Financial Efficiency Versus Real Efficiency*

Alex Edmans
LBS, Wharton, NBER, CEPR, and ECGI

Mirko Heinle
Wharton

Chong Huang
UC Irvine

April 29, 2014

Abstract

This paper shows that improving financial efficiency may reduce real efficiency. Financial efficiency depends on the *total* amount of information in prices, but the manager's real decisions depend on the *relative* amounts of hard (verifiable) and soft (non-verifiable) information. Disclosing more hard information augments total information, raising financial efficiency and reducing the cost of capital. However, it also induces the manager to prioritize hard information over soft by cutting investment, lowering real efficiency. The optimal level of financial efficiency is non-monotonic in the investment opportunity. When it is weak, real efficiency is unimportant relative to the cost of capital and optimal financial efficiency is high. When it is strong, it will be pursued even with high financial efficiency. Even if low financial efficiency is optimal to induce investment, the manager may be unable to commit to it. Optimal government policy may involve upper, rather than lower, bounds on financial efficiency.

KEYWORDS: Financial efficiency, real efficiency, managerial myopia, investment, disclosure, cost of capital.
JEL CLASSIFICATION: G18, G31

*aedmans@wharton.upenn.edu, miheinle@wharton.upenn.edu, chong.h@uci.edu. We thank David Dicks, Vincent Glode, Itay Goldstein, David Hirshleifer, Liyan Yang, and conference and seminar participants at CFEA, London Business School, Philadelphia Fed, UC Irvine, and Wharton for valuable comments. AE thanks the Wharton Dean's Research Fund for financial support. CH thanks the CORCL Awards for financial support. This paper was previously circulated under the title "The Real Costs of Disclosure."

The link between financial efficiency and real efficiency is one of the most important questions in financial markets. Morck, Shleifer, and Vishny (1990) proposed that stock markets may be a "sideshow" that merely reflect the real economy but do not affect it. However, a long literature since then has identified numerous channels through which efficient financial markets improve real decisions. Focusing on primary financial markets, Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and others show that information asymmetries hinder capital raising and thus investment. Turning to secondary financial markets, the survey of Bond, Edmans, and Goldstein (2012) discusses two mechanisms through which they may have real effects. The first is the learning channel. Stock prices aggregate information from thousands of speculators (Hayek (1945)), e.g. on a firm's investment opportunities, which can guide real decisions. More efficient prices provide more information to decision makers and improve real efficiency. Early models in this spirit include Boot and Thakor (1997), Dow and Gorton (1997), and Subrahmanyam and Titman (1999). The second is the contracting channel. If the manager's contract is tied to the stock price, increasing the efficiency of the stock price – the extent to which it reflects fundamental value – improves the manager's incentives to improve fundamental value (Fishman and Hagerty (1989), Holmstrom and Tirole (1993), Admati and Pfleiderer (2009), Edmans (2009)).[1]

In the above models, financial efficiency improves real efficiency. As a result, many economic policies are evaluated based on their likely effects on financial efficiency. For example, some commentators advocate increased disclosure requirements based on arguments that they will increase financial efficiency[2]; others oppose trading restrictions (such as the proposed EU transaction tax) on the grounds that they will reduce price efficiency. Relatedly, financial efficiency is often taken as a measure of economic effectiveness. For example, Bai, Philippon, and Savov (2013) measure changes in financial efficiency over time to evaluate whether the increasing size of the financial sector has benefited the real economy.

This paper reaches a different conclusion. It shows that measures to increase financial efficiency can, surprisingly, reduce real efficiency. Central to our argument is the idea that financial markets can never be fully efficient, because certain types of

[1]In these models, the price is always semi-strong-form "efficient" (in that it equals expected firm value conditional upon an information set) because the market is rational. Our notion of efficiency is the informativeness of the stock price about the firm's fundamental value.

[2]For example, the Financial Accounting Standards Board states that the "benefits of financial reporting information include better investment, credit, and similar resource allocation decisions, which in turn result in more efficient functioning of the capital markets and lower costs of capital for the economy as a whole."

information are difficult to incorporate into prices through standard channels such as disclosure. For example, “hard” (quantitative and verifiable) information, e.g. on a firm’s earnings, can be credibly communicated, but “soft” (nonverifiable) information, e.g. on a firm’s intangible assets, cannot be. It may seem that this distinction does not matter: even though financial efficiency can never be perfect, due to the existence of soft information, firms and policymakers should strive to increase financial efficiency as much as possible by incorporating as much hard information into prices as possible. However, we show that real efficiency depends not on *total* financial efficiency, i.e. the aggregate amount of information in prices, but the *relative* amount of hard versus soft information. While incorporating more hard information into prices increases total information, it also distorts the relative amount of hard versus soft information, since the latter cannot be disclosed. In turn, this distorts the manager’s real decisions towards improving the hard signal at the expense of the soft signal – for example, cutting investment in intangible assets 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. We incorporate a standard benefit of financial efficiency well-established in the literature. 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 investor’s information disadvantage, and thus the cost of capital, depends on financial efficiency: the amount of information available in prices. To allow the manager to affect financial efficiency, we introduce a channel – disclosure – through which he can do so; however, as discussed below, our results apply to other potential channels. Specifically, the firm can disclose hard information (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 a real cost. A high-quality firm has the option to undertake an intangible investment that improves the firm’s long-run value, but also raises the probability of delivering low earnings. If low earnings are disclosed, the firm’s stock price rationally falls since a low-quality firm always delivers low earnings. The manager’s objective function places weight on both the short-term stock price and long-term firm value. This is the standard myopia problem, first modeled by Stein (1988, 1989). Our specific setup is similar to the myopia model of Edmans (2009), where real efficiency is increasing in financial efficiency, but we reach quite different conclusions.

We start with the benchmark case in which the firm's long-run value is hard information, and so it is possible to achieve perfect financial efficiency through full disclosure of firm value. Indeed, such a policy minimizes the cost of capital and also maximizes real efficiency – since the stock price equals firm value, the manager invests efficiently to optimize firm value. This is similar to the standard benefit of financial efficiency featured in prior literature. The more realistic case is when long-run value is soft information – since it is not realized until the future, it cannot be credibly disclosed – and so financial efficiency cannot go be perfect. This case leads to very different conclusions on the desirability of financial efficiency. Since investment improves soft information but worsens hard information, disclosure induces underinvestment. Thus, real efficiency is non-monotonic in financial efficiency. When long-run value is hard information, the manager invests efficiently if it is fully disclosed (in which case financial efficiency is maximized). When long-run value cannot be disclosed, the manager invests efficiently if earnings are not disclosed either (in which case financial efficiency is minimized); increasing the disclosure of earnings augments financial efficiency but reduces real efficiency. It may be better for prices to contain no information than partial information. This result echoes the theory of the second best, where it may be optimal to tax all goods rather than a subset.[3]

The optimal level of disclosure is a trade-off between increased financial efficiency (a lower cost of capital) and reduced real efficiency (lower investment). Thus, the model predicts how disclosure (and thus financial efficiency) should vary across firms. Intuition might suggest that firms with better growth opportunities will disclose less, since investment dominates the trade-off, but we show that the effect of growth opportunities is non-monotonic. Up to a point, increases in growth opportunities indeed reduce disclosure, but when investment opportunities are very strong, the manager will

[3] Holmstrom and Milgrom (1991) show that difficulties in measuring one task may lead to the principal optimally offering weak incentives for all tasks. Paul (1992) 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. Both papers study the optimal design of incentive contracts based on exogenously available information. Here, the information in prices is an endogenous decision of the firm, and we study the firm's optimal decision which trades off financial and real efficiency.

