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Alex Edmans
Mirko Heinle
Chong Huang

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ABSTRACT

This paper models the effect of disclosure on real investment. We show that, even if the act of disclosure is costless, a high-disclosure policy can be costly. Some information ("soft") cannot be disclosed. Increased disclosure of "hard" information augments absolute information and reduces the cost of capital. However, by distorting the relative amounts of hard and soft information, increased disclosure induces the manager to improve hard information at the expense of soft, e.g. by cutting investment. Investment depends on asset pricing variables such as investors' liquidity shocks; disclosure depends (non-monotonically) on corporate finance variables such as growth opportunities and the manager's horizon. Even if a low disclosure policy is optimal to induce investment, the manager may be unable to commit to it. If hard information turns out to be good, he will disclose it regardless of the preannounced policy. Government intervention to cap disclosure can create value, in contrast to common calls to increase disclosure.

Alex Edmans
The Wharton School
University of Pennsylvania
2460 Steinberg Hall - Dietrich Hall
3620 Locust Walk
Philadelphia, PA 19104
and NBER
aedmans@wharton.upenn.edu

Mirko Heinle
The Wharton School
University of Pennsylvania
1330 Steinberg Hall - Dietrich Hall
3620 Locust Walk
Philadelphia, PA 19104
miheinle@wharton.upenn.edu

Chong Huang
University of California, Irvine
The Paul Merage School of Business
Building 221 Periera Drive
CA 92697-3125
chong.h@uci.edu

1 Introduction

This paper analyzes the effect of a firm's disclosure policy on real investment. An extensive literature highlights numerous benefits of disclosure. Diamond (1985) shows that disclosing information reduces the need for each individual shareholder to bear the cost of gathering it. In Diamond and Verrecchia (1991), disclosure reduces the cost of capital by lowering the information asymmetry that shareholders suffer if they subsequently need to sell due to a liquidity shock. Kanodia (1980) and Fishman and Hagerty (1989) show that disclosure increases price efficiency and thus the manager's investment incentives.

However, the costs of disclosure have been more difficult to pin down. Standard models (e.g. Verrecchia (1983)) typically assume an exogenous cost of disclosure, justified by several motivations. First, the actual act of communicating information may be costly. While such costs were likely significant at the time of writing, when information had to be mailed to shareholders, nowadays these costs are likely much smaller due to electronic communication. Second, there may be costs of producing information. However, firms already produce copious information for internal or tax purposes. Third, the information may be proprietary (i.e., business sensitive) and disclosing it will benefit competitors (e.g., Verrecchia (1983) and Dye (1986)). However, while likely important for some types of disclosure (e.g., the stage of a patent application), proprietary considerations are unlikely to be for others (e.g., earnings).[1] Perhaps motivated by the view that, nowadays, the costs of disclosure are small relative to the benefits, recent government policies have increased disclosure requirements, such as Sarbanes-Oxley, Regulation FD, and Dodd-Frank.

This article reaches a different conclusion. We show that, even if the actual act of disclosure is costless, a high-disclosure policy can still be costly due to its effect on real investment. Central to our analysis is the idea that only some types of information ("hard", i.e., quantitative and verifiable) can be credibly disclosed, but others ("soft", i.e., non-verifiable) cannot be.[2] For example, a firm can credibly communicate its earnings, but not the quality of its corporate culture. It may seem that this distinction

[1] Fourth, Hirshleifer (1971) shows that disclosure in insurance markets may worsen risk-sharing, e.g. if it is made public which individuals will suffer heart attacks before they have a chance to take out medical insurance. Kanodia and Lee (1998) apply this idea to financial markets and show that disclosure of firm fundamentals before current investors can trade will impose risk on them; if they are more risk-averse than future investors, this in turn distorts investment decisions. However, Diamond (1985) argues that this cost is unlikely to be significant for financial markets, where continuous trading is possible.

[2] See, e.g., Stein (2002) and Petersen (2004) for the distinction between hard and soft information.

does not matter: even if a firm cannot increase the amount of soft information, it can still disclose more hard information. The *absolute* amount of overall information will rise, reducing the cost of capital. However, the manager's investment decision depends on the *relative* weighting between hard and soft information. If neither type of information is disclosed, the manager chooses the investment policy that maximizes firm value. In contrast, an increase in the absolute amount of hard information disclosed also augments the amount of hard information relative to soft. This in turn distorts the manager's actions towards improving the hard signal at the expense of the soft signal – for example, cutting investment in corporate culture to increase current earnings.

Our model features a firm initially owned and run by a manager, who must raise funds from an outside investor. After funds are raised, the firm turns out to be either high or low quality, and this type is unknown to the investor. As in Diamond and Verrecchia (1991), the investor may subsequently suffer a liquidity shock which forces her to trade additional shares. Also present in the market is a speculator (such as a hedge fund) who has private information on firm value, and a market maker. The investor expects to lose to the speculator from her liquidity trading and thus demands a larger stake when contributing funds, augmenting the cost of capital.

The manager can reduce the investor's informational disadvantage, and thus the cost of capital, by disclosing a hard signal (such as earnings) that is partially informative about firm value, just before the trading stage. We initially assume that the manager can commit to a disclosure policy when raising funds, as in the literature on mandatory disclosure. High disclosure indeed reduces the cost of capital, but has an important cost. A high-quality firm has the option to undertake an intangible investment that improves the firm's long-run value, but this value cannot be disclosed as it is soft information. The investment also raises the probability of delivering low earnings, which lowers the short-term stock price since low-quality firms always generate low earnings. Thus, a manager concerned with the stock price will underinvest. While existing literature typically assumes that firm value is exogenous and studies the optimal level of information to disclose about this fixed value, here firm value is endogenous to the disclosure policy (even absent a competitor who can use the disclosed information).

The optimal level of disclosure is thus a trade-off between the benefits of disclosure (reduced cost of capital) and its costs (inefficient investment). The manager chooses either full disclosure to minimize the cost of capital, or partial disclosure to maximize investment. Thus, the model delivers predictions on how disclosure should vary cross-sectionally across firms. The effect of firm characteristics on disclosure is typically non-monotonic. Up to a point, increases in growth opportunities reduce disclosure: investment becomes sufficiently important that the firm is willing to sacrifice disclosure to pursue it. For example, at the time of its IPO, Google announced that it would not provide earnings guidance as such disclosure would induce short-termism. Their founders's letter stated "[w]e recognize that our duty is to advance our shareholders' interests, and we believe that artificially creating short term target numbers serves our shareholders poorly."[3] However, when investment opportunities are very strong, the manager will exploit them fully even when disclosure is high. Thus, disclosure is lowest for firms with intermediate growth opportunities, and high for firms with weak or strong growth opportunities. For similar reasons, disclosure is high either when information asymmetry (the difference in value between high- and low-quality firms), shareholders' liquidity shocks, or signal imprecision (the risk that investment leads to a bad signal), are low, as the manager will invest fully even with high disclosure, or when these parameters are high, as the manager will invest fully even under high disclosure. For example, an increase in signal imprecision does not necessarily induce less disclosure of the signal. Such an increase makes the cost of capital relatively more important to investment, and so the manager may choose full disclosure to minimize the cost of capital.

More broadly, by combining investment, disclosure, informed trading, and capital raising within a unifying framework, we generate new empirical predictions linking investment (typically a corporate finance topic) to informed trading and the cost of capital (typically asset pricing topics) since both are linked through disclosure. While researchers typically study how investment depends on Tobin's Q or financial constraints, we show that it depends on microstructure features such as shareholders' liquidity needs, since they influence disclosure policy and thus investment. While the cost of capital depends on microstructure features such as information asymmetry, we show that it is also affected by corporate finance variables such growth opportunities and the manager's short-term concerns, since these influence disclosure policy and thus the cost of capital.

We next consider the case in which the manager cannot commit to a disclosure policy, as in the literature on voluntary disclosure. If investment is important, the manager would like to announce a "low disclosure, high investment" policy. However, if the manager invests and gets lucky, i.e., still delivers high earnings, he will renege

[3] Similarly, Porsche was expelled from the M-DAX stock market index in August 2001, after refusing to comply with its requirement for quarterly reporting, arguing that such disclosures would lead to myopia.

on the policy and disclose the high earnings anyway. Knowing that he will always disclose high earnings if realized, the manager will reduce investment, to maximize the probability that he realizes high earnings. Then, if the market does not receive any disclosure, it rationally infers that the signal must be low, else the manager would have released it – the "unraveling" result of Grossman (1981) and Milgrom (1981). The only dynamically consistent policy is full disclosure, and investment suffers as a result. In this case, government intervention can be desirable. By capping the feasible level of disclosure, it can allow the firm to implement the optimal policy. This conclusion contrasts earlier research which argues that regulation should increase disclosure due to externalities (Foster (1979), Coffee (1984), Dye (1990), Admati and Pfleiderer (2000), and Lambert, Leuz, and Verrecchia (2007)). If capping disclosure is difficult to implement, a milder implication of our model is that regulations to increase disclosure (e.g., Sarbanes-Oxley) may have real costs.

However, the effect of government intervention on firm value is unclear. First, even if the government's objective function were to maximize initial firm value, the optimal disclosure policy is firm-specific, whereas regulation cannot be tailored to an individual firm. Second, the government's policy may be to maximize total surplus. This objective function incorporates the benefits of investment but ignores investor losses from liquidity shocks, since they are offset by trading profits to the speculator. Then, the government will choose the disclosure policy that maximizes investment, which is inefficiently low for the firm as it leads to a high cost of capital. Third, Regulation FD attempts to "level the playing field" between different investors, suggesting an objective to minimize trading losses for retail investors. In this case, the government will maximize disclosure, at the expense of investment.

This paper is related to a large literature on the costs and benefits of disclosure, which is reviewed by Verrecchia (2001), Dye (2001), Beyer, Cohen, Lys, and Walther (2010), and Goldstein and Sapra (2012). Our main innovation is to identify and analyze a real cost of disclosure. Gigler, Kanodia, Sapra, and Venugopalan (2013) show that an interim signal can induce the manager to choose a short-term project over a long-term alternative, in a setting where both projects are ex ante unprofitable (in contrast to our model). They compare a social planner's payoff across two discrete regimes (with and without the interim signal), assuming that commitment is possible. We study the firm's optimal choice from a continuum of disclosure policies, thus delivering predictions on how firms' disclosure decisions depend (non-monotonically) on asset pricing and corporate finance factors. Here, disclosure also affects the cost of capital, and so investment variables affect the cost of capital through their impact on disclosure policy. We also consider the voluntary disclosure case where the firm cannot commit to a disclosure policy. In Hermalin and Weisbach (2012), disclosure affects the manager's incentives to engage in manipulation. They show that the manager prefers less disclosure ex post. Here, where disclosure is voluntary, the manager always discloses.

Consistent with our theory, survey results by Graham, Harvey, and Rajgopal (2005) suggest that 78% of executives would sacrifice long-term value to meet earnings targets. Bhojraj and Libby (2005) show experimentally that the expectation of future equity sales induces myopia, Cheng, Subrahmanyam, and Zhang (2007) document that firms that issue quarterly earnings guidance invest less in R&D, and Ernstberger, Link, and Vogler (2011) find that European Union firms in countries with quarterly rather than semi-annual reporting engage in greater short-termism.

Other researchers have noted that regulation should sometimes constrain disclosure. Fishman and Hagerty (1990) advocate limiting the set of signals from which the firm may disclose, whereas here the constraint is on the level of disclosure. In Fishman and Hagerty (1989), traders can only acquire a signal in one firm, and so disclosure draws traders away from one's rivals. Here, disclosure is excessive due to a commitment problem, rather than a negative externality. In models where disclosure is a costly signal with no real effects (e.g., Jovanovic (1982), Verrecchia (1983)), disclosure is a deadweight loss. Here, disclosure is costly even though the act of disclosure is costless.

