The Real Costs of Disclosure*

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Abstract

This paper analyzes the effect of a firm's information disclosure policy on its real investment decisions. We show that, even if the actual act of disclosure is costless, a high-disclosure policy can still be costly. Even if some information ("soft") cannot be disclosed, it seems desirable for the firm to disclose "hard" information, to increase the overall amount of information that investors have and reduce the cost of capital. However, by changing the *relative* amounts of hard and soft information disclosed, such a policy distorts the manager's real decisions towards improving hard information at the expense of soft information – such as cutting investment. Thus, firm value is endogenous to disclosure policy. Moreover, even if a low disclosure policy is optimal to induce investment, the firm may be unable to commit to it. If the signal turns out to be high, the manager has incentives to disclose it regardless of the preannounced policy. Government intervention to cap disclosure policy can be value-creating, in contrast to common arguments for regulation to increases disclosure.

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

However, the costs of disclosure have been more difficult to pin down. Standard models (e.g. Verrecchia (1983)) typically assume an exogenous cost of disclosure, justified by several motivations. First, the actual act of communicating information may be costly. While such costs were likely significant at the time those papers were written, when information had to be mailed to shareholders, nowadays these costs are likely much smaller due to electronic communication. Second, there may be costs of producing information. However, firms already produce copious amounts of information for internal or tax purposes.[1] Third, the information may be proprietary (i.e., business-sensitive) and disclosing it will benefit competitors (e.g. Verrecchia (1983) and Dye (1986)). However, while likely important for some types of disclosure (e.g. the stage at which a patent application is at), proprietary considerations are unlikely to be for others (e.g. earnings). Fourth, Hirshleifer (1971) shows that disclosure in insurance markets may worsen risk-sharing, for example if it is made public which individuals will suffer heart attacks before they have a chance to take out medical insurance.[2] However, Diamond (1985) argues that this cost is unlikely to be significant for financial markets, where continuous trading is possible. Perhaps motivated by the view that, nowadays, the costs of disclosure are small relative to the benefits, recent government policies have increased firms' disclosure requirements, such as Sarbanes-Oxley, Regulation FD, and Dodd-Frank.

This article reaches a different conclusion. We show that, even if the actual act of disclosure is costless, a high-disclosure policy can still be costly due to its effect on the firm's real investment decisions. Central to our analysis is the idea that only some

[1] Moreover, Diamond (1985) shows that, even if the firm faces the same costs of producing information as outside shareholders, it is still beneficial for the firm to disclose as the cost needs to be borne only once.

[2] Kanodia and Lee (1998) apply this idea to financial markets and show that disclosure of firm fundamentals before current investors can trade will impose risk on them; if they are more risk-averse than future investors, this in turn distorts investment decisions.

types of information ("hard", i.e. quantitative and verifiable) can be credibly disclosed, but others ("soft", i.e. non-verifiable) cannot be.[3] For example, a firm can credibly communicate its level of earnings, but not the quality of its corporate culture. It may seem that this distinction does not matter: even if a firm cannot increase the amount of soft information disclosed, it can still disclose more hard information. The *absolute* amount of overall information will rise, reducing the cost of capital.[4] However, we show that the manager's real investment decisions depend on the *relative* weighting between hard and soft information. If neither type of information is disclosed, the manager chooses the investment policy that maximizes firm value. In contrast, an increase in the absolute amount of hard information disclosed also augments the amount of hard information disclosed relative to soft information. This in turn distorts the manager's decision towards taking actions that increase the value of the hard information disclosed, even if it worsens the soft signal – for example, cutting investment in corporate culture to increase current earnings.