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 when uncertainty (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 either low, as the manager will invest fully even with high disclosure, or high, as financial efficiency becomes important relative to real efficiency. Surprisingly, an increase in signal imprecision may lead to more disclosure of the signal.

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 policy to maximize real efficiency. However, if he invests and gets lucky, i.e., still delivers high earnings, he will renege on the policy and disclose the high earnings anyway. Then, if the market receives no disclosure, it rationally infers low earnings, else the manager would have released them – the "unraveling" result of Grossman (1981) and Milgrom (1981). The only dynamically consistent policy is full disclosure, and real efficiency suffers. In this case, government intervention can be desirable. By capping disclosure (for example by increasing verification requirements), 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)), and the general view that government interventions should aim to increase financial efficiency.[4] Surprisingly, left to their own devices, firms will choose excessively high financial efficiency, and regulation can add value by reducing financial efficiency. Conversely, regulations to increase financial efficiency through augmenting disclosure (e.g., Sarbanes-Oxley) may have real costs.

However, the effect of government intervention on firm value is unclear, because the government may have a different objective function from the firm. First, it may wish to maximize real efficiency and ignore investor losses, since they are offset by trading profits to the speculator and thus do not affect total surplus. Then, the government would implement too low financial efficiency from the firm's perspective. Second, the government may wish to maximize financial efficiency – for example, Regulation FD attempts to "level the playing field" between different investors – leading to too little real efficiency. Third, even if the government's objective function were to maximize initial firm value (i.e. balance real and financial efficiency), the optimal disclosure

[4] In 2009, the erstwhile chairman of the SEC, Mary Schapiro, stated that "any system of regulation should be designed to facilitate fair and efficient financial markets, not to supplant them."

policy is firm-specific, whereas regulation cannot be tailored to an individual firm.

Our paper is not the first to recognize that financial efficiency need not coincide with real efficiency. Stein (1989) shows that, if managers cut investment to inflate earnings, a rational market will anticipate such behavior and discount earnings announcements. Thus, markets are efficient, but managers are trapped into behaving inefficiently. Dow and Gorton (1997) show that, if speculators do not produce information, the manager does not learn from prices and does not invest. Prices are efficient since they reflect the fact that no investment will occur, but real efficiency is low. In these papers, financial efficiency is an outcome of the model which decision makers have no control over. In contrast, we study the manager's choice of financial efficiency – through his disclosure policy – and derive empirical predictions on its determinants. While Stein (1989) does not consider disclosure (or financial efficiency) as a choice variable, one could intuitively apply the insights of his model to conjecture that greater disclosure will reduce investment, without the need to write down a new theory. Such an extension would suggest that greater growth opportunities reduce disclosure, but we show that disclosure is non-monotonic in growth opportunities. We also analyze mandatory versus voluntary disclosure and demonstrate a role for regulation. The survey of Bond, Edmans, and Goldstein (2012) terms the traditional notion of financial efficiency – the extent to which prices reflect fundamental values – as "forecasting price efficiency". This is the notion of financial efficiency studied in the present paper. Bond et al. argue that real efficiency instead depends on "revelatory price efficiency": the extent to which prices reveal the information necessary for decision-makers to take value-maximizing actions. In our setting, this is information about the firm's long-run value – but since it cannot be disclosed, the notion of revelatory price efficiency is moot.

In addition to the literature on financial and real efficiency, this paper is also related to the disclosure literature, reviewed by Verrecchia (2001), Dye (2001), Beyer, Cohen, Lys, and Walther (2010), and Goldstein and Sapra (2012). This literature studies the disclosure of hard information, because soft information by definition cannot be disclosed. One may think that the existence of soft information is moot, since it cannot be disclosed, and so managers should simply apply the insights of disclosure theories to hard information. We show that the existence of soft information reduces the optimal disclosure of hard information. Gigler, Kanodia, Sapra, and Venugopalan (2014) study a regulator's choice between two discrete disclosure regimes (with and without an interim signal). They assume that investment is observable but its horizon is not, and show that an interim signal induces the manager to choose the short-term project.

Greater growth opportunities lead the regulator to choose less disclosure. We study the firm's optimal choice from a continuum of policies where disclosure affects the cost of capital as well as investment, and show that disclosure is non-monotonic in growth opportunities. We also analyze the voluntary disclosure case where commitment is not possible. In Hermalin and Weisbach (2012), disclosure induces the manager to engage in manipulation, but there is no trade-off with financial efficiency; we also solve for the optimal level of disclosure. In their model, the manager prefers less disclosure ex post; here, he discloses too much where disclosure is voluntary.

In standard disclosure models (e.g. Verrecchia (1983), Diamond (1985), Dye (1986)), disclosure is limited because it involves a direct cost. Here, even though the actual act of disclosure is costless, a high-disclosure policy is costly. More recent models also feature indirect costs of disclosure, but in those papers disclosure is costly because it reduces financial efficiency and financial efficiency increases real efficiency; here, disclosure increases financial efficiency which reduces real efficiency. Disclosing information may reduce speculators' incentives to acquire private information (Gao and Liang (2013)), deter speculators from trading on private information (Bond and Goldstein (2012)), or attract noise traders (Han, Liu, Tang, Yang, and Yu (2013)), reducing the information in prices from which the manager can learn. In Fishman and Hagerty (1989), traders can only acquire a signal in one firm, and so disclosure draws traders away from one's rivals. Thus, disclosure can be socially suboptimal as it reduces financial efficiency in other firms. Fishman and Hagerty (1990) advocate limiting the set of signals from which the firm may disclose, to increase financial and thus real efficiency.

Finally, while we model disclosure as the specific channel through which firms or regulators can affect financial efficiency, the same principles apply to other determinants of financial efficiency. For example, regulations on trading, such as short-sales constraints, transactions taxes, or limits on high-frequency trading, will likely reduce financial efficiency, and this reduction is often used to argue against such regulations.[5] However, if such trading would be on the basis of hard information, then the reduction in financial efficiency may increase real efficiency. Our paper cautions against policymakers supporting blanket increases in financial efficiency. Such a view would suggest that any channel of increasing total financial efficiency (e.g. any informative disclosure, or any informed trade) is desirable. Instead, what matters for real decisions is the relative weights of different types of information in the stock price.