This paper also contributes to a literature on the real effects of financial markets. The survey of Bond, Edmans, and Goldstein (2012) identifies two channels through which financial markets (and thus disclosure) can affect the real economy. Our mechanism operates through the contracting channel: the manager's contract is contingent upon the stock price, and so his incentives to take real decisions depend on the extent to which they will be incorporated in the price. The second channel is that the manager uses information in the stock price to guide his decisions. This mechanism allows for a quite different real cost of disclosure. Disclosing information may reduce speculators' incentives to acquire private information (Gao and Liang (2013)) or to trade aggressively on private information (Bond and Goldstein (2012)). This in turn reduces the information in prices from which the manager can learn.[4]

[4] Other costs of disclosure need not operate through the real effects of financial markets. In Morris and Shin (2002), an agent's optimal decision depends on his expectation of other agents' actions (e.g. whether to run on a bank, or whether to buy a product with network externalities). The agent rationally over-reacts to publicly disclosed information, since he takes into account other agents' reactions to the information, and so under-utilizes his own private information. In Pagano and Volpin (2012) and Di Maggio and Pagano (2012), disclosed information can be understood costlessly by

This literature typically concludes that financial efficiency is desirable for real efficiency (e.g., Kanodia (1980), Fishman and Hagerty (1989)).[5] In contrast, we show that real efficiency is non-monotonic in financial efficiency. The manager invests efficiently if neither (hard) earnings nor (soft) fundamental value are disclosed (in which case financial efficiency is minimized), and also if both are disclosed (in which case financial efficiency is maximized). When soft information cannot be disclosed, then even though disclosure of hard information augments financial efficiency, it reduces real efficiency by lowering investment. It may be better for prices to contain no information than partial information. This result echoes the theory of the second best, which argues that it may be optimal to tax all goods rather than only a subset. Holmstrom and Milgrom (1991) show that difficulties in measuring one task may lead to the principal optimally offering weak incentives for all tasks. Our result also echoes Paul (1992), who shows that an efficient financial market weights information according to its informativeness about asset value, but to incentivize efficient real decisions, information should be weighted according to its informativeness about the manager's actions. While a higher hard signal is a positive indicator of firm type, it is a negative indicator of investment.

This paper is organized as follows. Section 2 lays out the model. Section 3 analyzes the case in which the firm can commit to disclosure and solves for the optimal policy. Section 4 considers the case of voluntary disclosure and introduces a role for regulation, and Section 5 concludes. Appendix A contains all proofs not in the main text.

2 The Model

The model consists of four players. The *manager* initially owns the entire firm and chooses the firm's disclosure and investment policies. The *investor* contributes equity financing and may subsequently suffer a liquidity shock. The *speculator* has private information on firm value and trades on this information. The *market maker* clears the market and sets prices. All players are risk-neutral and there is no discounting.

There are five periods. At $t = 0$, the manager must raise financing of K, which is injected into the firm. He first commits to a disclosure policy $\sigma \in [0, 1]$ and then sells a stake α to the investor, which is publicly observed, and chosen so that the investor breaks even.

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speculators but not by hedgers, and so disclosure increases information asymmetry.

[5] In these models, the price is always semi-strong-form "efficient", regardless of disclosure, in that it equals expected firm value conditional upon an information set. Greater disclosure means that the price is now efficient relative to a richer information set. We refer to this as greater price efficiency.

The firm has two possible types, $\theta \in \Theta \equiv \{L, H\}$, that occur with equal probability. Type L (H) corresponds to a low- (high-) quality firm. At $t = 1$, the firm's type θ is realized. We will sometimes refer to a firm of type θ as a "θ-firm" and its manager as a "θ-manager". As in the myopia model of Edmans (2009), an L-manager has no investment decision and his firm will be worth $V^L = R^L$ at $t = 4$, but an H-manager chooses an investment level $\lambda \in [0, 1]$ and his firm is worth $R^H + \lambda g$ at $t = 4$, where $g > 0$ parameterizes the desirability of the investment opportunity.[6] (All values are inclusive of the K raised by the financing.) Since $g > 0$, $\lambda = 1$ is first-best. The type θ and the investment level λ are observable to both the manager and the speculator (and so both know the fundamental value V), but neither are observable to the investor and market maker.

At $t = 2$, a hard (verifiable) signal $y \equiv \{G, B, \varnothing\}$ is generated. A real-life example of such a signal is earnings, and so we will sometimes refer to the signal as "earnings". With probability $1 - \sigma$, the signal is the null signal $\varnothing$, which corresponds to no disclosure. With probability σ, a partially informative signal is disclosed. An L-firm always generates signal B. An H-firm generates B with probability $\rho\lambda^2$ and G with probability $1 - \rho\lambda^2$. The variable ρ parameterizes the extent to which investment increases the probability of $y = B$; we will sometimes refer to ρ as the noise in the signal.

At $t = 3$, the investor suffers a liquidity shock with probability ϕ, which forces her either to buy or sell β shares with equal probability. With probability $1 - \phi$, she suffers no shock; she will not trade voluntarily as she is uninformed. Her trade is therefore given by $I = \{-\beta, 0, \beta\}$. If $y = G$, the speculator has no private information and will not trade, but if $y \in \{B, \varnothing\}$, the public signal is not fully informative and the speculator will take advantage of his private information on V by trading an amount S. Similar to Dow and Gorton (1997), the market maker observes each individual trade, but not the identity of each trader. For example, if the vector of trades Q equals $(-\beta, \beta)$, he does not know which trader (speculator or investor) bought β, and which trader sold β, and so this order vector is uninformative. The market maker is competitive and sets a price P equal to expected firm value conditional upon the observed trades. He clears any excess demand or supply from his own inventory.

At $t = 4$, firm value $V \in \{V^H, V^L\}$ becomes known and payoffs are realized. The variable V is soft information prior to $t = 4$ and thus cannot be credibly communi-

[6] The specification $V^H = R^H + \lambda g$ implies that the growth opportunity is independent of the amount of financing raised (e.g. the funds K could be required to repay debt, rather than to fund the growth opportunity). The model's results remain unchanged to parameterizing $g = hK$, so that the growth opportunity does depend on the amount of financing raised.

cated.[7] Note that, even though it is unverifiable, soft information is still present in the model, because the speculator has information on V and trades on it. We will briefly consider a variant of the model in which V is hard information.

The manager's objective function is given by $(1-\alpha)(\omega P + (1-\omega) V)$. After raising financing, the manager's stake in the firm is $(1-\alpha)$. The parameter ω represents the weight that he puts on the $t = 3$ stock price P compared to the $t = 4$ fundamental value V. The concern for the short-term stock price is standard in the myopia literature and can arise from a number of sources introduced by prior research. One example is the manager expecting to sell a fraction ω of his remaining shares at $t = 3$ and hold the remaining $1-\omega$ until $t = 4$, as in Stein (1989).[8] Alternatively, stock price concerns can stem from takeover threat (Stein (1988)) or concern for managerial reputation (Narayanan (1985), Scharfstein and Stein (1990)).[9]

Before solving the model, we discuss its assumptions. Investment improves fundamental value but potentially lowers short-term earnings, as in the classic managerial myopia models of Stein (1988, 1989). This specification captures the fact that intangible investment can be costly in the short term before its benefits materialize. Costs incurred in training employees are expensed; outside investors cannot distinguish whether high expenses are due to desirable investment (an H-firm choosing a high λ) or low firm quality (an L-firm). Similarly, R&D and advertising are nearly always expensed. Even though these items can be separated out in an income statement, outside investors do not know whether high R&D or advertising is efficient, or stems from a low-quality manager wasting cash. Also as in myopia models, short-term earnings are verifiable but long-run fundamental value is not (prior to the final period). This specification captures the fact that intangible investment does not pay off until the long run, and it is very difficult for the manager to credibly certify the quality of his firm's intangible assets (e.g., its corporate culture).

Outside investors have no information on the firm's type, and the speculator has perfect information. This seemingly stark dichotomy is purely for simplicity; we only

[7] In Almazan, Banerji, and De Motta (2008), the signal is soft but disclosure matters because it may induce a speculator to investigate the disclosure. Here, any disclosure of V is non-verifiable.

[8] Under this interpretation, we assume that the market maker can observe any sales by the manager. This simplifies the analysis as the stock market equilibrium is not affected by the manager's trading. An alternative assumption would be for him to sell shortly after the speculator and investor have traded at $t = 3$.

[9] Under these interpretations, it may seem that a more natural objective function is $(1-\alpha) V + \xi P$ where $(1-\alpha) V$ is the value of the manager's stake and ξP represents his short-term concerns from these additional sources. The objective function of $(1-\alpha)(\omega P + (1-\omega) V)$ is simply $1-\omega$ times this objective function, where $\xi = \frac{(1-\alpha)\omega}{1-\omega}$.

require the speculator to have some information advantage over outside investors. Many shareholders (e.g., retail investors) are atomistic and lack the incentive to gather information about the firm, or are unsophisticated and lack the expertise to do so. In contrast, speculators such as hedge funds often closely monitor firms that they do not currently have a stake in to generate trading ideas.

The liquidity-enforced selling occurs because the investor may suffer a sudden demand for funds, e.g., to pursue another investment opportunity. Liquidity-enforced buying occurs because the investor may have a sudden inflow of cash. The investor will invest a disproportionate fraction of these new funds into the firm if she is less aware about the existence of stocks she does not currently own (e.g., Merton (1987)).[10] The results continue to hold if the investor only faces the probability of liquidity-enforced selling. All we require is that the investor may have to trade against a more informed speculator, regardless of the direction of her trade, as in Diamond and Verrecchia (1991).

We now formally define a Perfect Bayesian Equilibrium as our solution concept.

Definition 1 *The manager's disclosure policy $\sigma \in [0,1]$, the H-manager's investment strategy $\lambda : [0,1] \to [0,1]$, the speculator's trading strategy $S : \Theta \times [0,1] \times \{G, B, \varnothing\} \to \mathbb{R}$, the market maker's pricing strategy $P : [0,1] \times \{G, B, \varnothing\} \times \mathbb{R}^2 \to \mathbb{R}$, the market maker's belief μ about $\theta = H$, and the belief $\hat{\lambda}$ about the H-manager's investment level constitute a Perfect Bayesian Equilibrium, if:*

1. *given μ and $\hat{\lambda}$, P causes the market maker to break even for any $\sigma \in [0,1]$, $y \in \{G, B, \varnothing\}$, and $Q \in \mathbb{R}^2$;*
2. *given $\hat{\lambda}$ and P, S maximizes the speculator's payoff for any V, $\sigma \in [0,1]$, and $y \in \{G, B, \varnothing\}$;*
3. *given S and P, λ maximizes the H-manager's payoff given $\sigma \in [0,1]$;*
4. *given λ, S, and P, σ maximizes the manager's payoff;*
5. *the belief μ is consistent with the strategy profile; and*
6. *the belief $\hat{\lambda} = \lambda$, i.e., is correct in equilibrium.*

[10] In Holmstrom and Tirole (1993), Bolton and von Thadden (1998), Kahn and Winton (1998), and Edmans (2009), liquidity purchases also stem from existing owners.

3 Analysis

3.1 First-Best Benchmark

As a benchmark against which to compare future results, we first consider the case in which fundamental value V is hard information, i.e., the manager can commit to disclosing it with probability σ_V. Since V is perfectly informative about firm value, if V is disclosed then $P = V$ regardless of the order flow. Thus, the investor makes no trading losses and the H-manager faces no trade-off between stock price and fundamental value when making his investment decision. He chooses $\lambda = 1$ as this maximizes $P = V^H = R^H + \lambda g$.

Since disclosure of V both maximizes investment and minimizes the cost of capital, the manager chooses $\sigma_V = 1$. Thus, financial and real efficiency are both maximized and the first best is achieved. Since y is uninformative conditional upon V, the manager's disclosure policy σ for the signal y is irrelevant, and so he is indifferent between any $\sigma \in [0, 1]$. This result is given in Lemma 1 below.

Lemma 1 *(Disclosure of fundamental value): If fundamental value V is hard information, the manager chooses $\sigma_V = 1$, $\lambda^* = 1$, and any $\sigma \in [0, 1]$.*

We now return to the core model in which V is soft information and thus cannot be disclosed. We solve this model by backward induction. We start by determining the stock price at $t = 3$, given the market's belief about the manager's investment. We then move to the manager's $t = 2$ investment decision, which is a best response to the market maker's $t = 3$ pricing function. Finally, we turn to the manager's choice of disclosure at $t = 0$, which takes into account the impact on his subsequent investment decision and the investor's losses from liquidity shocks.

3.2 Trading Stage

The trading game at $t = 3$ is played by the speculator and the market maker. At this stage, the manager's investment decision λ (if $\theta = H$) has been undertaken, but is unknown to the market maker. Thus, he sets the price using his equilibrium belief $\hat{\lambda}$.

There are three cases to consider. If $y = G$, all players know that $\theta = H$, so the unique equilibrium in this subgame is that the market maker sets $P = \widehat{V^H} = R^H + \hat{\lambda} g$. Since the speculator values the firm at V^H (and, in equilibrium, $\hat{\lambda} = \lambda$), he has no motive to trade. If the investor suffers a liquidity shock, she trades at a price of $P = \widehat{V^H}$ and breaks even.

When $y = B$, the signal is imperfectly informative for any $\hat{\lambda} > 0$: it can be generated by both firm types. Since the speculator observes V, and other market participants only observe the noisy signal y, he has an information advantage. Since the investor either buys or sells β shares (or does not trade), the speculator will buy β shares if $V = V^H$ and sell β shares if $V = V^L$, to hide his information.

Given the speculator's equilibrium strategy, the market maker's equilibrium pricing function is given by Bayes' rule in Lemma 2.