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

The founder can reduce the investor's information asymmetry, and thus the cost of capital, by disclosing a hard signal (such as short-term earnings) that is partially informative about the firm's type, just before the trading stage. We initially assume that the founder can commit to a disclosure policy when raising funds, as in the literature on mandatory disclosure. High disclosure indeed reduces the cost of capital, but has an important cost. The manager of a high-quality firm has the option to undertake an intangible investment that improves the firm's long-run value, but this value cannot be disclosed as it is soft information. The investment also raises the probability of delivering low earnings, which lowers the short-term stock price since low-quality

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

[4]This idea echoes the informativeness principle developed in Holmstrom (1979), who shows that any informative signal improves the evaluation of an agent's performance. Here, any informative signal improves the efficiency of the price as an "evaluator" of the firm's type.

firms always generate low earnings. Thus, if the manager is concerned with the stock price, he will underinvest. While existing literature typically assumes that firm value is exogenous and studies the optimal level of information to disclose about this fixed value, here firm value is endogenous to the disclosure policy (even in the absence of a competitor who can use the disclosed information).

The optimal level of disclosure is thus a trade-off between the benefits of disclosure (reduced cost of capital) and its costs (inefficient investment). Thus, the model delivers predictions on how disclosure policies should vary cross-sectionally across firms. Disclosure should be lower in firms in which growth opportunities are more important. For example, at the time of its IPO, Google announced that it would not provide earnings guidance as such disclosure would induce short-termism. Their founders' letter stated "[w]e recognize that our duty is to advance our shareholders' interests, and we believe that artificially creating short term target numbers serves our shareholders poorly." Similarly, Porsche was expelled from the M-DAX, Deutsche Börse's mid-cap stock market index, in August 2001 after refusing to comply with its requirement for quarterly reporting, arguing that such disclosures would lead to myopia. In contrast, disclosure will be higher in firms in which shareholders are more likely to be at an information disadvantage compared to other market participants (e.g. atomistic or retail investors), and more likely to trade for non-informational reasons.

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

We next consider the case in which the founder cannot commit to a disclosure policy (as in the literature on voluntary disclosure), because it is the manager who controls whether to release information. If investment is important, the founder would like to announce a "low disclosure, high investment" policy. However, if the manager invests and gets lucky, i.e. still delivers high earnings, he will renege on the policy and disclose the high earnings anyway. Knowing that he will always disclose high earnings if they are realized, the manager will reduce investment, to maximize the probability that he realizes (and thus can announce) high earnings. Then, if the market does not receive any disclosure, it rationally infers that the signal must be low, else the manager would have released it – the "unraveling" result of Grossman (1981) and Milgrom (1981). Put differently, the only dynamically consistent disclosure policy is always to disclose the hard signal, and investment suffers as a result. In this case, government intervention can be desirable. By capping the feasible level of disclosure, the government can allow the firm to implement the optimal policy. This conclusion contrasts earlier research which argues that the government should increase disclosure due to externalities (Foster (1979), Coffee (1984), Dye (1990), Admati and Pfleiderer (2000), and Lambert, Leuz, and Verrecchia (2007)).

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

This paper is related to a large literature on the costs and benefits of disclosure, which is reviewed by Verrecchia (2001), Dye (2001), Beyer, Cohen, Lys, and Walther (2010), and Goldstein and Sapra (2012). Our main innovation is to identify and analyze a real cost of disclosure. Most closely related is Gigler, Kanodia, Sapra, and Venugopalan (2012), who show that an interim signal can induce the manager to choose a short-term project over a long-term alternative, in a setting where both projects are ex ante unprofitable (in contrast to our model). They compare a social planner's payoff across two discrete regimes (with and without the interim signal), assuming that commitment is possible. We study the firm's optimal choice of disclosure policy, thus delivering predictions on how disclosure should vary across companies. Here, disclosure also affects information asymmetry and the cost of capital, thus generating implications on how these variables interplay with disclosure policy, investment, and managerial incentives (all of which are continuous variables). We also consider the voluntary disclosure case where the firm cannot commit to a disclosure policy. In Hermalin and Weisbach (2012), disclosure affects the manager's incentives to engage in manipulation. They show that the founder prefers more disclosure and the manager prefers less disclosure. Here, the founder may prefer less disclosure because it induces myopia, and the manager prefers more disclosure – where disclosure is voluntary, the manager always discloses.