[5] For example, in February 2014, the German parliament voted to require that high frequency traders hold a license issued by the German regulator of financial markets, and that the ratio of demand orders to executions must meet certain thresholds.

1 The Model

The model consists of four players. The *manager* initially owns the entire firm and chooses its 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 chosen so that the investor breaks even.

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". We consider a standard myopia problem. As in Edmans (2009), an L-manager has no investment decision and his firm is 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 investment.[6] (All values are inclusive of the K raised by the financing.) Since $g > 0$, $\lambda = 1$ is first-best, and higher levels of λ correspond to greater real efficiency. The type θ and the investment level λ are observable to both the manager and the speculator (and so both know V), but neither are observable to the investor or market maker.

At $t = 2$, a hard (verifiable) signal $y \equiv \{G, B, \varnothing\}$ (such as earnings) is generated. With probability $1-\sigma$, it 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 $\rho \in (0,1)$ 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 to either 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 public signal is fully informative and so the speculator will not trade, but if $y \in \{B, \varnothing\}$, it is imperfect and the speculator will take advantage of his private information on V by trading an endogenous amount S. As

[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.

in 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. 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 $V \in \left\{V^H, V^L\right\}$ becomes known and payoffs are realized. We consider two versions of the model. In a preliminary benchmark, V is hard information and can be credibly disclosed at $t = 2$. In the core model, V is soft information prior to $t = 4$ and thus cannot be credibly disclosed.[7] Note that soft information is still present in the model, because the speculator has information on V and trades on it.

The manager's objective function is $(1 - \alpha)(\omega P + (1 - \omega) V)$. After raising financing, the manager's stake in the firm is $(1 - \alpha)$. The concern for the short-term stock price $\omega \in (0, 1)$ is standard in the myopia literature and can arise from a number of sources introduced by prior research: takeover threat (Stein (1988)), concern for managerial reputation (Narayanan (1985), Scharfstein and Stein (1990))[8], or the manager expecting to sell a fraction ω of his remaining shares just after $t = 3$ and hold the remaining $1 - \omega$ until $t = 4$, as in Stein (1989).

Before solving the model, we discuss its assumptions. Investment improves fundamental value but potentially lowers earnings, as in the myopia models of Stein (1988, 1989). Investment in R&D, advertising, or training employees is nearly always expensed; 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). Short-term earnings are verifiable but long-run fundamental value is not (prior to the final period) in the core model. 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 assumption can be weakened: we only require the speculator to have some information advantage over outside investors. Many shareholders (e.g., retail investors) lack the expertise to gather information about the firm. The liquidity-

[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 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 $\xi = \frac{(1-\alpha)\omega}{1-\omega}$.

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. She will invest a disproportionate fraction of these new funds into the firm if she is less aware of stocks she does not currently own (e.g., Merton (1987)).[9] The results continue to hold with only liquidity-enforced selling.

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.*

We are interested in the trade-off between financial and real efficiency. Since investment increases fundamental value, we use λ as a measure of real efficiency. We measure financial efficiency as follows:

Definition 2 *Financial efficiency is measured by*

$$-E\left[\Lambda\left(P\right)\right] = -E\left[\frac{Var\left[V|P\right]}{Var\left[V\right]}\right]. \tag{1}$$

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

Our measure of financial efficiency is price informativeness: the negative of the variance of fundamental value conditional on the price, relative to the prior variance of fundamental value. This measure is similar to Kyle (1985) except that we divide by the prior variance to obtain a relative rather than absolute measure. Note that we distinguish the information content of a specific price realization, $-\Lambda(P)$, from the expected information content, $-E[\Lambda(P)]$.

2 Analysis

2.1 First-Best Benchmark

As a benchmark, we first assume that V is hard information, i.e., the manager can commit to disclosing it with probability σ_V. In this case, perfect financial efficiency can be achieved. If V is disclosed, then $P = V$ regardless of the order flow, and financial efficiency is maximized: $-E[\Lambda(P)] = 0$. It is easy to show that the investor makes no trading losses, and the cost of capital is minimized. Real efficiency is also maximized: the H-manager faces no trade-off between stock price and fundamental value, and so chooses $\lambda = 1$ as this maximizes both.

Since disclosure of V maximizes both financial and real efficiency, 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. (All proofs are in Appendix A).

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 turn to the core model in which V is soft information and thus cannot be disclosed. Thus, there is always some information not in the price, and so financial efficiency cannot be maximized. 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 financial efficiency (and thus the cost of capital) and real efficiency (his investment decision).

2.2 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 $\hat{\lambda} > 0$, and so the speculator will trade on his private information on V. 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. Similarly, when $y = \varnothing$, the speculator again has an information advantage and will trade. 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:*

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

. (2)

We use $P(Q, y)$ to denote the price of a firm for which signal y has been disclosed and the order vector is Q. The price is perfectly informative about the true fundamental value except in two cases. We denote the first case $P' = P((\beta, -\beta), \varnothing)$ and the second case $P'' = P((\beta, -\beta), B)$. Note that in all other cases $\Lambda(P) = 0$. We have $\Lambda(P') = 1$ (P' is completely uninformative) and $\Lambda(P'') = 4\frac{\rho\lambda^2}{(1+\rho\lambda^2)^2}$ (since in equilibrium, $\hat{\lambda} = \lambda$). Thus, our measure of financial efficiency is given by

$$
\begin{aligned}
-E[\Lambda(P)] &= -\frac{1}{2}(1-\sigma)\phi\Lambda(P') - \frac{1}{4}\sigma\phi\left(1+\rho\lambda^2\right)\Lambda(P'') \\
&= -\phi\left[\frac{1}{2}(1-\sigma) - \sigma\frac{\rho\lambda^2}{(1+\rho\lambda^2)}\right]. \qquad (3)
\end{aligned}
$$

There are two effects of an increase in σ on financial efficiency. First, it directly reduces financial efficiency since $\frac{\rho\lambda^2}{(1+\rho\lambda^2)} < \frac{1}{2}$. Second, we will show in Proposition 1 that λ is weakly decreasing in σ, also lowering $E[\Lambda(P)]$. Therefore, as σ increases, financial efficiency increases. In addition, financial efficiency is decreasing in the probability of the liquidity shock ϕ, as this liquidity trades camouflage the speculator's informed trades, and the signal noise ρ.

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

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

$$X \equiv \frac{g(\rho+1)}{\Omega\phi\rho(\Delta+g)}, \tag{4}$$

$r(\sigma)$ is the root of the quadratic

$$\Psi(\lambda,\sigma) \equiv \left(\frac{1}{\Omega} - \sigma\phi\right)\lambda^2 - \sigma\phi\frac{\Delta}{g}\lambda + \frac{1}{\Omega\rho} = 0, \tag{5}$$

for which $\Psi'(r,\sigma) < 0$. It is strictly decreasing and strictly convex. 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. As is intuitive, $\sigma \leq X$ is more likely to be satisfied 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 V rather than y. Thus, the manager is less concerned about emitting the bad signal. Finally, 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 H by delivering $y = G$.