Lemma 2 *(Prices): Upon observing signal y and the vector of order flows Q, the prices set by the market maker are given by the following table:*

$y = G$	$y = B$		$y = \varnothing$	
	Q	P	Q	P
	(β, β)	$\widehat{V^H}$	(β, β)	$\widehat{V^H}$
	$(\beta, 0)$	$\widehat{V^H}$	$(\beta, 0)$	$\widehat{V^H}$
$P = \widehat{V^H}$	$(\beta, -\beta)$	$\frac{\rho\hat{\lambda}^2}{1+\rho\hat{\lambda}^2}\widehat{V^H} + \frac{1}{1+\rho\hat{\lambda}^2}V^L$	$(\beta, -\beta)$	$\frac{1}{2}\left(\widehat{V^H} + V^L\right)$
	$(-\beta, 0)$	V^L	$(-\beta, 0)$	V^L
	$(-\beta, -\beta)$	V^L	$(-\beta, -\beta)$	V^L

. (1)

We sometimes use $P(Q, y)$ to denote the price of a firm for which signal y has been disclosed and the order vector is Q. Since y is an informative signal, financial efficiency is greater with $y = B$ than $y = \varnothing$. This can be seen by the difference in prices with an uninformative order vector of $(\beta, -\beta)$. Without a signal, the price is the unconditional expected value based on the prior probability of type H $(\frac{1}{2})$, but conditional on $y = B$, the probability is updated to the posterior $\frac{\rho\hat{\lambda}^2}{\rho\hat{\lambda}^2+1}$. Separately, it is simple to show that, at $t = 2$, the expected price equals expected firm value, i.e., $\mathbb{E}(P) = \mathbb{E}(V)$: this is a consequence of market efficiency.

Let $\widetilde{P}(y|\theta = H)$ denote the expected stock price of an H-firm for which signal y has been disclosed, where the expectation is taken over the possible realizations of order flow. We thus have:

$$
\begin{aligned}
P(G|\theta = H) &= \widehat{V^H}, \\
\tilde{P}(B|\theta = H) &= \widehat{V^H} - \frac{\phi}{2}\frac{\widehat{V^H} - V^L}{1 + \rho\hat{\lambda}^2}, \text{ and} \\
\tilde{P}(\varnothing|\theta = H) &= \widehat{V^H} - \frac{\phi}{2}\frac{\widehat{V^H} - V^L}{2},
\end{aligned}
$$

where we suppress the tilde on $P(G|\theta = H)$ as the price is independent of the order flow. For any σ and $\hat{\lambda}$, since $\widehat{V^H} > V^L$ and $\rho\hat{\lambda}^2 \leq 1$, we have

$$\tilde{P}(B|\theta = H) < \tilde{P}(\varnothing|\theta = H) < P(G|\theta = H).$$

3.3 Investment Stage

We now move to the investment decision of the H-manager at $t = 2$. At this stage, the disclosure policy σ is known. The manager chooses λ to maximize his expected payoff:

$$\max_{\lambda} U_m\left(\lambda, \widehat{\lambda}\right) = (1-\alpha)\left(\omega\mathbb{E}(P|\theta = H) + (1-\omega)V^H\right), \tag{2}$$

where the expected price of an H-firm is

$$\begin{aligned}\mathbb{E}(P|\theta = H) &= \sigma\left(1-\rho\lambda^2\right)P(G|\theta = H) + \sigma\rho\lambda^2\tilde{P}(B|\theta = H) \\ &\quad + (1-\sigma)\tilde{P}(\varnothing|\theta = H) \\ &= \widehat{V^H} - \frac{\phi}{2}\left(\frac{1}{2}(1-\sigma) + \sigma\frac{\rho\lambda^2}{1+\rho\hat{\lambda}^2}\right)\left(\widehat{V^H} - V^L\right).\end{aligned}$$

His first-order condition is given by

$$\frac{\partial U_m\left(\lambda, \widehat{\lambda}\right)}{\partial\lambda} = (1-\alpha)\left(-\omega\phi\sigma\frac{\rho\lambda}{1+\rho\hat{\lambda}^2}\left(\widehat{V^H} - V^L\right) + (1-\omega)g\right) = 0. \tag{3}$$

Since

$$\frac{\partial^2 U_m\left(\lambda, \widehat{\lambda}\right)}{\partial\lambda^2} = -(1-\alpha)\,\omega\phi\sigma\frac{\rho}{1+\rho\hat{\lambda}^2}\left(\widehat{V^H} - V^L\right) < 0,$$

the manager's objective function is strictly concave and so equation (3) is sufficient for a maximum. Plugging $\lambda = \widehat{\lambda}$ into the first-order condition (3) yields the quadratic:

$$\Psi(\lambda, \sigma) = \left(\frac{1}{\Omega} - \sigma\phi\right)\lambda^2 - \sigma\phi\frac{\Delta}{g}\lambda + \frac{1}{\Omega\rho}, \tag{4}$$

where we define $\Omega \equiv \frac{\omega}{1-\omega}$ as the relative weight on the stock price and $\Delta \equiv R^H - R^L$ as the difference in firm values.

Given a σ, the solution to the manager's investment decision is given in Proposition 1 below.

Proposition 1 *(Investment): For any $\sigma \in [0,1]$, there is a unique equilibrium investment level in the subgame following σ, which is given by:*

$$\lambda^* = \begin{cases} r(\sigma), & \text{if} \quad \sigma > X; \\ 1, & \text{if} \quad \sigma \leq X, \end{cases}$$

where

$$X \equiv \frac{g(\rho+1)}{\Omega\phi\rho(\Delta+g)}, \tag{5}$$

$r(\sigma)$ is the root of the quadratic $\Psi(\lambda,\sigma) = 0$ for which $\Psi'(r,\sigma) < 0$, and $r(\sigma)$ is strictly decreasing and strictly concave. Fixing any $\sigma > X$, the partial investment level $r(\sigma)$ is increasing in g and decreasing in ω, ϕ, ρ, and Δ. The threshold X is increasing in g and decreasing in ω, ϕ, ρ, and Δ.

The intuition behind Proposition 1 is as follows. The cost of investment (from the manager's perspective) is that it increases the probability of disclosing a bad signal. This cost is increasing in disclosure σ. Thus, the manager engages in full investment if and only if σ is sufficiently low: weakly below a threshold X. As is intuitive, $\sigma \leq X$ is more likely to be satisfied (i.e., full investment is more likely to be undertaken) if ω is low (the manager is less concerned with the stock price), ρ is low (investment only leads to a small increase in the probability of a bad signal) and g is high (investment is more attractive). Somewhat less obviously, $\sigma \leq X$ is more likely to be satisfied if ϕ is low. When the investor receives fewer liquidity shocks, trading becomes dominated by the speculator, who has information on V. The price becomes more reflective of fundamental value V rather than the noisy signal y. Thus, the manager is less concerned about emitting the bad signal. Finally, the investment is likelier if Δ, the baseline value difference between H- and L-firms, is low, as this reduces the incentive to be revealed as a high-quality firm by delivering $y = G$.

When $\sigma > X$, disclosure is sufficiently high that the manager reduces investment below the first-best optimum, and we have an interior solution. Additional increases in σ cause investment to fall further, since $r(\sigma)$ is decreasing in σ. Thus, while a rise in σ augments financial efficiency, it reduces real efficiency.

3.4 Disclosure Stage

We finally turn to the manager's disclosure decision at $t = 0$. He chooses σ to maximize his expected payoff, net of the stake sold to outside investors:

$$\max_{\sigma} \Pi(\sigma) = (1 - \alpha(\sigma)) (\omega \mathbb{E}(P) + (1 - \omega)\mathbb{E}[V]) \\ = (1 - \alpha(\sigma)) \mathbb{E}[V]. \tag{6}$$

The manager takes into account two effects of σ. First, it affects α, because the investor's stake must be sufficient to compensate for her trading losses. Second, it affects λ and thus V^H, as shown in Proposition 1. Lemma 3 addresses the first effect. The stake demanded by the investor will depend on her conjecture for the manager's investment decision, $\widehat{\lambda}$. In equilibrium, her conjecture $\widehat{\lambda}$ will equal the actual investment level λ, and so λ appears in Lemma 3 below.

Lemma 3 *(Stake sold to investor): The stake α sold to the investor is given by*

$$\alpha(\sigma) = \frac{2K}{V^H + R^L} + \kappa, \tag{7}$$

where

$$\kappa = \frac{\beta\phi\left(V^H - R^L\right)\left[\frac{1}{2}(1-\sigma) + \frac{\rho\lambda^2}{1+\rho\lambda^2}\sigma\right]}{V^H + R^L}.$$

The partial derivative of κ with respect to σ is negative, and the partial derivatives with respect to ω, ϕ, ρ, β, λ, and g are positive.

Lemma 3 shows that the stake α that the manager must sell comprises two components. The "baseline" component $\frac{2K}{V^H+R^L}$ is the stake that the investor would require if she did not risk trading losses (e.g., if $\phi = 0$). It simply ensures that the dollar value of her stake in the firm equals the dollar amount she is investing: it is her capital contribution K divided by expected firm value and independent of disclosure σ. The second term, κ is the additional stake that the investor demands to compensate for her expected trading losses. An increase in σ reduces these losses and thus α: greater disclosure reduces her information disadvantage versus the speculator. We will refer κ as the "excess cost of capital" (or sometimes "cost of capital" for short). It reflects the wedge between the percentage stake that the manager is selling to the investor and the percentage contribution that he is receiving from the investor.

The partial derivatives for κ are intuitive. An increase in the noise in the public signal ρ raises the speculator's information advantage and thus the expected loss from a liquidity shock, augmenting the cost of capital. The probability ϕ and magnitude β of a liquidity shock also increases the expected loss and thus the cost of capital. Disclosure σ reduces information asymmetry and thus the cost of capital. Increases in investment λ and the productivity of investment g both augment the value difference between H- and L-firms $(\Delta + \lambda g)$ and thus the cost of capital.

Plugging (7) into (6) yields

$$\Pi(\sigma) = \left[\frac{1}{2}\left(V^H + R^L\right) - K\right] - \beta\phi\frac{1}{2}\left(V^H - R^L\right)\left[\frac{1}{2}(1-\sigma) + \frac{\rho\lambda^2}{1+\rho\lambda^2}\sigma\right],$$

where the first term is expected firm value (net of the injected funds) and the second term represents the investor's expected trading losses.

We now solve for the manager's choice of disclosure policy. There are two cases to consider. The first is $X \geq 1$. Since $\sigma \in [0,1]$, $\sigma \leq X$. Thus, from Proposition 1, the investment level following any $\sigma \in [0,1]$ is $\lambda^* = 1$. Since there is no trade-off between disclosure and investment, the manager chooses maximum disclosure, $\sigma^* = 1$. Thus, full disclosure and full investment can be implemented simultaneously. This result is stated in Proposition 2.

Proposition 2 *(Full disclosure and full investment): If $X \geq 1$, the model has a unique equilibrium, in which the disclosure policy is $\sigma^* = 1$ and the investment level is $\lambda^* = 1$.*

The condition $X \geq 1$ is equivalent to

$$\phi\frac{\rho}{1+\rho}\frac{\Delta+g}{g}\Omega \leq 1. \tag{8}$$

Thus, the manager will invest efficiently even with full disclosure when g is high, and ω, ϕ, ρ, and Δ are all low. The intuition is the same as in the discussion following Proposition 1.

The second case is $X < 1$. In this case, we solve for the manager's choice of disclosure policy in two steps. First, we solve for the optimal disclosure policy in the set $[0, X]$, and then in the set $[X, 1]$. Since $r(\sigma)$ is continuous at $\sigma = X$ $(r(X) = 1)$, X lies in both sets. This implies that both sets are compact and thus an optimal disclosure policy exists in each. Second, we solve for the optimal disclosure policy overall, which involves comparing the manager's payoffs under the optimal disclosure policies in $[0, X]$

and $[X, 1]$. Put differently, the first step solves for the optimal level of disclosure if the manager implements full investment, and the optimal level of disclosure if the manager implements partial investment. The second step compares the manager's payoff under the best outcome with full investment to the best outcome with partial investment, to solve for the optimal disclosure policy overall.

We first analyze the optimal disclosure policy in $[0, X]$. From Proposition 1, $\lambda^*(\sigma) = 1$ for all $\sigma \in [0, X]$. Thus, for $\sigma \in [0, X]$, the manager's payoff becomes

$$\Pi(\sigma) = \frac{1}{2}\left(R^H + g + R^L\right) - K - \beta\phi\frac{1}{2}(\Delta + g)\left[(1-\sigma)\frac{1}{2} + \sigma\frac{\rho}{1+\rho}\right], \tag{9}$$

which is strictly increasing in σ as a higher σ reduces trading losses.

Lemma 4 *(Disclosure under full investment): In an equilibrium where $\sigma \in [0, X]$ and $X < 1$, the optimal disclosure policy is*

$$\sigma^* = X,$$

and the equilibrium investment level is $\lambda^* = 1$.

