm{V} = \begin{bmatrix} h^{-1} & h^{-1} & a_m h^{-1} \\ h^{-1} & h^{-1} + n^{-1} & a_m h^{-1} + b_m n^{-1} \\ a_m h^{-1} & a_m h^{-1} + b_m n^{-1} & a_m^2 h^{-1} + b_m^2 n^{-1} + \eta^{-1} \end{bmatrix}
\end{array}
$$

where $a_m = \dfrac{h}{(h+n)Q}$, $b_m = \dfrac{-n}{(h+n)Q}$, and $Q = 2\lambda + \lambda^2\tau\eta^{-1}$. Then, using the normality assumption, we compute the above and collect terms to establish that the original conjecture about the form of the linear pricing rule is consistent. *Q.E.D.*

Proof of Lemma 2. The proof is the same as that of Proposition 2 in Baiman and Verrecchia [1995]. One first finds the manager's unconditional expected utility using Lemma 1 and the moment-generating function for a normally distributed random variable. Next, take the first-order condition of the manager's unconditional expected utility with respect to e. This gives $e = \alpha + \beta$. Substituting this back into the entrepreneur's stage 2 problem and taking the first-order condition with respect to e and α gives the desired solution. *Q.E.D.*

Proof of Proposition 1. Substituting the solution for s into the entrepreneur's stage 1 objective function gives:

$$E[(1-s)\ (\tilde{u} - c(\cdot))] = E\left[\left\{\frac{E[\tilde{u} - c(\cdot)] - K - q\lambda\Delta^{-1}}{E[\tilde{u} - c(\cdot)]}\right\}(\tilde{u} - c(\cdot))\right]$$

$$= E[\tilde{u} - c(\cdot)] - K - q\lambda\Delta^{-1} = e - e^2 - \gamma - K - q\lambda\Delta^{-1},$$

where the latter follows from Lemma 2 and the fact that $E(\tilde{u}) = e$. Next, solve for the constant component of the compensation function, γ, necessary to satisfy the manager's outside opportunity wage, L. From Baiman and Verrecchia [1995] it follows that $\gamma = \frac{\tau}{2}(h^{-1} + n^{-1})\alpha^2 + \tau h^{-1}\alpha\beta + \frac{\tau}{2}A\beta^2 + \frac{\ln J}{\tau} + \frac{L}{2}$, where $A = \dfrac{\tau n + Q(h+n)^2}{h(h+n)(\tau + Q(h+n))}$ and $J = \left[\dfrac{Q(h+n)}{Q(h+n)+\tau}\right]^{\frac{1}{2}}$. One can then substitute γ into $E[\tilde{u} - c(\cdot)] - K - q\lambda\Delta^{-1} = e - e^2 - \gamma - K - q\lambda\Delta^{-1}$, use the fact that $\alpha + \beta = e$ to collect terms, and simplify to give the solution. *Q.E.D.*

Proof of Proposition 2. The proofs of (a) and (b) are similar, therefore, we provide the proof for only (a). Represent the entrepreneur's stage 1 objective function as $OBJ(n,q) = \frac{e}{2} - q\lambda\Delta^{-1} - \frac{L}{2} + \frac{1}{2\tau}\ln\left[\dfrac{Q(h+n)+\tau}{Q(h+n)}\right]$. The optimal n^* is the solution to $\frac{dOBJ(n, q)}{dn} = 0$. An interior solution to n^* implies that $\frac{d^2OBJ(n, q)}{dn^2} < 0$. Varying the first-order condition for n, in q, and letting $\lambda' = \frac{d\lambda}{dn} < 0$, gives $\frac{d^2OBJ(n, q)}{dn^2} dn^* - \lambda' \Delta^{-1} dq = 0$ or $\frac{dn^*}{dq} = \frac{\lambda' \Delta^{-1}}{\frac{d^2OBJ(n, q)}{dn^2}} > 0$. *Q.E.D.*

Proof of Corollary 5. The proof follows from Proposition 2 and the fact that the expected profit from insider trading decreases in n. *Q.E.D.*

Proof of Proposition 3. Part (a): Let n^* be the entrepreneur's optimal choice of disclosure. Assuming an interior solution in n, n^* satisfies $\frac{dOBJ(n,\tau)}{dn} = 0$, where $OBJ(n,\tau)$ is the entrepreneur's objective function with the n and τ arguments made explicit. Therefore, $\frac{dn^*}{d\tau} = -\frac{\frac{d}{d\tau}\left[\frac{dOBJ(n,\tau)}{dn}\right]}{\frac{d^2OBJ(n,\tau)}{dn^2}}$. Because n^* is assumed to be an interior solution, $\frac{d^2OBJ(n,\tau)}{dn^2} < 0$. Therefore, Sign $\{\frac{dn^*}{d\tau}\}$ = Sign $\{\frac{d}{d\tau}\left[\frac{dOBJ(n,\tau)}{dn}\right]\}$.