When $\sigma > X$, disclosure is sufficiently frequent 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. 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.

The negative link between financial efficiency and real efficiency contrasts with Edmans (2009), who theoretically demonstrates a positive link. In his model, financial efficiency is increased by blockholders gathering information on V and incorporating it into stock prices by informed trading. They do not gather information on y as it is a public signal. Here, financial efficiency is increased by the firm disclosing y – it cannot disclose V as it is soft information. Thus, it is not the case that any channel that increases financial efficiency will also increase real efficiency – the *source* of the increase in real efficiency is important. While incorporating information about both V and y into prices increases financial efficiency, it has opposite effects on real efficiency. This idea is linked to Bond, Edmans, and Goldstein's (2012) contrast between forecasting price efficiency and revelatory price efficiency. The former is the extent to which prices reflect fundamental values: it is the traditional notion of financial efficiency which is also used in this paper. Incorporating any information into prices augments financial efficiency. The latter is the extent to which prices reflect the information necessary for decision-makers to take value-maximizing actions. Here, this is information on V. In Edmans (2009), blockholders increase financial efficiency by incorporating information on V, and doing so also augments real efficiency. Here, the concept of revelatory price efficiency is moot as V cannot be disclosed, but the manager's disclosure decisions still affect real efficiency.

2.4 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:

$$\begin{aligned}\max_{\sigma} \Pi(\sigma) &= (1-\alpha(\sigma))\left(\omega \mathbb{E}(P) + (1-\omega)\mathbb{E}[V]\right) \\ &= (1-\alpha(\sigma))\,\mathbb{E}[V]. \end{aligned} \tag{6}$$

It is simple to show that, at $t = 2$, $\mathbb{E}(P) = \mathbb{E}(V)$ (a consequence of market efficiency) which leads to the final equality.

The manager takes into account two effects of σ. First, it increases financial efficiency and thus reduces 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, reducing real efficiency. Lemma 3 addresses the first effect.[10]

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

$$\begin{aligned}\kappa &= \frac{\beta\phi\left(V^H - R^L\right)\left[\frac{1}{2}(1-\sigma) + \frac{\rho\lambda^2}{1+\rho\lambda^2}\sigma\right]}{V^H + R^L} \\ &= \beta\frac{V^H - R^L}{V^H + R^L} E\left[\Lambda(P)\right]. \end{aligned} \tag{8}$$

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 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 is her investment K divided by expected firm value, and independent of σ. The second term κ is the additional stake that she demands to compensate for her expected trading losses. An increase in σ reduces these losses and thus α. We will refer κ as the "excess cost of capital" (or "cost of capital" for short).

[10]The stake demanded by the investor depends on her conjecture for the manager's investment decision, $\widehat{\lambda}$. In equilibrium, $\widehat{\lambda} = \lambda$, and so λ appears in Lemma 3.

Equation (8) shows that the cost of capital is increasing in the magnitude of the liquidity shock β, the value difference between H- and L-firms as a percentage of their aggregate value $\frac{V^H - R^L}{V^H + R^L}$, and – most importantly – the negative of financial efficiency $E[\Lambda(P)]$. Thus, the cost of capital falls if financial efficiency increases, which can in turn result from a fall in signal noise ρ, a fall in the probability of a liquidity shock ϕ, or an increase in disclosure σ. Separately, increases in investment λ and the productivity of investment g both augment the value difference between H- and L-firms $(V^H - R^L = \Delta + \lambda g)$ and thus the cost of capital.

Plugging (7) into (6) yields

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

where the first term is expected firm value (net of the injected funds) and the second term represents the investor's expected trading losses, which are decreasing in disclosure σ (holding λ constant).

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

Proposition 2 *(Financial and real efficiency): 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

$$\phi\frac{\rho}{1+\rho}\frac{\Delta + g}{g}\Omega \leq 1. \qquad (10)$$

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 of 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 $[0, X]$ (i.e., if the manager implements full investment), and then in $[X, 1]$ (i.e., if the manager implements partial investment).[11] Second, we solve for the optimal disclosure

[11] 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.

policy overall, which involves comparing the manager's payoffs under the best outcome in $[0, X]$ with full investment, to the best outcome in $[X, 1]$ with partial investment.

We first analyze optimal disclosure in $[0, X]$. From Proposition 1, $\lambda^*(\sigma) = 1$ for all $\sigma \in [0, X]$. Since full investment arises for all σ, the manager chooses the highest σ that supports full investment, which is X. This result is stated in Lemma 4 below:

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

$$\sigma^* = X,$$

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

We next turn to optimal disclosure in $[X, 1]$. For any $\sigma \in [X, 1]$, the equilibrium in the following subgame is $r(\sigma)$. From $\Psi(\lambda, \sigma) = 0$, the disclosure policy σ that implements a given investment level λ is:

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

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

Using (11) to substitute for σ in the objective function (9) yields firm value as a function of investment alone:

$$\Pi\left(\lambda\right) = D + E\lambda + \frac{F}{\lambda}, \tag{12}$$

where

$$D \equiv R^H - \frac{1}{2}(1 + \frac{1}{2}\beta\phi)\Delta - K, \tag{13}$$

$$E \equiv g\left[1 - \frac{1}{2}(1 + \frac{1}{2}\beta\phi) - \frac{\beta}{4\Omega}\right], \text{ and} \tag{14}$$

$$F \equiv \frac{\beta g}{4\rho\Omega}. \tag{15}$$

Since $\Pi\left(\lambda\right)$ is globally convex (due to the convexity of $\frac{F}{\lambda}$), the solution to $\Pi'\left(\lambda\right) = 0$ is a minimum. The maximum value of $\Pi\left(\lambda\right)$ is attained at a boundary: we have either

$\lambda^* = r(X) = 1$ or $\lambda^* = r(1)$. The intuition is as follows. From (9), the benefits of increasing investment are linear in λ, but the cost term is convex, because disclosure is convex in investment as shown by (11). Raising investment requires disclosure to fall, but at a decreasing rate. Intuitively, when disclosure is already low, further decreases in disclosure have a large relative effect, and so an increase in investment only requires a small decrease in disclosure. The convexity is likely common to all functional forms: since disclosure and investment are bounded below by zero, an increase in disclosure must reduce investment at a declining rate. Hence, if it is optimal for the manager to increase disclosure from X to $X + \varepsilon$, it is optimal to increase it all the way to 1. Thus, he chooses either full investment or full disclosure. This result is given in Lemma 5 below.