Intuitively, if the manager wishes to implement $\lambda^* = 1$, he should choose the highest possible σ that supports full investment, which is X.

We next turn to the optimal disclosure policy in $[X, 1]$. For any $\sigma \in [X, 1]$, the equilibrium in the following subgame is $r(\sigma)$. Thus, the manager's problem becomes

$$\begin{aligned} \max_{\sigma \in (X,1)} \Pi(\sigma) = & \left[\frac{1}{2}\left(R^H + \lambda g + R^L\right) - K\right] \\ & - \frac{1}{2}\beta\phi(\Delta + \lambda g)\left[(1-\sigma)\frac{1}{2} + \sigma\frac{\rho\lambda^2}{1+\rho\lambda^2}\right] \\ \text{s.t.} \quad & \Psi(\lambda, \sigma) = 0. \end{aligned} \tag{10}$$

From $\Psi(\lambda, \sigma) = 0$, the disclosure policy σ that implements a given investment level λ is given by:

$$\sigma = \frac{g\left(1 + \rho\lambda^2\right)}{\lambda\Omega\phi\rho(\Delta + \lambda g)}. \tag{11}$$

As shown in Proposition 1, $r(\sigma)$ is strictly decreasing and strictly convex. Since also $\frac{\partial\lambda}{\partial\sigma} < 0$, this implies that σ is strictly decreasing and strictly convex in λ. Increased disclosure reduces investment; however, since investment cannot fall below zero, it does so at a decreasing rate.

Equation (10) shows that there are four effects of a larger λ on the manager's objective function. The first is the "value creation effect", the positive effect of investment on firm value, which can be seen by λ entering the first term of equation (10). The second is the "variance" effect, which is negative. A higher λ augments the difference in value, $\Delta + \lambda g$, between H- and L-firms. This in turn increases the investor's information disadvantage, her trading loss, and thus her required stake α. The effect can be seen by λ appearing in the first part of the second term. The third is the "disclosure effect", which is also negative. It can be seen by σ appearing in the second part of the second term. Implementing higher investment λ requires less disclosure σ (equation (11)), augmenting the cost of capital. The fourth is the "signal distortion effect", which too is negative. Higher investment means that the signal y is less informative about firm type, because $y = B$ is more likely to be generated by an H-firm. Thus, the investor (who observes y) suffers a greater information disadvantage relative to the speculator. This effect can be seen by λ appearing in the term $\frac{\rho\lambda^2}{\rho\lambda^2+1}$.[11]

Equation (10) can be rewritten:

$$\Pi(\lambda, \sigma) = \left[\frac{1}{2}\left(R^H + \lambda g + R^L\right) - K\right] - \frac{1}{4}\beta\phi\left(\Delta + \lambda g\right) + \frac{1}{4}\beta\phi\left(\Delta + \lambda g\right)\sigma\frac{1-\rho\lambda^2}{1+\rho\lambda^2}. \quad (12)$$

The first term is expected firm value. The second term represents the investor's losses in the absence of disclosure ("maximum trading losses"), which also captures the variance effect if there were no disclosure. The terms in λ in the first line sum to $\frac{1}{2}\lambda g\left(1 - \frac{1}{2}\beta\phi\right) > 0$, and so the value creation effect outweighs the variance effect. This is intuitive: if investment could be chosen independently of disclosure, the manager is always better off with higher investment. The third term constitutes the reduction in expected losses that stems from increased disclosure ("loss mitigation"). This reduction is increasing in the initial variance in firm value $(\Delta + \lambda g)$ and decreasing in λ due to the signal distortion effect.

Using equation (11) to substitute for σ in the objective function (12) yields firm

[11] This term affects the price set by the market maker upon seeing $y = B$ and $Q = (\beta, -\beta)$ (see Lemma 2): a rise in λ augments $P((\beta, -\beta), B)$ since $((\beta, -\beta), B)$ is more likely to be generated by a H-firm. On the one hand, this higher price reduces the investor's losses if she is forced to sell and the speculator buys. On the other hand, it increases the investor's losses if she is forced to buy and the speculator sells. The second effect is dominant, because when $y = B$, it is more likely that the speculator sells, and so overall, a rise in λ augments the investor's loss through changing the price set by the market maker.

value as a function of investment alone:

$$\Pi(\lambda) = D + E\lambda + \frac{F}{\lambda}, \tag{13}$$

where

$$D \equiv R^H - \frac{1}{2}(1 + \frac{1}{2}\beta\phi)\Delta - K, \tag{14}$$

$$E \equiv g\left[1 - \frac{1}{2}(1 + \frac{1}{2}\beta\phi) - \frac{\beta}{4\Omega}\right], \tag{15}$$

$$F \equiv \frac{\beta g}{4\rho\Omega}. \tag{16}$$

The convex component in firm value (the $\frac{1}{\lambda}$ term) comes from substituting σ into the loss mitigation term. Differentiating (13) yields

$$\Pi'(\lambda) = E - \frac{F}{\lambda^2},$$

$$\Pi''(\lambda) = \frac{2F}{\lambda^3} > 0.$$

Since $\Pi(\lambda)$ is globally convex (which follows from the convexity of $\frac{F}{\lambda}$), the solution to $\Pi'(\lambda) = 0$ is a minimum. The maximum value of $\Pi(\lambda)$ is attained at a boundary: we either have $\lambda^* = r(X) = 1$ or $\lambda^* = r(1)$. The intuition behind the boundary solution is as follows. From equation (12), the benefits of increasing investment to the manager are linear in the level of investment. One of the costs, the maximum trading losses, is also linear, but the loss mitigation term is convex, because disclosure is convex in investment as shown by equation (11). When investment rises, disclosure must fall to support the higher level of investment, thus reducing the loss mitigation effect – but at a decreasing rate. Intuitively, when disclosure is already low, further decreases in disclosure are high relative to the baseline level of disclosure, and so an increase in investment only requires a small decrease in disclosure. The convexity is likely common to all functional forms, because disclosure and investment are necessarily bounded below by zero. An increase in disclosure must reduce investment at a declining rate, since investment falls towards zero asymptotically. As a result of the convexity, it is optimal for the manager to increase disclosure by a small amount from X to $X + \varepsilon$, it is optimal for him to increase it all the way to 1. Thus, the manager chooses either full investment or full disclosure. This result is given in Lemma 5 below.

Lemma 5 *(Partial disclosure or partial investment): When $\sigma \in [X, 1]$, the equilibrium investment level is either $\lambda^* = r(1)$, in which case the equilibrium disclosure policy is $\sigma^* = 1$, or $\lambda^* = 1$, in which case the equilibrium disclosure policy is $\sigma^* = X$.*

We now move to the second step. Having found the optimal disclosure policy in $[0, X]$ and in $[X, 1]$, we now solve for the optimal disclosure policy overall, which involves comparing the manager's payoff across these two sets. In doing so, we formally prove existence of an equilibrium in the model and characterize it. The equilibrium is given by Proposition 3 below:

Proposition 3 *(Trade-off between disclosure and investment): If $X < 1$, the equilibrium is given as follows:*

(i) *If $\Pi(r(1), 1) > \Pi(1, X)$, the manager chooses full disclosure ($\sigma^* = 1$) and partial investment ($\lambda^* = r(1) < 1$).*

(ii) *If $\Pi(r(1), 1) < \Pi(1, X)$, the manager chooses partial disclosure ($\sigma^* = X$) and full investment ($\lambda^* = 1$).*

(iii) *If $\Pi(r(1), 1) = \Pi(1, X)$, both ($\lambda^* = r(1)$, $\sigma^* = 1$) and ($\lambda^* = 1$, $\sigma^* = X$) are equilibria.*

The condition $\Pi(r(1), 1) > \Pi(1, X)$ is equivalent to

$$\beta > \widetilde{\beta} = \frac{1 - r(1)}{\phi \frac{1}{2} \frac{\Delta + g}{g} - \frac{1}{\Omega} \left[\frac{1}{2} \left(\frac{1}{\rho} - 1 \right) + r(1) \right]} > 0. \tag{17}$$

The threshold $\tilde{\beta}$ is increasing in g, and decreasing in ϕ, ρ, and Δ. It is decreasing in ω when ω is small and increasing when ω is large.

When $X < 1$, the manager faces a trade-off: he must choose between either full disclosure or full investment, as it is impossible to achieve both. He chooses the former if and only if the liquidity shock β is sufficiently large (above a threshold $\widetilde{\beta}$), as this means that cost of capital considerations dominate the trade-off. Importantly, the partial investment level $r(1)$ in the definition of $\widetilde{\beta}$, which is why we use β as the cut-off parameter.

The intuition behind the comparative statics for the threshold $\widetilde{\beta}$ arises because changes in these parameters have up to three effects. First, as g rises, and ϕ, ρ, and Δ fall, equation (5) shows that the maximum disclosure X that implements full investment is higher. Thus, full investment becomes more attractive to the manager, as it can be sustained with a lower cost of capital. Second, the same changes also augment the partial investment level $r(1)$ that is implemented by full disclosure. Thus, full disclosure also becomes more attractive to the manager, as it does not lead to as much underinvestment. These two effects work in opposite directions. This ambiguity is resolved through a third effect: a rise in g, and a fall in ϕ, ρ, and Δ, make investment more important relative to the cost of capital. Thus, they augment the cutoff $\widetilde{\beta}$, making it more likely that full investment is optimal.

In contrast, a fall in ω only has the first two effects: it reduces both $r(1)$ and X, making both the full disclosure and full investment equilibria less attractive. Since ω affects neither the value of the growth opportunity nor the cost of capital, the third effect is absent, and so the effect of ω on $\widetilde{\beta}$ is ambiguous. When ω is very low, full investment can be sustained with high disclosure and so the manager prefers the full investment equilibrium. When ω is very high, full disclosure leads to substantial underinvestment and so the manager again prefers the full investment equilibrium. The manager chooses full disclosure for intermediate values of ω, and so the derivative of $\widetilde{\beta}$ with respect to ω is non-monotonic.

We now combine the comparative static analysis of cases of $X < 1$ and $X \geq 1$ to analyze how parameters globally affect equilibrium disclosure and investment. Proposition 4 gives the global comparative statics for g and Δ.

Proposition 4 *(Global comparative statics for g and Δ):*

(i) *The equilibrium investment policy λ^* is weakly increasing in the profitability of investment g. The equilibrium disclosure policy σ^* is first weakly decreasing and then weakly increasing in g. Specifically:*

- ***(i-a)*** *If β exceeds a threshold, the equilibrium disclosure policy (σ^*) is always 1.*
- ***(i-b)*** *If β is below this threshold, $\sigma^* = 1$ for low levels of g. Once g rises above a threshold, σ^* falls discontinuously to X, and then weakly increases with further increases in g.*

(ii) *The equilibrium investment policy λ^* is weakly decreasing in the difference in firm values Δ. The equilibrium disclosure policy σ^* is first weakly increasing and then weakly decreasing in Δ. Specifically:*

(ii-a) *If β exceeds a threshold, the equilibrium disclosure policy (σ^*) is always 1.*

(ii-b) *If β is below this threshold, $\sigma^* = 1$ for high levels of Δ. Once Δ falls below a threshold, σ^* falls discontinuously to X, and then weakly increases with further decreases in Δ.*

The intuition behind the global comparative statics for g are as follows. When g is low, investment is sufficiently unattractive that the manager chooses partial investment. Within this regime, increases in g augment the partial investment level, as is intuitive, but do not affect disclosure which remains fixed at 1. If β is sufficiently low, then there exists a threshold such that if g rises above this threshold, investment becomes sufficiently attractive that we move to the full investment equilibrium. At this threshold, investment rises discontinuously to 1 and disclosure drops discontinuously from 1 to X. Further increases in g augment disclosure, because the investment opportunity is sufficiently attractive that the manager invests fully even with high disclosure.

Overall, investment is weakly increasing in g. As the investment becomes more attractive, the manager pursues it to a greater extent even with full disclosure, and after a point it becomes so attractive that the manager switches to full investment. The effect of g on disclosure is more surprising. As is intuitive, increases in g make investment more important and mean that the manager wishes to reduce disclosure, to implement full investment. However, within the full investment equilibrium, further increases in g actually increase disclosure.

The intuition for Δ is exactly the opposite, because Δ and g appear together as the ratio $\frac{\Delta+g}{g}$ in both X and $\tilde{\beta}$. Intuitively, when making his investment decision, the manager trades off the benefits of investment g with the incentive to be revealed as a H-firm, Δ. The comparative statics for g are illustrated in Figure 1 below.