That part of the $OBJ(n, \tau)$ which reflects the liquidity effect is $-q\lambda\Delta^{-1}$. Therefore, the effect of increasing the manager's risk coefficient on the optimal level of disclosure through the liquidity effect has the same sign as $-q\Delta^{-1}\lambda_{n\tau}$, where $\lambda_{n\tau}$ is the derivative of λ with respect to n and τ.

Using the equilibrium condition $F(\lambda) = 0$, we can establish that $\lambda_\tau = -\lambda^3\tau z^{-1}$ and $\lambda_n = -Q^3\eta z^{-1}$, where $z = 4\eta^2 + 6\lambda\eta\tau + 3\lambda^2\tau^2$. Taking the partial derivative of λ_n with respect to τ yields:

$$\begin{aligned}
\lambda_{n\tau} &\propto -3Q^2\lambda^2(2\eta + \lambda\tau)^2 + \eta Q^3(6\eta(Q-\lambda) + 6\lambda_\tau\eta\lambda^{-1}\tau(Q-\lambda)) \\
&= -3Q^2\lambda^2\eta^2\lambda^{-2}Q^2 + 6\eta^2Q^3(Q-\lambda)(1+\lambda_\tau\lambda^{-1}\tau) \\
&\propto -Q + 2(Q-\lambda)(1-\lambda^2\tau^2z^{-1}) \\
&\propto -Q(4\lambda^2 + 6\lambda\eta\tau + 3\lambda^2\tau^2) + 2(Q-\lambda)(4\lambda^2 + 6\lambda\eta\tau + 3\lambda^2\tau^2 - \lambda^2\tau^2) \\
&\propto (Q-2\lambda)(4\lambda^2 + 6\lambda\eta\tau + \lambda^2\tau^2) - 2\lambda^3\tau^2 \\
&= \lambda^2\tau\eta^{-1}(4\lambda^2 + 3\lambda^2\tau^2) + 4\lambda^3\tau^2 > 0.
\end{aligned}$$

Therefore, $-q\Delta^{-1}\lambda_{n\tau} < 0$, and the result is proved. *Q.E.D.*

Part (b): Let n^* be the entrepreneur's optimal choice of disclosure. Assuming an interior solution in n, n^* satisfies $\frac{dOBJ(n,\tau)}{dn} = 0$, where $OBJ(n,\tau)$ is the entrepreneur's objective function with the n and τ

arguments made explicit. Therefore $\frac{dn^*}{d\tau} = -\frac{\frac{d}{d\tau}\left[\frac{dOBJ(n,\tau)}{dn}\right]}{\frac{d^2OBJ(n,\tau)}{dn^2}}$. Because n^* is assumed to be an interior solution, $\frac{d^2OBJ(n,\tau)}{dn^2} < 0$. Therefore, Sign $\{\frac{dn^*}{d\tau}\}$ = Sign $\{\frac{d}{d\tau}\left[\frac{dOBJ(n,\tau)}{dn}\right]\}$.

That part of the $OBJ(n,\tau)$ which reflects the subsidy effect is $\frac{1}{2\tau}$ ln $\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]$. Therefore, the effect of increasing the manager's risk coefficient on the optimal level of disclosure through the liquidity effect has the same sign as $\frac{d^2}{dn\,d\tau}\left[\frac{1}{2\tau}\ln\left[\frac{Q(h+n)+\tau}{Q(h+n)}\right]\right] = \frac{d^2}{dn\,d\tau}\left[\frac{1}{2\tau}\ln\left[\frac{A+\tau}{A}\right]\right]$, where $A = Q(h+n) = \lambda^{-1}Q^{-1}\eta(Q-\lambda)$.

Letting $A_n = \frac{dA}{dn}$, $\frac{d}{dn}\left[\frac{1}{2\tau}\ln\left[\frac{A+\tau}{A}\right]\right] = -\frac{A_n}{2A(A+\tau)}$. Letting $C = \lambda\tau$, we can express

$$-\frac{A_n}{2A(A+\tau)} = -\frac{\lambda(4\eta^3+6\eta^2C+4\eta C^2+C^3)}{(h+n)(4\eta^4+18\eta^2C+25\eta^2C^2+15\eta C^3+3C^4)}.$$

Therefore, $\frac{d^2}{dn\,d\tau}\left[\frac{1}{2\tau}\ln\left[\frac{A+\tau}{A}\right]\right] = -\frac{d}{d\tau}\left[\frac{A_n}{2A(A+\tau)}\right] = D_1C_\tau - D_2\lambda_\tau$, where D_1, $D_2 > 0$, $C_\tau > 0$, and $\lambda_\tau < 0$. Hence $\frac{d^2}{dn\,d\tau}\left[\frac{1}{2\tau}\ln\left[\frac{A+\tau}{A}\right]\right] > 0$. *Q.E.D.*

Part (c) is established by numerical examples. *Q.E.D.*

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