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

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, by comparing the manager's payoff across these two sets ($\Pi(r(1), 1)$ versus $\Pi(1, X)$). 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 financial efficiency and real efficiency): If $X < 1$, the equilibrium is given as follows:*

(i) *If $\beta > \widetilde{\beta}$, the manager chooses full disclosure ($\sigma^* = 1$) and partial investment ($\lambda^* = r(1) < 1$). Financial efficiency is maximized but real efficiency is not.*

(ii) *If $\beta < \widetilde{\beta}$, the manager chooses partial disclosure ($\sigma^* = X$) and full investment ($\lambda^* = 1$). Real efficiency is maximized but financial efficiency is not.*

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

The threshold $\tilde{\beta}$ is given by

$$\widetilde{\beta} = \frac{1 - r(1)}{\phi \frac{1}{2} \frac{\Delta + g}{g} - \frac{1}{\Omega} \left[\frac{1}{2} \left(\frac{1}{\rho} - 1 \right) + r(1) \right]} > 0. \tag{16}$$

It increases in g, decreases in ϕ, ρ, and Δ, and is U-shaped in ω.

When $X < 1$, the manager chooses between financial and real efficiency. He chooses the former if and only if the liquidity shock β is sufficiently large (above a threshold $\widetilde{\beta}$), as then cost of capital considerations dominate the trade-off. Importantly, the partial investment level $r(1)$ is independent 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 parameters have up to three effects. First, as g rises, and ϕ, ρ, and Δ fall, (4) shows that the maximum disclosure X that implements full investment is higher. 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, as it leads to less 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.

Proposition 4 *(Global comparative statics):*

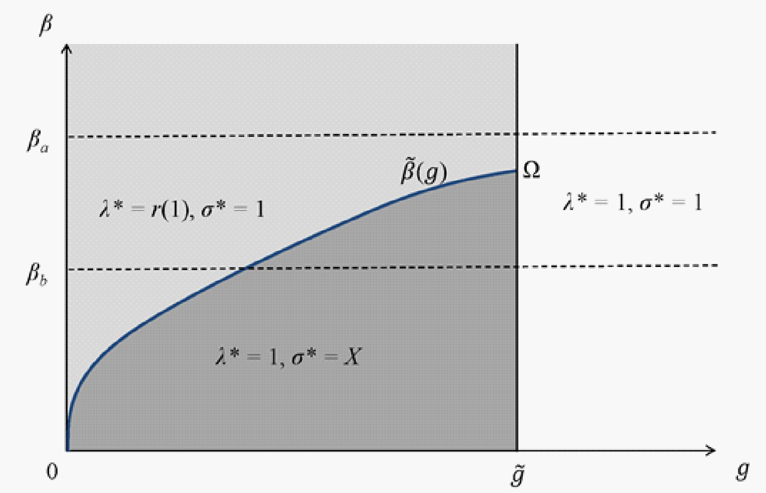
(i) *Equilibrium investment λ^* is weakly increasing in the profitability of investment g. Equilibrium disclosure σ^* is first weakly decreasing and then weakly increasing in g.*

(ii) *Equilibrium investment λ^* is weakly decreasing in the difference in firm values Δ. Equilibrium disclosure σ^* is first weakly increasing and then weakly decreasing in Δ.*

(iii) *Equilibrium investment λ^* is weakly decreasing in the probability of the liquidity shock ϕ. Equilibrium disclosure σ^* is first weakly decreasing and then weakly increasing in ϕ.*

(iv) *Equilibrium investment λ^* is weakly decreasing in the noise in the signal ρ. Equilibrium disclosure σ^* is first weakly decreasing and then weakly increasing in ρ.*

(v) *Equilibrium investment λ^* is weakly decreasing in the manager's short-term concerns ω. Equilibrium disclosure σ^* is non-monotonic in ω.*



The case $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$

Figure 1: Global comparative statics for g

More precise details on the comparative statics are given in the proof of Proposition 4. Figure 1 illustrates the comparative statics for g when $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$. In this case, there exists $\widetilde{g}$ such that, if $g \geq \widetilde{g}$, then $X \geq 1$ and so we have $(\lambda^* = 1, \sigma^* = 1)$. For $g < \widetilde{g}$ we have two cases. If $\beta > \Omega$ (e.g., at β_a in Figure 1), the firm chooses partial investment for all $g < \widetilde{g}$. If $\beta < \Omega$ (e.g., at β_b), it chooses partial investment only when g is low. Within the partial investment regime, increases in g *augment* the partial investment level, but do not affect disclosure which remains fixed at 1. When g rises above a threshold (i.e., crosses the solid curve), investment becomes sufficiently attractive that we move to full investment. At the threshold, investment rises discontinuously to 1 and disclosure drops discontinuously from 1 to X. Further increases in g augment disclosure, because the investment is sufficiently attractive that the manager invests fully even with high disclosure. The case of $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} \leq 1$ (so that $X < 1 \; \forall \; g$) is similar except that we never reach the $(\lambda^* = 1, \sigma^* = 1)$ equilibrium.

Overall, investment is weakly increasing in g. As 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. Increases in g make investment more important and induce the manager to reduce disclosure, to implement full investment. However, within the full investment equilibrium, further increases in g 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 $\tilde{\beta}$. The manager trades off the benefits of investment g with the incentive to be revealed as a H-firm, Δ.