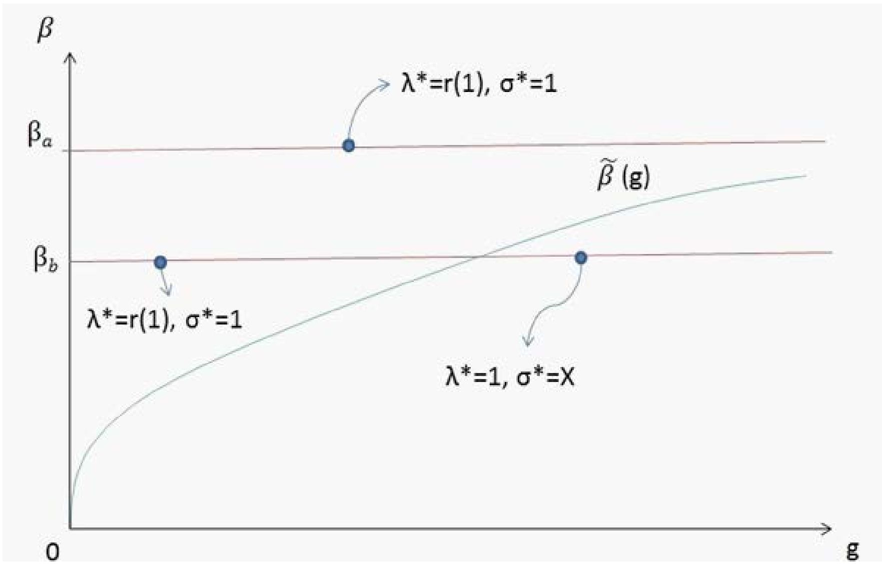

Figure 1: Global comparative statics for g

Proposition 5 gives the global comparative statics for ϕ and ρ.

Proposition 5 *(Global comparative statics for ϕ and ρ):*

(i) *The equilibrium investment policy λ^* is weakly decreasing in the probability of the liquidity shock ϕ, and the equilibrium disclosure policy σ^* is first weakly decreasing and then weakly increasing in ϕ. Specifically:*

(i-a) *If $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, the equilibrium is always $(\lambda^* = 1,\ \sigma^* = 1)$.*

(i-b) *If $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$ and $\beta > \Omega$, then for small ϕ, the equilibrium is always $(\lambda^* = 1,\ \sigma^* = 1)$. Once ϕ rises above a threshold, the equilibrium is $(\lambda^* = r(1),\ \sigma^* = 1)$. Investment falls continuously; further increases in ϕ reduce λ^*, but σ^* is unaffected.*

(i-c) *If $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$ and $\beta < \tilde{\beta}(\phi = 1)$, then for small ϕ, the equilibrium is $(\lambda^* = 1,\ \sigma^* = 1)$. Once ϕ rises above a threshold, the equilibrium is $(\lambda^* = 1,\ \sigma^* = X)$. Disclosure falls continuously; further increases in ϕ reduce σ^*, but λ^* is unaffected.*

(i-d) *If $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$ and $\beta \in \left(\tilde{\beta}(\phi = 1), \Omega\right)$, then for small ϕ, the equilibrium is $(\lambda^* = 1,\ \sigma^* = 1)$. Once ϕ rises above a threshold, the equilibrium is $(\lambda^* = 1,\ \sigma^* = X)$. Disclosure falls continuously; further increases in ϕ*

reduce σ^*, but λ^* is unaffected. Once ϕ rises above a second threshold, the equilibrium switches to $(\lambda^* = r(1),\ \sigma^* = 1)$. Disclosure rises discontinuously and investment falls discontinuously; further increases in ϕ reduce λ^* but have no effect on σ^*.

(ii) *The equilibrium investment policy λ^* is weakly decreasing in the noise in the signal ρ, and the equilibrium disclosure policy σ^* is first weakly decreasing and then weakly increasing in ρ. Specifically:*

(ii-a) *If $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} \geq 1$, the equilibrium is always $(\lambda^* = 1,\ \sigma^* = 1)$.*

(ii-b) *If $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} < 1$ and $\beta > \Omega$, then for small ρ, the equilibrium is always $(\lambda^* = 1,\ \sigma^* = 1)$. Once ρ rises above a threshold, the equilibrium is $(\lambda^* = r(1),\ \sigma^* = 1)$. Investment falls continuously; further increases in ρ reduce λ^*, but σ^* is unaffected.*

(ii-c) *If $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} < 1$ and $\beta < \tilde{\beta}(\rho = 1)$, then for small ρ, the equilibrium is $(\lambda^* = 1,\ \sigma^* = 1)$. Once ρ rises above a threshold, the equilibrium is $(\lambda^* = 1,\ \sigma^* = X)$. Disclosure falls continuously; further increases in ρ reduce σ^*, but λ^* is unaffected.*

(ii-d) *If $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} < 1$ and $\beta \in \left(\tilde{\beta}(\rho = 1), \Omega\right)$, then for small ρ, the equilibrium is $(\lambda^* = 1,\ \sigma^* = 1)$. Once ρ rises above a threshold, the equilibrium is $(\lambda^* = 1,\ \sigma^* = X)$. Disclosure falls continuously; further increases in ρ reduce σ^*, but λ^* is unaffected. Once ρ rises above a second threshold, the equilibrium switches to $(\lambda^* = r(1),\ \sigma^* = 1)$. Disclosure rises discontinuously and investment falls discontinuously; further increases in ρ reduce λ^* but have no effect on σ^*.*

The intuition behind the global comparative statics for ϕ are as follows. When $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, then (8) is satisfied for all ϕ. Thus, we always have $X \geq 1$ and the $(\lambda^* = 1,\ \sigma^* = 1)$ equilibrium. The benefits of investment are so strong relative to the costs that, regardless of ϕ, full investment and full disclosure can be sustained simultaneously. Thus, there are no comparative statics with respect to ϕ. When $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$, then for low ϕ, the $(\lambda^* = 1,\ \sigma^* = 1)$ equilibrium is sustainable. For high ϕ, there is a trade-off between investment and disclosure, and we are in one of three cases. In case (i-b), the magnitude of the liquidity shock β is sufficiently high that $\beta > \widetilde{\beta}$ always. Within the trade-off region, the manager always chooses full disclosure and partial investment, and so investment falls below 1 when ϕ crosses above the threshold that makes ($\lambda^* = 1,\ \sigma^* = 1$) no longer sustainable; additional increases in ϕ reduce the partial investment level further. In case (i-c), the magnitude of the liquidity shock β is sufficiently low that $\beta < \widetilde{\beta}$ always. Within the trade-off region, the manager always chooses full investment and partial disclosure, and so disclosure falls below 1 when ϕ crosses above the threshold; additional increases in ϕ reduce the partial disclosure level further. In case (i-d), within the trade-off region, for low levels of ϕ, $\beta < \widetilde{\beta}$ and the manager chooses full investment and partial disclosure, but for high ϕ, $\beta > \widetilde{\beta}$ and the manager switches to full disclosure and partial investment.

Considering all cases together, as with g and Δ in Proposition 4, ϕ has a monotonic effect on investment, but a non-monotonic effect on disclosure. The intuition behind the global comparative statics for ρ is identical. The comparative statics for ϕ for the interesting case of $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$ are illustrated in Figure 2 below.

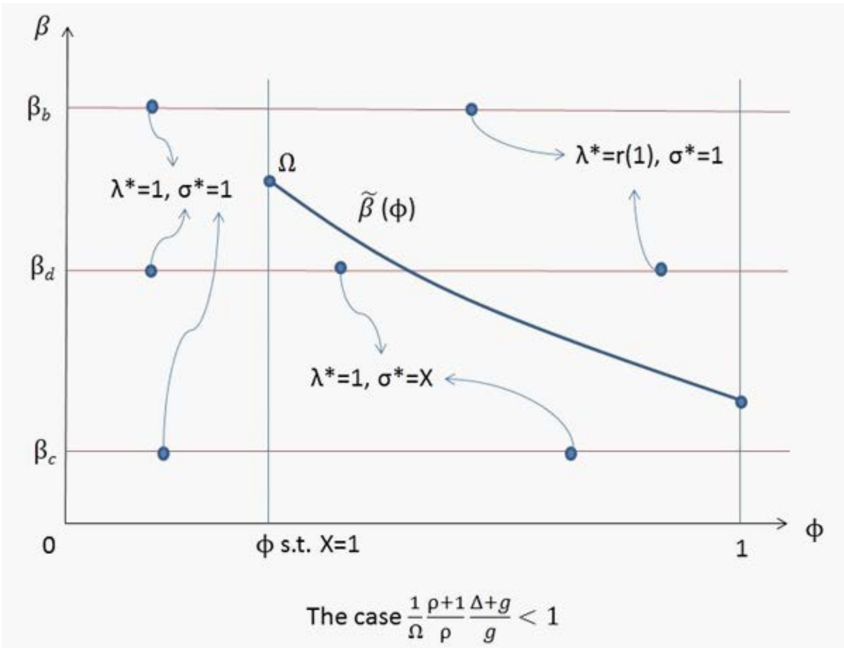

Figure 2: Global comparative statics for ϕ

Proposition 6 gives the global comparative statics for ω.

Proposition 6 *(Global comparative statics for ω): The equilibrium investment policy λ^* is weakly decreasing in the manager's short-term concerns ω, and the equilibrium disclosure policy σ^* is non-monotonic in ω. Let $\underline{\beta}$ denote the minimum $\tilde{\beta}$ over all ω such that $X \leq 1$. Specifically:*

(i) *If* $\beta < \underline{\beta}$*, then for low* ω*, the equilibrium is* $(\lambda^* = 1, \sigma^* = 1)$*; once* ω *rises above a threshold, the equilibrium is* $(\lambda^* = 1,\ \sigma^* = X)$*. Disclosure falls continuously; further increases in* ω *lower* σ^* *but have no effect on* λ^**.*

(ii) *If* $\beta > \max\left\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\right\}$*, then for low* ω*, the equilibrium is* $(\lambda^* = 1, \sigma^* = 1)$*. Once* ω *rises above a threshold, the equilibrium is* $(\lambda^* = r(1), \sigma^* = 1)$*. Investment falls continuously; further increases in* ω *lower* λ^**, but* σ^* *is unaffected.*

(iii) *If* $\tilde{\beta}(X = 1) > \beta > \tilde{\beta}(X = 0)$*, then, in addition to the effects in part (b), once* ω *rises above a second threshold, the equilibrium switches to* $(\lambda^* = 1,\ \sigma^* = X)$*. Investment rises discontinuously and disclosure falls discontinuously; further increases in* ϕ *lower* σ^* *but have no effect on* λ^**.*

(iv) *If* $\beta \in \left(\underline{\beta}, \min\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\}\right)$*, then for low* ω*, the equilibrium is* $(\lambda^* = 1, \sigma^* = 1)$*. Once* ω *rises above a threshold, the equilibrium is* $(\lambda^* = 1,\ \sigma^* = X)$*. Disclosure falls continuously; further increases in* ω *lower* σ^**, but* λ^* *is unaffected. Once* ω *rises above a second threshold, the equilibrium switches to* $(\lambda^* = r(1), \sigma^* = 1)$*. Disclosure rises discontinuously and investment falls discontinuously; further increases in* ω *lower* λ^* *but have no effect on* σ^**. Once* ω *rises above a third threshold, the equilibrium switches to* $(\lambda^* = 1,\ \sigma^* = X)$*. Investment rises discontinuously and disclosure falls discontinuously; further increases in* ϕ *lower* σ^* *but have no effect on* λ^**.*

The intuition behind the global comparative statics for ω are as follows. When ω is low, myopia is sufficiently weak that the manager invests efficiently even with full disclosure. When ω is sufficiently high, there is a trade-off. In case (i), the magnitude of the liquidity shock β is sufficiently low that the manager always chooses full investment and partial disclosure, and additional increases in ω reduce the partial disclosure level further. In case (ii), the magnitude of the liquidity shock β is sufficiently high that the manager chooses full disclosure and partial investment, and additional increases in ω reduce the partial investment level. Recall that $\widetilde{\beta}$ is first decreasing and then increasing in ω. In case (iii), if also $\tilde{\beta}(X = 1) > \beta > \tilde{\beta}(X = 0)$, then when ω becomes sufficiently high, $\widetilde{\beta}$ crosses back above β and so the manager switches to full investment and partial disclosure. In case (iv), within the trade-off region, the manager chooses partial disclosure for low and high β, and partial investment for intermediate β.

Considering all cases together, as with the other parameters, ω has a monotonic effect on investment, but a non-monotonic effect on disclosure. The comparative statics for ω are illustrated in Figure 3 below.