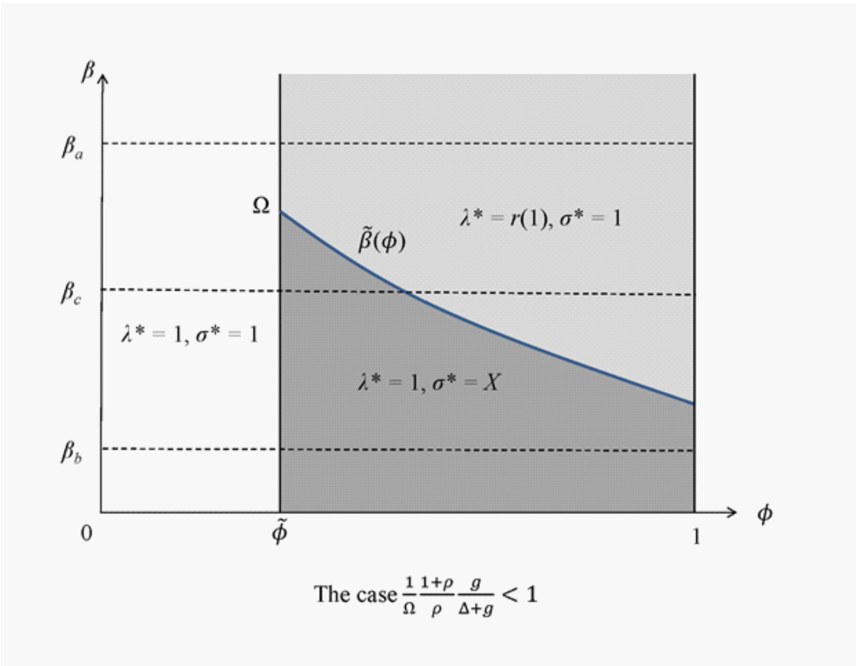


Figure 2: Global comparative statics for ϕ

The intuition behind the global comparative statics for ϕ is as follows. When $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, then (10) 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. The interesting case of $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} < 1$ is illustrated in Figure 2. For low ϕ, $X \geq 1$ and the $(\lambda^* = 1,\ \sigma^* = 1)$ equilibrium is sustainable. When ϕ crosses a threshold $\widetilde{\phi}$, $X < 1$ and $(\lambda^* = 1,\ \sigma^* = 1)$ is no longer sustainable; there is a trade-off between investment and disclosure. We have three cases. When $\beta > \Omega$ (e.g., at β_a in Figure 2), $\beta > \widetilde{\beta}\ \forall\ \phi$. Thus, for $\phi > \widetilde{\phi}$, the manager always chooses partial investment. Investment falls below 1 when ϕ crosses above $\widetilde{\phi}$; additional increases in ϕ reduce the partial investment level further. When β is low (e.g., at β_b), $\beta > \widetilde{\beta}\ \forall\ \phi$. Thus, for $\phi > \widetilde{\phi}$, the manager always chooses partial disclosure. Disclosure falls below 1 when ϕ crosses above $\widetilde{\phi}$; additional increases in ϕ reduce the partial disclosure level further. When β is intermediate (e.g., at β_c), then when $\phi > \widetilde{\phi}$ but remains low, $\beta < \widetilde{\beta}$ and the manager chooses partial disclosure, but for when ϕ crosses the solid curve, $\beta > \widetilde{\beta}$ and the manager switches to 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.

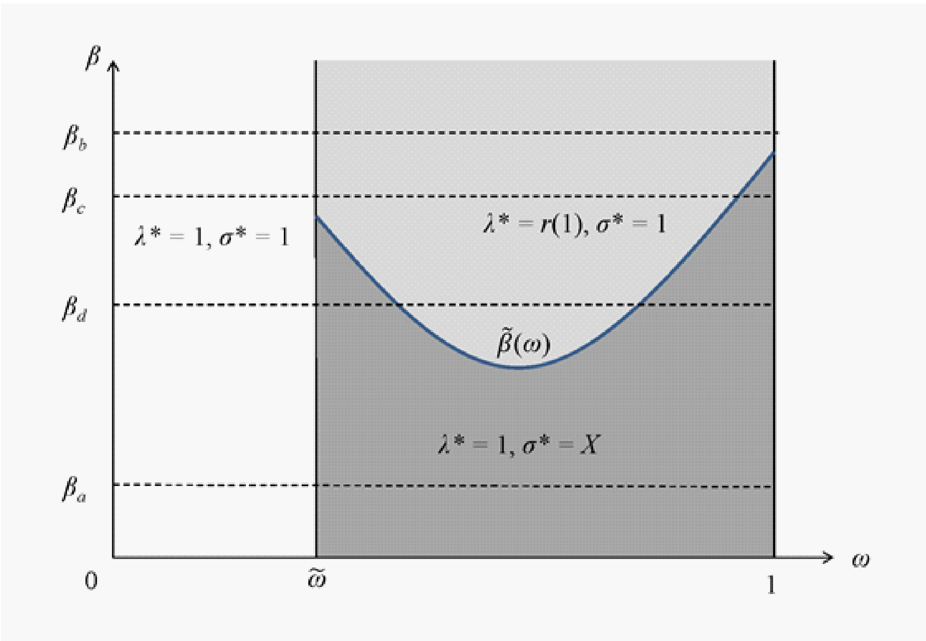


Figure 3: Global comparative statics for ω

The global comparative statics for ω are illustrated in Figure 3 and the intuition is as follows. When ω is low, myopia is sufficiently weak that the manager invests efficiently even with full disclosure. When ω rises above a threshold $\widetilde{\omega}$, $(\lambda^* = 1,\ \sigma^* = 1)$ is no longer sustainable and there is a trade-off. When β is very low (e.g., at β_a in Figure 3), the manager always chooses partial disclosure, and additional increases in ω reduce the partial disclosure level further. When β is very high (e.g., at β_b), the manager always chooses partial investment, and additional increases in ω reduce the partial investment level further. Recall that $\widetilde{\beta}$ is first decreasing and then increasing in ω. When β is moderately high (e.g., at β_c), and if also $\tilde{\beta}(X=1) > \beta > \tilde{\beta}(X=0)$, then when ω becomes sufficiently high (i.e. crosses the solid curve), $\widetilde{\beta}$ crosses back above β and so the manager switches to partial disclosure. When β is moderately low (e.g., at β_d), 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.

Overall, Proposition 4 yields 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 that investment also 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 signal noise ρ and uncertainty 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 are non-monotonic. One might expect that, since disclosure policy is a trade-off between financial and real efficiency, better growth opportunities mean that investment dominates the trade-off, and so disclosure is lower. Instead, firms with intermediate growth opportunities disclose the least, because growth opportunities are sufficiently strong that the manager prefers full investment to full disclosure, but also sufficiently weak that he will only invest fully if disclosure is low. Firms with weak growth opportunities have high disclosure, because financial efficiency dominates the trade-off. Firms with strong growth opportunities have high disclosure for a different reason – the growth opportunity is sufficiently attractive that the firm will pursue it even with high disclosure.

For similar reasons, firms with moderate uncertainty Δ, moderate size β and frequency ϕ of liquidity shocks, and moderate signal noise ρ will have low disclosure, but firms with either high or low levels of these variables will feature high disclosure. For example, it may seem that, when uncertainty Δ rises, the manager will always disclose more in response. 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 more important, encouraging full disclosure. Thus, changes in these parameters not only affect the cost of capital directly (see equation (3)) but also indirectly through changing disclosure, and thus their overall effect is non-obvious. As Beyer, Cohen, Lys, and Walther'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 endogenous response of disclosure also means that these parameters have unclear effects on the cost of capital. In contrast, Diamond and Verrecchia (1991) predict that the cost of capital is monotonically decreasing in information asymmetry and the magnitude of liquidity shocks.

The non-monotonic effects of firm characteristics on disclosure policy (and thus financial efficiency) contrast with prior theories. Baiman and Verrecchia (1996) predict that a larger liquidity shock monotonically reduces disclosure. Gao and Liang (2013) predict that firms with higher growth opportunities disclose less, to encourage investors to acquire private information about the growth option and incorporate it into prices by trading, thus informing the manager. More generally, the model points to variables (e.g., g, β, ϕ, Δ, ρ) that empiricists should control for when studying the effect of a different variable (outside our model) on disclosure. In addition, it emphasizes that disclosure, investment, and the cost of capital are all simultaneously determined by underlying parameters, rather than affecting each other. As Beyer, Cohen, Lys, and Walther (2010) note: " 'equilibrium' concepts for the market for information defy a simplified view of cause and effect".

3 Voluntary Disclosure

The analysis of Section 2 shows that, if the manager is able to commit to a disclosure policy, he may commit to partial disclosure even though this reduces real efficiency. This section considers the case of voluntary disclosure, where the manager cannot commit to a disclosure policy and thus a level of financial efficiency. We focus on the interesting case where $X < 1$ (so that there is a trade-off between financial and real efficiency) and now assume that the manager always possesses the signal y and chooses whether to disclose it. In reality, companies already have to produce copious amounts of information for tax or internal purposes, so the manager cannot commit to not having information. Thus, while the manager may announce a disclosure policy at $t = 0$, he may renege on it at $t = 2$.[12]

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 disclosure reveals that $y = B$. The manager cannot claim that he is not disclosing to follow his pre-announced low-disclosure policy, because the market knows that he would have reneged on the policy 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 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. Thus, 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 5 below.

Proposition 5 *(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 $\sigma^* = 1$: full financial efficiency and real inefficiency.*

Proposition 5 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).[13] Similarly, it could limit what type of information can be reported in official (e.g., SEC) filings, which investors may view as more truthful than information disseminated through, for example, company press releases. Alternatively, the government could audit disclosures with sufficient intensity

[12] For example, he could implement a disclosure policy σ 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, even if the device lands on "non-disclose", he may renege and 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.

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

that the manager chooses not to disclose: even if disclosure is always truthful, so there is no risk of a fine, 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.[14] He will thus choose $\lambda^* = \lambda(\zeta)$. 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. The government implements less disclosure than the manager would choose himself, since he is unable to commit to low disclosure. 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. If caps on disclosure are difficult to implement, a milder implication of our model is that regulations to increase financial efficiency by augmenting disclosure (such as Sarbanes-Oxley) may have real costs.

However, government regulation may not maximize firm value. First, the policy that maximizes firm value varies from firm to firm. Even if all managers wish 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 $X > \zeta$, since $\sigma = X$ is sufficient to implement full investment. 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 maximize real efficiency if $\Pi(1, X) < \Pi(r(1), 1)$ for their firm. Thus, a regulation aimed at inducing full investment will reduce firm value.

Second, the government's goal may not be to maximize firm value, but total surplus. In this case, it ignores the benefits of disclosure, since the investor's trading losses are a pure transfer to the speculator and do not affect 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 maximize financial efficiency, to minimize trading profits and losses. One example is the SEC's focus on "leveling the playing field" between investors. Under this objective function,

[14] 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.

it will minimize the investor's trading losses[15] 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 6 below.

Proposition 6 *(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* $\lambda^* = r(1)$*.*

4 Conclusion

Conventional wisdom is that financial efficiency increases real efficiency through two channels. First, greater financial efficiency increases the information in the stock price that the manager can learn from. Second, it increases the extent to which stock prices reflect the firm's fundamental value and thus the manager's incentives to take actions to improve fundamental value. We consider a standard myopia model that captures the second channel, and show that, surprisingly, financial efficiency can reduce real efficiency.

Central to our model is the notion that perfect financial efficiency cannot be achieved, because some information (such as on the firm's long-run value) is soft and thus cannot be disclosed, in contrast to hard information such as current earnings. It may seem that this observation is moot: firms should simply try to achieve the highest feasible level of financial efficiency. We reach a different conclusion. While actions to increase the amount of hard information in prices, such as disclosure, increase the total amount of information in prices (and thus financial efficiency), they also distort the relative amount of hard versus soft information. These actions thus encourage the manager to take actions to improve the hard signal at the expense of the soft signal, such as cutting investment. Thus, real efficiency is non-monotonic in financial efficiency – the manager invests efficiently in a hypothetical world in which fundamental value can be fully disclosed (in which case financial efficiency is maximized) or if neither earnings nor fundamental value are disclosed (in which case financial efficiency is minimized).

[15] 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.

The optimal disclosure policy, and thus level of financial efficiency, is a trade-off between its benefits (reduced cost of capital) and costs (reduced investment). Thus, if the manager can commit to a disclosure policy, it may seem that disclosure should be lowest where investment opportunities are greatest, but we show that disclosure is non-monotonic in growth opportunities. 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. Moreover, while our paper specifically models disclosure as the channel through which firms or policymakers can affect financial efficiency, the model also applies to other channels that increase the amount of short-term information in prices. Examples include reducing short-sales constraints, transactions taxes, and limits on high-frequency trading, if the trades thus encouraged are likely to be based on information about earnings.

In addition to the contributions to the literature on financial and real efficiency, the model has implications for the disclosure literature. This literature studies the disclosure of hard information, because only it can be credibly disclosed. It may seem that the existence of soft information does not change its conclusions: the disclosure of soft information is moot and so firms should simply apply the insights of disclosure theories to hard information. This paper reaches a different conclusion – the existence of soft information reduces the optimal disclosure of hard information. Similarly, the model shows that, even though the actual act of disclosure is costless, a high-disclosure policy may be costly. This result contrasts standard disclosure models where direct costs are required to deter full 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. 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.[16] In addition, we have assumed that the manager's disclosure is always truthful. If earnings management is

[16] 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.

possible, a good manager can avoid reporting a bad signal, increasing real efficiency but reducing financial efficiency. Incorporating earnings management may deliver insights as to when discretion is beneficial and when it is harmful. On the empirical side, our study delivers new predictions on the real effects of disclosure on investment, on how investment depends on asset pricing variables such as liquidity shocks, and on how the cost of capital and disclosure depend on corporate finance variables such as growth opportunities.

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A Appendix

Proof of Proposition 1

The manager chooses λ to maximize his expected payoff:

$$\max_{\lambda} U_m\left(\lambda, \widehat{\lambda}\right) = (1-\alpha)\left(\omega \mathbb{E}\left(P|\theta = H\right) + (1-\omega)V^H\right). \tag{17}$$

where the expected price of an H-firm is

$$\mathbb{E}\left(P|\theta = H\right) = \sigma\left(1-\rho\lambda^2\right) P\left(G|\theta = H\right) + \sigma\rho\lambda^2 \tilde{P}\left(B|\theta = H\right) + (1-\sigma)\tilde{P}\left(\varnothing|\theta = H\right) \tag{18}$$

and $\widetilde{P}\left(y|\theta = H\right)$ denotes 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 have:

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

where we suppress the tilde on $P\left(G|\theta = H\right)$ as the price is independent of the order flow.