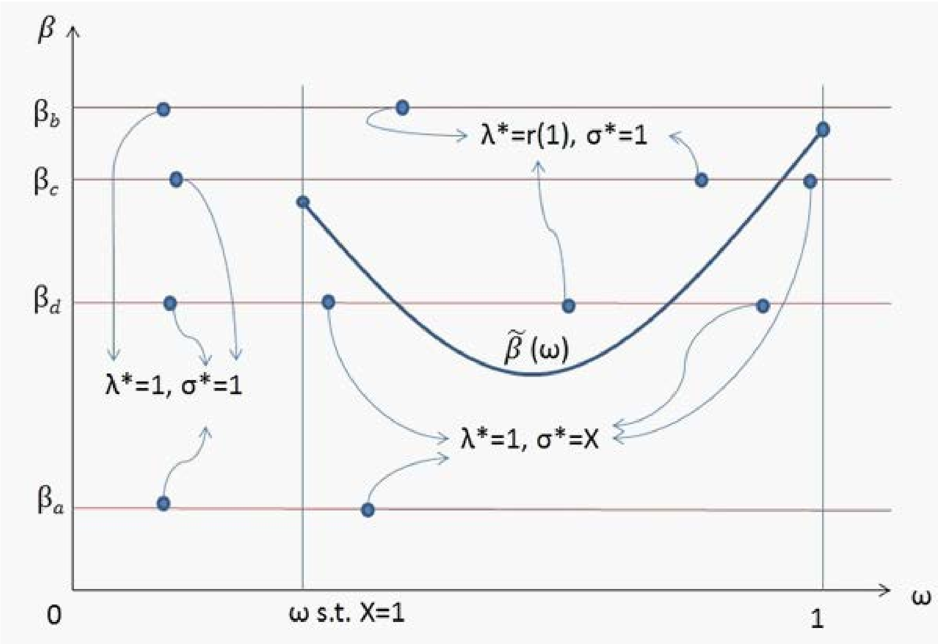

Figure 3: Global comparative statics for ω

Overall, Propositions 4, 5, and 6 yield empirical predictions for how investment and disclosure vary cross-sectionally across firms. As is intuitive, and predicted by many other models, investment depends on corporate finance variables – it is increasing in the profitability of investment opportunities and decreasing in the manager's short-term concerns. More unique to our framework is the predictions that investment depends on asset pricing variables. It decreases with the frequency of liquidity shocks and the information asymmetry suffered by small investors (which in turn depends on the noise of the public signal ρ and the baseline value difference between H- and L-firms, Δ). Increases in these variables augment the cost of capital, and may induce the manager to switch from full investment to full disclosure.

The effects of corporate finance and asset pricing characteristics on disclosure policy are non-monotonic. Firms with intermediate growth opportunities disclose little, because growth opportunities are sufficiently strong that the manager prefers the full investment equilibrium if there is a trade-off, but also sufficiently weak that he will only pursue them fully if disclosure is low. Firms with weak growth opportunities will have high disclosure, because the cost of capital dominates the trade-off and so the manager implements the full-disclosure, partial-investment equilibrium. Firms with strong growth opportunities will have high disclosure for a different reason. Even though investment is more important than disclosure, the growth opportunity is sufficiently attractive that the firm will pursue it even with high disclosure. For similar reasons, firms with moderate information asymmetry Δ, moderate size β and frequency ϕ of liquidity shocks, and moderate noise in the signal ρ will have a low level of disclosure, but firms with either high or low levels of these variables will feature high disclosure. For example, it may seem that, when information asymmetry Δ rises, the manager will always disclose more to counteract the rise in information asymmetry. However, if it remains optimal to implement full investment, the manager must reduce disclosure to do so. Similarly, it may seem that, when ρ rises, the manager should disclose less as the signal is noisier. However, a rise in ρ makes the cost of capital relatively more important, and so the manager may now wish to implement full disclosure. As Beyer et al.'s (2010) survey paper emphasizes, "it is necessary to consider multiple aspects of the corporate information environment in order to conclude whether it becomes more or less informative in response to an exogenous change." The effect of the manager's short-term concerns is more complex and depends on which of the three cases we are in, but in all cases, disclosure is highest when short-term concerns are low, because the manager can disclose fully without suffering underinvestment.

The non-monotonic effects of firm characteristics on disclosure policy contrast with prior theories. Baiman and Verrecchia (1996) predict that an increase in the size of the liquidity shock monotonically reduces the optimal level of disclosure. Gao and Liang (2013) predict that firms with higher growth opportunities disclose less, because disclosing information about assets in place crowds out the acquisition of private information about the growth option. More generally, the model points to variables (both from corporate finance and asset pricing) that empiricists should control for when studying the effect of a different variable (not in our model) on disclosure. In addition, it emphasizes that disclosure, investment, and the cost of capital are all simultaneously and endogenously determined by underlying parameters, rather than affecting each other. As Beyer et al. (2010) note: " 'equilibrium' concepts for the market for information defy a simplified view of cause and effect".

Lemma 3 derived monotonic partial derivatives for the excess cost of capital with respect to underlying parameters. However, the excess cost of capital depends also on σ, which depends non-monotonically on the same parameters. Thus, due to the endogenous response of disclosure policy, the overall effects of these parameters on the cost of capital is unclear. In contrast, Diamond and Verrecchia (1991) predict that the cost of capital is monotonically decreasing in information asymmetry and the magnitude of liquidity shocks.

4 Voluntary Disclosure

The analysis of Section 3 shows that, if the manager is able to commit to a disclosure policy, he may commit to partial disclosure even though this raises his cost of capital.

This section considers the case of voluntary disclosure, where the manager is unable to commit to a disclosure policy. We now assume that the manager always possesses the signal y, and chooses whether to disclose it. Thus, while the manager may announce a disclosure policy at $t = 0$, he may renege on it at $t = 2$. Specifically, consider the manager announcing a disclosure policy σ. Theoretically, the manager could implement the policy by using a private randomization device, e.g., spinning a wheel that has a fraction σ of "disclose" outcomes and $1 - \sigma$ of "non-disclose" outcomes, and disclosing the signal if and only if the wheel lands on "disclose". However, he may renege on the policy: even if the device lands on "non-disclose", he may disclose anyway. In keeping with the literature on voluntary disclosure, the manager can never falsify the signal (e.g., release $y = G$ if the signal was $y = B$), and only has discretion on whether or not to disclose it.

Since $P(G) > \widetilde{P}(\varnothing)$, the manager will choose to disclose the signal if it turns out to be good. Thus, the absence of a disclosure means that the signal must be $y = B$. No disclosure is tantamount to the disclosure of a bad signal, and so the manager is indifferent between them. The manager cannot choose not to disclose and claim that he is doing so to follow his pre-announced low-disclosure policy, because the market knows that he would have reneged on the policy and chosen to disclose if the signal were good. No news is bad news – the "unraveling" result of Grossman (1981) and Milgrom (1981).

The manager knows that he will always disclose the signal y at $t = 2$, either literally, by disclosing $y = G$, or implicitly, by not disclosing and the market inferring that $y = B$. Therefore, he will make his $t = 1$ investment decision assuming that $\sigma = 1$, i.e., choose $\lambda^* = r(1)$ irrespective of the preannounced policy. Since the only disclosure policy that the manager can commit to is $\sigma = 1$, the voluntary disclosure model is equivalent to the mandatory disclosure model with $\sigma = 1$. Even if $\Pi(1, X) > \Pi(r(1), 1)$, and so the manager would like to commit to low disclosure, he is unable to do so. This result is stated in Proposition 7 below.

Proposition 7 *(Voluntary Disclosure): Consider the case in which the manager always possesses the signal y and has discretion over whether to disclose it at $t = 3$. The only Perfect Bayesian Equilibrium involves $\lambda^* = r(1)$ and $\sigma^* = 1$.*

Proposition 7 implies a potential role for government intervention. We now allow for the government to set a regulatory policy ζ at $t = 0$. At $t = 2$, with probability $1 - \zeta$, the manager either cannot or chooses not to disclose due to the government's policy. For example, the government could ban disclosure (e.g., prohibit the disclosure of earnings more frequently than a certain periodicity).[12] Similarly, the government could limit what type of information can be reported in official (e.g., SEC) filings, which reduces disclosure under the assumption that investors view official filings as more truthful than information disseminated through, for example, company press releases. Alternatively, the government could audit disclosures with sufficient intensity that the manager chooses not to disclose: even if disclosure is always truthful, so there is no cost of a lawsuit, responding to an audit is costly.

Now, when making his $t = 1$ investment decision, he knows that he will disclose at $t = 2$ only with probability ζ.[13] He will thus choose an investment level $\lambda^* = \lambda(\zeta)$. Therefore, if the government's goal is to maximize firm value to existing shareholders (i.e., the manager's payoff), it will choose a disclosure policy $\zeta = X$, thus implementing the $(\lambda^* = 1, \sigma = X)$ equilibrium. Thus, the government implements a lower level of disclosure than the one that managers will voluntarily choose themselves. This conclusion contrasts some existing models (e.g., Foster (1979), Coffee (1984), Dye (1990), Admati and Pfleiderer (2000), Lambert, Leuz, and Verrecchia (2007)) which advocate that regulators should set a floor for disclosure, because firms have insufficient incentives to release information. It also contrasts recent increases in disclosure regulation, such as Sarbanes-Oxley, and is consistent with concerns that such regulation may reduce investment. If caps on disclosure are difficult to implement, a milder implication of our model is that government regulations to increase disclosure may have real costs.

However, government regulation may not maximize firm value. First, the policy that maximizes the manager's payoff varies from firm to firm. Even if all managers wish

[12] This is similar in spirit to the "quiet period" that precedes an initial public offering, which limits a firm's ability to disclose information.

[13] An alternative way to regulate may be to affect σ directly. For example, if the government allows greater discretion in accounting policies, managers have greater latitude for earnings management, and so earnings are a less informative signal.

to implement full investment, the disclosure policy $\zeta = X \equiv \frac{g(1+\rho)}{\Omega\phi\rho(\Delta+g)}$ depends on firm characteristics. Regulation is typically economy-wide, rather than at the individual firm level. A policy of ζ will induce suboptimally low disclosure in a firm for which $X > \zeta$: disclosure only needs to be as low as X to implement full investment, and $\zeta < X$ leads to an excessively high cost of capital. In contrast, a policy of ζ will not constrain disclosure enough in a firm for which $X < \zeta$. The manager will invest only $r(\zeta) < 1$, although this is still higher than the benchmark of no regulation. Moreover, some managers will not wish to implement the full-investment policy if $\Pi(1, X) < \Pi(r(1), 1)$ for their firm. Thus, a regulation aimed at inducing full investment will be inefficient.

Second, the government's goal may not be to maximize firm value, but total surplus. The manager takes into account both the benefits of disclosure (lower cost of capital) and its costs (lower investment). However, only the latter affects total surplus. The former comes at the expense of the speculator, as disclosure reduces his trading profits. Put differently, the speculator earns trading profits off the investor, which are passed onto the manager in the form of a higher cost of capital. Increased disclosure causes a transfer from the speculator to the manager, but no change in aggregate wealth. Thus, if the government's goal is to maximize total surplus, it will choose any $\zeta \in [0, X]$ to implement $\lambda^* = 1$. Such a policy will be suboptimal for the manager if $\Pi(1, X) < \Pi(r(1), 1)$.

Third, the government may have distributional considerations and aim to minimize informed trading profits and losses. One example is the SEC's focus on "leveling the playing field" between investors. Under this objective function, it will minimize the investor's trading losses[14] and ignore investment, which is achieved with $\zeta = 1$. Thus will reduce firm value if $\Pi(1, X) > \Pi(r(1), 1)$.

These results are stated in Proposition 8 below.

Proposition 8 *(Regulation): If the government wishes to maximize firm value, it will set a policy of* $\zeta = X$ *if* $\Pi(1, X) > \Pi(r(1), 1)$ *and* $\zeta = 0$ *otherwise. If the government wishes to maximize total surplus, it will choose any* $\zeta \in [0, X]$*, which will implement* $\lambda^* = 1$*. If the government wishes to minimize the investor's trading losses, it will choose* $\zeta = 1$*, which will implement* $\lambda^* = r(1)$*.*

[14]Note that minimizing the investor's trading losses is not the same as maximizing her objective function. The investor breaks even in all scenarios, since the initial stake that she requires takes into account her trading losses.

5 Conclusion

This paper has shown that, even if the actual act of disclosing information is costless, a high-disclosure policy may be costly. While increasing the disclosure of hard information augments the total amount of information available to investors, and thus reduces the cost of capital, it also increases the amount of hard information disclosed relative to soft information. This change causes the manager to distort his real decisions in favor of those that produce favorable hard information, even at the expense of soft information, such as cutting investment. Thus, real efficiency is non-monotonic in financial efficiency: investment is efficient with full disclosure of hard and soft information, or with no disclosure of either, and least efficient with full disclosure of only hard information.