Substituting into (18) yields:

$$\mathbb{E}\left(P|\theta = H\right) = \widehat{V^H} - \frac{\phi}{2}\left(\frac{1}{2}(1-\sigma) + \sigma\frac{\rho\lambda^2}{1+\rho\hat{\lambda}^2}\right)\left(\widehat{V^H} - V^L\right).$$

The manager's first-order condition is given by

$$\frac{\partial U_m\left(\lambda, \widehat{\lambda}\right)}{\partial \lambda} = (1-\alpha)\left(-\omega\phi\sigma\frac{\rho\lambda}{1+\rho\hat{\lambda}^2}\left(\widehat{V^H} - V^L\right) + (1-\omega)g\right) = 0. \tag{19}$$

Since $\frac{\partial^2 U_m\left(\lambda, \widehat{\lambda}\right)}{\partial \lambda^2} < 0$, the manager's objective function is strictly concave and so equation (19) is sufficient for a maximum. Plugging $\lambda = \widehat{\lambda}$ into (19) yields the quadratic $\Psi\left(\lambda, \sigma\right) = 0$, where $\Psi\left(\lambda, \sigma\right)$ is defined in (5).

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.,

$$z(\sigma) \equiv \phi^2 \frac{\Delta^2}{g^2}\sigma^2 - 4\left(\frac{1}{\Omega} - \sigma\phi\right)\frac{1}{\Omega\rho} \geq 0. \tag{20}$$

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., (20) 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.,:

$$\sigma \leq \frac{2g}{\Omega\phi(2g+\Delta)}. \tag{21}$$

However, further algebra shows that

$$X > Z > \frac{2g}{\Omega\phi(2g+\Delta)}. \tag{22}$$

Thus, if roots exist ($\sigma \geq Z$), (21) 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 (22). 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

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

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 convexity, 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:

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

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 (4) easily shows that X is increasing in g, and decreasing in ω, ϕ, ρ, and Δ.

Proof of Lemma 4

Since $\lambda^*(\sigma) = 1$ for all $\sigma \in [0, X]$, the manager's payoff becomes

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

which is strictly increasing in σ as a higher σ reduces trading losses. Thus, the manager chooses the maximum σ in $[0, X]$, which is X.

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:

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

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 (5)). 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 first provide more precise details on the global comparative statics of Proposition 4.

(i) Comparative statics for g:

- ***(i-a)*** If $\beta > \lim_{g\to\infty}\tilde{\beta}$, $\sigma^* = 1$ and $\lambda^* = r(1)$, which increases as g increases.
- ***(i-b)*** If $0 < \beta < \Omega$ and $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$, $\sigma^* = 1$ and $\lambda^* = r(1)$ for low levels of g. Once g rises above a threshold, σ^* falls discontinuously to X, and λ^* jumps discontinuously to 1. As g increases further, σ^* keeps increasing to 1 (for g such that $X \geq 1$), while $\lambda^* = 1$.
- ***(i-c)*** If $0 < \beta < \lim_{g\to\infty}\tilde{\beta}$ and $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} \leq 1$, $\sigma^* = 1$ and $\lambda^* = r(1)$ for low levels of g. Once g rises above a threshold, σ^* falls discontinuously to X, and λ^* jumps discontinuously to 1. As g increases further, σ^* keeps increasing but remains below 1, while $\lambda^* = 1$.

(ii) Comparative statics for Δ:

(ii-a) If $\beta > \lim_{\Delta \to 0} \tilde{\beta}$, $\sigma^* = 1$ and $\lambda^* = r(1)$, which increases as Δ decreases.

(ii-b) If $0 < \beta < \Omega$ and $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} \leq 1$, $\sigma^* = 1$ and $\lambda^* = r(1)$ for high levels of Δ. Once Δ drops below a threshold, σ^* falls discontinuously to X, and λ^* jumps discontinuously to 1. As Δ decreases further, σ^* keeps increasing but remains below 1, while $\lambda^* = 1$.

(ii-c) If $0 < \beta < \lim_{\Delta \to 0} \tilde{\beta}$ and $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$, $\sigma^* = 1$ and $\lambda^* = r(1)$ for high levels of Δ. Once Δ drops below a threshold, σ^* falls discontinuously to X, and λ^* jumps discontinuously to 1. As Δ decreases further, σ^* keeps increasing to 1 (for Δ such that $X \geq 1$), while $\lambda^* = 1$.

(iii) Comparative statics for ϕ:

(iii-a) 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.

(iii-b) 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.

(iii-c) 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^*.

(iii-d) If $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, $X \geq 1$ for all ϕ. Then the equilibrium is always $(\lambda^* = 1,\ \sigma^* = 1)$.

(iv) Comparative statics for ρ:

(iv-a) 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.

(iv-b) 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.

(iv-c) 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^*.

(iv-d) If $\frac{1}{\Omega}\frac{2}{\phi}\frac{g}{\Delta+g} \geq 1$, $X \geq 1$ for all ρ. Then the equilibrium is always $(\lambda^* = 1, \ \sigma^* = 1)$.

(v) Comparative statics for ω. Let $\underline{\beta}$ denote the minimum $\tilde{\beta}$ over all ω such that $X \leq 1$:

(v-a) 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^*.

(v-b) 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.

(v-c) 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^*.

(v-d) 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^*.

We now prove the proposition. 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, $\widetilde{\beta}$ is strictly increasing in g for $X < 1$. For part (i-a), if $\beta > \lim_{g\to\infty} \tilde{\beta}$, $\beta > \tilde{\beta}$ for all g. Then by Proposition 3, $\sigma^* = 1$ for all g, and $\lambda^* = r(1)$, which is strictly increasing in g.

For part (i-b), since $\tilde{\beta} = 0$ when $g = 0$, 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.

Part (i-c) is similar to part (i-b), except that $\frac{1}{\Omega}\frac{1}{\phi}\frac{1+\rho}{\rho} > 1$. In this case, there exists a threshold g' such that, when $g \geq g'$, (10) 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.

We now turn to part (iii). In part (iii-a), $\frac{1}{\Omega}\frac{1+\rho}{\rho}\frac{g}{\Delta+g} \geq 1$, (10) 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. In part (iii-b), $\beta \geq \Omega$, then $\beta \geq \tilde{\beta}$ always and so we have partial investment. In part (iii-c), $\beta \leq \tilde{\beta}(\phi = 1)$, then $\beta \leq \tilde{\beta}$ always and so we always have partial disclosure. Finally, in part (iii-d) $\beta \in \left(\Omega, \tilde{\beta}(\phi = 1)\right)$, 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 partial disclosure. After ϕ reaches a threshold, then $\tilde{\beta}$ falls below β and so we move to partial investment.

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

Finally, we prove part (v). 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 (v-a), when $\beta < \underline{\beta}$, then $\beta < \tilde{\beta}$. Thus, when $X < 1$, we always have the partial disclosure equilibrium of $(\lambda^* = 1, \sigma^* = X)$. For part (v-b), when $\beta > \max\left\{\tilde{\beta}(X = 1), \tilde{\beta}(X = 0)\right\}$, $\beta > \tilde{\beta}$. Thus, when $X < 1$, we always have the partial investment equilibrium of $(\lambda^* = r(1), \sigma^* = 1)$. For part (v-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 (v-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 partial disclosure. 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 partial investment.