If the manager can commit to a disclosure policy, his optimal policy will vary according to the importance of growth opportunities versus the cost of capital. Investment depends not only on traditional corporate finance variables (such as the profitability of growth opportunities and the manager's horizon) but also asset pricing variables such as shareholders' liquidity needs and information disadvantage. The effect of firm characteristics on disclosure policies is subtle. As predicted by other models, the optimal disclosure policy depends on asset pricing variables such as the level of information asymmetry faced by investors. However, here, the effect of such variables is non-monotonic. When information asymmetry is moderate, or investors suffer moderately frequent liquidity shocks, investment is more important than disclosure and so the manager reduces disclosure to pursue investment. When these parameters are high, disclosure dominates the trade-off and so the manager maximizes it; when these parameters are low, the manager is able to increase disclosure without suffering underinvestment. In addition, disclosure also depends on corporate finance variables such as the manager's short-term concerns and the profitability of growth opportunities. In a similar vein, the model delivers predictions on how the cost of capital depends not only on traditional microstructure factors such as information asymmetry, but also on the above corporate finance variables.

If the manager cannot commit to a disclosure policy, then even if a "high-investment, low-disclosure" policy is optimal, he may be unable to implement it as he will opportunistically disclose a good signal, regardless of the preannounced policy. Thus, there may be a role for government regulation to reduce disclosure.

The model suggests a number of avenues for future research. On the theory side, the paper has endogenized investment and disclosure, and studied how these decisions interplay with the manager's short-term concerns and the need to raise capital, which are taken as given. A potential extension would be to endogenize the manager's contract and the amount of capital raised, to study how these are affected by the same factors that drive investment and disclosure. In a similar vein, while the firm raises capital only by equity financing in our model, disclosure reduces the information asymmetry of equity more than for risky debt, and thus may have implications for a firm's choice of capital structure. Future studies could also relax the assumption that investors know the growth opportunities of a high-quality firm, in which case disclosure may have a role in signaling such opportunities.[15] On the empirical side, it delivers a number of new predictions on the real effects of disclosure on investment, on how investment depends on asset pricing variables, and on how the cost of capital and disclosure depend on corporate finance variables. In addition, while previous papers derived predictions on how the cost of capital and disclosure depend on asset pricing variables, our model predicts non-monotonic effects.

[15] In the current model, where only firm type is unknown, allowing for signaling (e.g. for managers to learn their type before setting disclosure policy) will simply lead to pooling equilibria as L-managers will mimic H-managers.

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A Appendix

Proof of Proposition 1

Fix any $\sigma \in [0,1]$. The quadratic $\Psi(\lambda, \sigma)$ has real roots if and only if the discriminant is non-negative, i.e.,

$$z(\sigma) \equiv \phi^2 \frac{\Delta^2}{g^2}\sigma^2 - 4\left(\frac{1}{\Omega} - \sigma\phi\right)\frac{1}{\Omega\rho} \geq 0. \tag{18}$$

The quadratic $z(\sigma)$ is a strictly convex function of σ with two roots. Since and $z(0) < 0$, it has one positive root which is given by:

$$Z \equiv \frac{g^2}{\Delta^2}\left[\frac{2}{\phi\Omega\rho}\sqrt{1+\rho\frac{\Delta^2}{g^2}} - \frac{2}{\phi\Omega\rho}\right].$$

Since $\sigma \in [0,1]$, for $z(\sigma) \geq 0$ (i.e., (18) to hold), σ must be weakly larger than the positive root Z. Thus, $\sigma \geq Z$ is necessary and sufficient for Ψ to have real roots.

Since $\Psi(0,\sigma) = \frac{1}{\Omega\rho} > 0$ and $\Psi'(0,\sigma) < 0$, Ψ may have up to two positive roots. One root, r, is such that $\Psi'(r,\sigma) < 0$. The second root, r', is such that $\Psi'(r',\sigma) \geq 0$. This second root, r', lies in $[0,1]$ if and only if $\Psi'(1,\sigma) \geq 0$, i.e.,:

$$\sigma \leq \frac{2g}{\Omega\phi(2g+\Delta)}. \tag{19}$$

However, further algebra shows that

$$X > Z > \frac{2g}{\Omega\phi(2g+\Delta)}. \tag{20}$$

Thus, if roots exist ($\sigma \geq Z$), (19) is violated and so the second root r' cannot lie in $[0,1]$. Therefore, the quadratic form of $\Psi(\lambda,\sigma)$ implies that there is at most one interior solution to the equation $\Psi(\lambda,\sigma) = 0$ for any $\sigma \in [0,1]$.

First, consider $\sigma \leq X$. Then $\Psi(1,\sigma) \geq 0$ by definition of X. Suppose there is $r' \in (0,1)$ such that $\Psi(r',\sigma) = 0$. The quadratic form of $\Psi(\lambda,\sigma)$ and $\Psi(0,\sigma) > 0$ implies that $\Psi'(1,\sigma) > 0$, which contradicts equation (20). Therefore, when $\sigma \leq X$, $\Psi(\lambda,\sigma) \geq 0$ (with equality only when $\lambda = 1$ and $\sigma = X$). Thus, the manager always wants to increase the investment level, and the unique equilibrium investment level is $\lambda^* = 1$.

Second, consider $\sigma > X$, in which case $\Psi(1,\sigma) < 0$. Then, when the market maker conjectures $\widehat{\lambda} = 1$, the manager has an incentive to deviate to a lower investment level. As a result, $\lambda = 1$ cannot be an equilibrium. Since $\Psi(0,\sigma) > 0$ and $\Psi(\lambda,\sigma)$ is continuous in λ, $\Psi(\lambda,\sigma) = 0$ has a solution $r \in [0,1]$. As argued previously, we must have $\Psi'(r,\sigma) < 0$.

We now prove that $r(\sigma)$ is strictly decreasing and strictly concave. Recall that

$$\Psi(\lambda,\sigma) = \left(\frac{1}{\Omega} - \sigma\phi\right)\lambda^2 - \sigma\phi\frac{\Delta}{g}\lambda + \frac{1}{\Omega\rho},$$

and so we can calculate

$$\left.\frac{\partial\Psi}{\partial\lambda}\right|_r = 2\left(\frac{1}{\Omega} - \sigma\phi\right)r - \sigma\phi\frac{\Delta}{g} < 0$$
$$\left.\frac{\partial\Psi}{\partial\sigma}\right|_r = -\phi\left(r^2 + \frac{\Delta}{g}r\right) < 0.$$

Thus, the Implicit Function Theorem yields:

$$\frac{dr}{d\sigma} = -\frac{\partial\Psi/\partial\sigma}{\partial\Psi/\partial\lambda} < 0,$$

i.e., $r(\sigma)$ is strictly decreasing.

To prove strict concavity, note that

$$\frac{\partial^2 r}{\partial\sigma^2} = \frac{1}{(\partial\Psi/\partial\lambda)^2}\left\{-\left[\frac{\partial^2\Psi}{\partial\sigma\partial\lambda}\frac{\partial\lambda}{\partial\sigma} + \frac{\partial^2\Psi}{\partial\sigma^2}\right]\frac{\partial\Psi}{\partial\lambda} + \frac{\partial\Psi}{\partial\sigma}\left[\frac{\partial^2\Psi}{\partial\lambda^2}\frac{\partial\lambda}{\partial\sigma} + \frac{\partial^2\Psi}{\partial\lambda\partial\sigma}\right]\right\}.$$

Since $\partial^2\Psi/\partial\sigma^2 = 0$, plugging in $\frac{dr}{d\sigma} = -\frac{\partial\Psi/\partial\sigma}{\partial\Psi/\partial\lambda}$ yields:

$$\frac{d^2 r}{d\sigma^2} > 0$$
$$\Leftrightarrow \frac{\partial^2\Psi}{\partial\lambda^2}\left(\frac{\partial\Psi/\partial\sigma}{\partial\Psi/\partial\lambda}\right) - 2\frac{\partial^2\Psi}{\partial\lambda\partial\sigma} > 0$$
$$\Leftrightarrow \left(\frac{1}{\Omega} - \sigma\phi\right)\frac{-\left(r^2 + \frac{\Delta}{g}r\right)}{2\left(\frac{1}{\Omega} - \sigma\phi\right)r - \sigma\phi\frac{\Delta}{g}} + \left(2r + \frac{\Delta}{g}\right) > 0.$$

There are two cases to consider. First, if $\frac{1}{\Omega} - \sigma\phi \geq 0$, the above inequality automatically holds. Second, if $\frac{1}{\Omega} - \sigma\phi < 0$, we have

$$\left(\frac{1}{\Omega} - \sigma\phi\right) \frac{-\left(r^2 + \frac{\Delta}{g} r\right)}{2\left(\frac{1}{\Omega} - \sigma\phi\right) r - \sigma\phi\frac{\Delta}{g}} + \left(2r + \frac{\Delta}{g}\right) > 0$$

$$\Leftrightarrow -\left(\frac{1}{\Omega} - \sigma\phi\right)\left(r^2 + \frac{\Delta}{g} r\right) + \left[2\left(\frac{1}{\Omega} - \sigma\phi\right) r - \sigma\phi\frac{\Delta}{g}\right]\left(2r + \frac{\Delta}{g}\right) < 0$$

$$\Leftrightarrow 3\left(\frac{1}{\Omega} - \sigma\phi\right) r^2 + \left(\frac{1}{\Omega} - \sigma\phi\right)\frac{\Delta}{g} r - 2\sigma\phi\frac{\Delta}{g} r - \sigma\phi\left(\frac{\Delta}{g}\right)^2 < 0.$$

The last equation holds because all terms on the left-hand side are negative. Therefore, $r(\sigma)$ is strictly convex.

Now assume $X < 1$, and fix $\sigma > X$. We wish to show that $r(\sigma)$ is increasing in g, and decreasing in ω, ϕ, ρ, and Δ. Since $\sigma > X$ implies $\Psi'(r, \sigma) < 0$, the Implicit Function Theorem gives us that the signs of partial derivatives $\partial r/\partial g$, $\partial r/\partial \omega$, $\partial r/\partial \phi$, $\partial r/\partial \rho$, and $\partial r/\partial \Delta$ are the same as those of $\partial \Psi/\partial g$, $\partial \Psi/\partial \omega$, $\partial \Psi/\partial \phi$, $\partial \Psi/\partial \rho$, and $\partial \Psi/\partial \Delta$, respectively. By taking partial derivatives of Ψ (evaluated at $r(\sigma)$), we have

$$\frac{\partial \Psi}{\partial g} = \sigma\phi\frac{\Delta}{g^2} r > 0,$$

$$\frac{\partial \Psi}{\partial \omega} = -\frac{r^2 + \frac{1}{\rho}}{\omega^2} < 0,$$

$$\frac{\partial \Psi}{\partial \phi} = -\sigma\left(r^2 + \frac{\Delta}{g} r\right) < 0,$$

$$\frac{\partial \Psi}{\partial \rho} = -\frac{1-\omega}{\omega}\frac{1}{\rho^2} < 0.$$

Therefore,

$$\frac{\partial r}{\partial g} > 0, \frac{\partial r}{\partial \omega} < 0, \frac{\partial r}{\partial \phi} < 0, \text{ and } \frac{\partial r}{\partial \rho} < 0.$$

Finally, analyzing equation (5) easily shows that X is increasing in g, and decreasing in ω, ϕ, ρ, and Δ.

Proof of Proposition 3

When choosing the disclosure policy, the manager compares the payoffs from $\sigma = 1$ (in which case $\lambda = r(1)$) and $\sigma = X$ (in which case $\lambda = 1$). Thus, the equilibrium is $(\lambda^* = r(1), \sigma^* = 1)$ if $\Pi(r(1), 1) > \Pi(1, X)$, and $(\lambda^* = 1, \sigma^* = X)$ otherwise.

The manager chooses $(\lambda^* = 1, \sigma^* = X)$ if $\Pi(1, X) - \Pi(r, 1) > 0$, i.e.,

$$(1-r)\left[\frac{1}{2} - \frac{1}{4}\beta\phi - \frac{1}{4}\beta\frac{1-\omega}{\omega}\right] + \frac{1-\omega}{\omega}\frac{\beta}{4\rho} + \frac{1}{4}\frac{1-\omega}{\omega}\beta r - \frac{1}{4}\beta\phi r - \frac{\beta\phi(\Delta)}{4g} > 0,$$

where we write r rather than $r(1)$ to economize on notation. Here, r can be solved from $\Psi(r, 1) = 0$, and $\Psi'(r, 1) < 0$. Since Ψ is not a function of β, the above inequality is equivalent to

$$1 - r > \beta\left\{\frac{1}{2}\phi\frac{\Delta + g}{g} - \frac{1-\omega}{\omega}\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right]\right\}.$$

The term multiplied by β on the right-hand side is

$$\begin{aligned}
&\frac{1}{2}\phi\frac{\Delta + g}{g} - \frac{1-\omega}{\omega}\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right] \\
>&\frac{1}{2}\phi\frac{\Delta + g}{g} - \phi\frac{\Delta + g}{g}\frac{\rho}{\rho + 1}\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right] \\
=&\phi\frac{\Delta + g}{g}\frac{\rho}{\rho + 1}[1 - r] \\
>&0.
\end{aligned}$$

The first inequality is due to the condition $X < 1$. As a result,

$$\widetilde{\beta} = \frac{1 - r}{\frac{1}{2}\phi\frac{\Delta + g}{g} - \frac{1-\omega}{\omega}\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right]} > 0.$$

Since the denominator of $\widetilde{\beta}$ is strictly greater than $\frac{1-\omega}{\omega}\frac{1}{X}(1 - r)$, we have $\widetilde{\beta} < \frac{\omega}{1-\omega}X$. Thus, the manager strictly prefers $(\lambda^* = 1, \sigma^* = X)$ if and only if $\beta < \widetilde{\beta}$.

When $X < 1$, to derive the comparative statics of $\tilde{\beta}$, we first define

$$\chi(\beta) = (1 - r) - \beta\left\{\frac{1}{2}\phi\frac{\Delta + g}{g} - \frac{1-\omega}{\omega}\left[\left(\frac{1}{2}\frac{1}{\rho} - 1\right) + r\right]\right\}.$$

It is clear that $\chi\left(\widetilde{\beta}\right) = 0$ and $\chi'\left(\widetilde{\beta}\right) < 0$. Thus, the signs of $\partial\widetilde{\beta}/\partial g$, $\partial\widetilde{\beta}/\partial\phi$, $\partial\widetilde{\beta}/\partial\rho$, and $\partial\widetilde{\beta}/\partial\omega$ are the same as those of $\partial\chi/\partial g$, $\partial\chi/\partial\phi$, $\partial\chi/\partial\rho$, and $\partial\chi/\partial\omega$ (evaluated at $\widetilde{\beta}$).

First, we show that $\partial\chi/\partial g > 0$, so $\partial\widetilde{\beta}/\partial g > 0$.

$$\begin{aligned}
\partial\chi/\partial g &= \left(\widetilde{\beta}\frac{1-\omega}{\omega} - 1\right)\frac{\partial r}{\partial g} + \frac{1}{2}\widetilde{\beta}\phi\frac{\Delta}{g^2} > 0 \\
\Leftrightarrow & \frac{\frac{1-\omega}{\omega}\left[\frac{1}{2\rho}+\frac{1}{2}\right]r - \frac{1}{2}\phi\frac{\Delta+g}{g}r}{\phi\frac{\Delta}{g} - 2\left[\frac{1-\omega}{\omega}-\phi\right]r} + \frac{1}{2}(1-r) > 0 \\
\Leftrightarrow & (r-1)^2 > 0.
\end{aligned}$$

The last inequality is automatic, because $r < 1$ when $X < 1$.

Second, we also show $\partial\chi/\partial\phi < 0$, so $\partial\widetilde{\beta}/\partial\phi < 0$.

$$\begin{aligned}
&\partial\chi/\partial\phi < 0 \\
\Leftrightarrow & \left(\widetilde{\beta}\frac{1-\omega}{\omega} - 1\right)\frac{\partial r}{\partial\phi} - \frac{1}{2}\widetilde{\beta}\frac{\Delta+g}{g} < 0 \\
\Leftrightarrow & \left[-\left(\frac{1-\omega}{\omega}-\phi\right)r + \frac{1-\omega}{\omega}\frac{1}{\rho}\right]\left(\frac{\Delta}{g}+r\right) \\
& \quad - \left[-\left(\frac{1-\omega}{\omega}-\phi\right)r + \frac{1-\omega}{\omega}\frac{1}{\rho}\frac{1}{r}\right]\left(\frac{\Delta}{g}+1\right) < 0.
\end{aligned}$$

The final inequality is true because all of the following inequalities hold:

$$\begin{aligned}
-\left(\frac{1-\omega}{\omega}-\phi\right)r + \frac{1-\omega}{\omega}\frac{1}{\rho}\frac{1}{r} &> -\left(\frac{1-\omega}{\omega}-\phi\right)r + \frac{1-\omega}{\omega}\frac{1}{\rho}, \\
-\left(\frac{1-\omega}{\omega}-\phi\right)r + \frac{1-\omega}{\omega}\frac{1}{\rho}\frac{1}{r} &> 0 \quad \text{(because } \Psi'(r,1) < 0\text{), and} \\
\frac{\Delta}{g} + 1 &> \frac{\Delta}{g} + r.
\end{aligned}$$

Then, we show $\partial\chi/\partial\rho < 0$, so $\partial\widetilde{\beta}/\partial\rho < 0$.

$$\partial\chi/\partial\phi = \left(\widetilde{\beta}\frac{1-\omega}{\omega} - 1\right)\frac{\partial r}{\partial\rho} - \widetilde{\beta}\frac{1-\omega}{2\omega}\frac{1}{\rho^2}.$$

Hence,

$$\begin{aligned}
&\partial\chi/\partial\phi < 0 \\
\Leftrightarrow & -\left(\frac{1-\omega}{\omega}-\phi\right)(1-r)^2 < 0.
\end{aligned}$$

Finally, we show that $\partial\chi/\partial\omega$ depends on ω, so the sign of $\partial\widetilde{\beta}/\partial\omega$ depends on ω.

$$\partial\chi/\partial\omega = \left(\widetilde{\beta}\frac{1-\omega}{\omega} - 1\right)\frac{\partial r}{\partial\omega} - \widetilde{\beta}\frac{1}{\omega^2}\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right].$$

When ω is small, so that X is close to 1, we have $\widetilde{\beta}\frac{1-\omega}{\omega} - 1 \to 0$ and $r \to 1$. Thus, $\partial\chi/\partial\omega < 0$. When $\omega \to 1$, $r \to 0$ (from equation (4)). Then,

$$\begin{aligned}
&\partial\chi/\partial\omega > 0 \\
\Leftrightarrow &\frac{-\frac{1-\omega}{\omega}\left(\frac{1}{2\rho} + \frac{1}{2}\right) + \frac{1}{2}\phi\frac{\Delta+g}{g}}{\phi\frac{\Delta}{g} - 2\frac{1-\omega}{\omega}r}\left[r^2 + \frac{1}{\rho}\right] \\
&\quad - (1-r)\left[\frac{1}{2}\left(\frac{1}{\rho} - 1\right) + r\right] > 0.
\end{aligned}$$

The left-hand side converges to $\frac{1}{2\rho}\frac{g}{\Delta} + \frac{1}{2} > 0$.

Proof of Proposition 4

We start with part (i), the global comparative statics with respect to g; the effect of Δ in part (ii) is exactly the opposite since Δ and g appear together as the ratio $\frac{\Delta+g}{g}$ in both X and $\tilde{\beta}$. From Proposition 3, $\tilde{\beta} = 0$ when $g = 0$, and then $\widetilde{\beta}$ is strictly increasing in g for $X < 1$. Since X is also strictly increasing in g, there are two cases to consider. The first is $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} \leq 1$, in which case (8) is violated for any g and so we always have $X < 1$. If $\beta > \lim_{g\to\infty}\tilde{\beta}$, then we always have $\beta > \tilde{\beta}$ for any g, and so the partial investment equilibrium $(\lambda^* = r(1), \sigma^* = 1)$ is always implemented. As g increases, the investment level $r(1)$ rises, while the level of disclosure remains fixed at 1. If $\beta \in \left(0, \lim_{g\to\infty}\tilde{\beta}\right)$ then when g is small, $\beta > \tilde{\beta}$, and so the equilibrium is $(\lambda^* = r(1), \sigma^* = 1)$. As g increases, the equilibrium remains $(\lambda^* = r(1), \sigma^* = 1)$ but the investment level $r(1)$ is increasing. When g hits the point at which $\tilde{\beta} = \beta$, the equilibrium jumps to $(\lambda^* = 1, \sigma^* = X)$, so investment rises and disclosure falls. As g continues to increase, λ^* is constant at 1, while σ^* increases but remains strictly below 1: since $X < 1$, we can never have full disclosure alongside full investment.

The second case is $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$. In this case, there exists a threshold g' such that, when $g \geq g'$, (8) is satisfied and we have $X \geq 1$. Note that $X = 1 \Leftrightarrow \tilde{\beta} = \Omega$. If $\beta \geq \Omega$, then we always have $\beta > \tilde{\beta}$ and full disclosure. When $g < g'$, the equilibrium is $(\lambda^* = r(1), \sigma^* = 1)$. As g rises, $\lambda^* = r(1)$ rises. When g crosses above g', we now have full investment as well as full disclosure: the equilibrium becomes

$(\lambda^* = 1,\ \sigma^* = 1)$. If $\beta \in (0, \Omega)$, then for low g, we have the partial investment equilibrium $(\lambda^* = r(1), \sigma^* = 1)$. As g rises, σ^* remains constant at 1 and the partial investment level $r(1)$ rises, until $\tilde{\beta}$ crosses above β and we move to the full partial disclosure equilibrium $(\lambda^* = 1,\ \sigma^* = X)$. Note this crossing point for g is below g', because $\beta < \Omega$. As g continues to increase, λ^* is constant at 1 and σ^* rises. When g crosses above g', we have $X \geq 1$ so σ^* rises to 1. Unlike in the $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} \leq 1$ case, we can have full disclosure alongside full investment.

Proof of Proposition 5

We start with part (i). When $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, (8) is satisfied for all ϕ. Thus, we always have $X \geq 1$, which yields the equilibrium $(\lambda^* = 1,\ \sigma^* = 1)$. When $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$, there are several cases to consider. If $\beta \geq \Omega$, then $\beta \geq \tilde{\beta}$ always and so we always have the partial investment equilibrium. If $\beta \leq \tilde{\beta}(\phi = 1)$, then $\beta \leq \tilde{\beta}$ always and so we always have the partial disclosure equilibrium. When $\beta \in \left(\Omega, \tilde{\beta}(\phi = 1)\right)$, for small ϕ, we have $X \geq 1$, so the equilibrium is $(\lambda^* = 1, \sigma^* = 1)$. When ϕ rises so that X crosses below 1, then $\tilde{\beta}$ crosses above Ω and so we have $\beta < \tilde{\beta}$, which yields the partial disclosure equilibrium. After ϕ reaches a threshold, then $\tilde{\beta}$ falls below β and so we move to the partial investment equilibrium. λ^*

The proof of part (ii) is very similar, except that the cases of $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \gtreqless 1$ are replaced by $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} \gtreqless 1$, and $\tilde{\beta}(\phi = 1)$ is replaced by $\tilde{\beta}(\rho = 1)$.

Proof of Proposition 6

When ω is sufficiently small that $X \geq 1$, the equilibrium is $(\lambda^* = 1, \sigma^* = 1)$. When ω is sufficiently large, $X < 1$. The remainder of this proof will focus on which equilibrium is chosen when $X < 1$.

Proposition 3 shows that when ω is small so that X is close to 1 (while remaining below 1), $\tilde{\beta}$ is decreasing in ω. When ω is large, $\tilde{\beta}$ is increasing in ω. If $\underline{\beta}$ denotes the minimum $\tilde{\beta}$ over all ω such that $X \leq 1$, then $\underline{\beta} < \min\left\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\right\}$.

For part (a), when $\beta \leq \underline{\beta}$, then $\beta \leq \tilde{\beta}$. Thus, when $X < 1$, we always have the partial disclosure equilibrium of $(\lambda^* = 1, \sigma^* = X)$.

For part (b), when $\beta \geq \max\left\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\right\}$, $\beta \geq \tilde{\beta}$. Thus, when $X < 1$, we always have the partial investment equilibrium of $(\lambda^* = r(1), \sigma^* = 1)$.

For part (c), when $\beta > \min\left\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\right\}$, then when ω rises sufficiently for X to cross below 1, $\beta > \tilde{\beta}$ and so we have the partial investment equilibrium of $(\lambda^* = r(1), \sigma^* = 1)$. If we also have $\tilde{\beta}(X = 1) > \beta > \tilde{\beta}(X = 0)$, then once ω crosses a second threshold, then $\tilde{\beta}$ crosses below β and so we move to the partial disclosure equilibrium of $(\lambda^* = 1,\ \sigma^* = X)$.

For part (d), when $\beta \in \left(\underline{\beta}, \min\{\tilde{\beta}(X=1), \tilde{\beta}(X=0)\}\right)$, then when ω rises sufficiently for X to cross below 1, then $\beta < \tilde{\beta}$ and so we have the partial disclosure equilibrium of $(\lambda^* = 1, \sigma^* = X)$. Since $\tilde{\beta}$ is decreasing in ω for low ω, When ω crosses a second threshold, then $\tilde{\beta}$ crosses below β and so we move to the partial disclosure equilibrium. Since $\tilde{\beta}$ is increasing in ω for high ω, when ω crosses a third threshold, then $\tilde{\beta}$ crosses back above β and so we move to the partial investment equilibrium.