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

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

This paper also contributes to a literature on the real effects of financial markets. The survey of Bond, Edmans, and Goldstein (2012) identifies two channels through which financial markets (and thus disclosure) can affect the real economy. Our mechanism operates through the contracting channel: the manager's contract is contingent upon the stock price, and so his incentives to take real decisions depend on the extent to which they will be incorporated in the stock price. The second channel is that the manager learns from information in the stock price to guide his real decisions. This mechanism allows for a quite different real cost of disclosure. Disclosing information may reduce the value of speculator's private information, reducing their incentives to engage in costly information acquisition (Gao and Liang (2013)) or to trade aggressively on this information (Bond and Goldstein (2012)). This in turn reduces price discovery, and thus the manager's ability to learn from prices to guide his real actions.[5]

This literature typically concludes that financial efficiency is desirable for real efficiency (e.g. Kanodia (1980), Fishman and Hagerty (1989)).[6] In contrast, we show that real efficiency is non-monotonic in financial efficiency. If neither (hard) earnings nor (soft) fundamental value are disclosed, financial efficiency is minimized. However, since the manager's investment decision does not affect the stock price, he invests optimally and real efficiency is maximized. If both soft and hard information is disclosed, financial efficiency is maximized; moreover, since price always equals fundamental value, the manager faces no trade-off between them when choosing investment, and real efficiency is again maximized. When soft information cannot be disclosed, then even though disclosure of hard information augments financial efficiency, it also reduces real efficiency by inducing underinvestment. It may be better for prices to contain no information than partial information. This result echoes the theory of the second best in taxation policy, which argues that it may be optimal to distort the prices of all goods via a blanket tax, rather than only a subset of goods. Here, it may be optimal to "distort" information transfer by disclosing neither hard nor soft information, rather than allowing the non-disclosure of only soft information. Holmstrom and Milgrom (1991) illustrate this idea in a multi-tasking setting where difficulties in measuring one task may lead to the principal optimally offering weak incentives for all tasks. Our result also echoes Paul (1992), who shows that an efficient financial market weights information according to its informativeness about asset value, but to incentivize efficient real decisions, information should be weighted according to its informativeness about the manager's actions. While a higher hard signal is a positive indicator of firm type, it is a negative indicator of efficient investment.

This paper is organized as follows. Section 1 lays out the model. Section 2 analyzes the case in which the firm can commit to disclosure and solves for the optimal disclosure

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

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

policy. Section 3 considers the case of voluntary disclosure and introduces a role for government regulation, and Section 4 concludes. Appendix A contains all proofs not in the main text.

1 The Model

The model consists of five players. The *founder* initially owns the entire firm. He then raises equity financing from an *investor*, who may subsequently suffer a liquidity shock that forces her to trade. The *speculator* has private information on firm quality and trades on this information. The *market maker* clears the market and sets prices. The *manager* takes the firm's investment decision. All players are risk-neutral and there is no discounting.

There are five periods. At time $t = 0$, the founder must raise financing of K for the firm to continue to operate; the funds raised are injected into the firm. He first commits to a disclosure policy $\sigma \in [0, 1]$ and then sells a stake α to the investor, which is publicly observed. The fraction α is chosen so that the investor breaks even, taking into account the effect of σ on her subsequent trading losses and the manager's investment decision.

At $t = 1$, the firm's type $\theta \in \Theta \equiv \{L, H\}$ is realized. γ is the prior probability of $\theta = H$. The type is privately known to the manager and to the speculator, but unknown to the investor and non-verifiable. We will sometimes refer to a firm of type θ as a "θ-firm" and its manager as a "θ-manager". As in the myopia model of Edmans (2009), type $\theta = L$ corresponds to a low-quality firm, in which the manager has no investment decision and the firm will be worth $V^L = R^L$ at $t = 4$. (All values are inclusive of the K raised by the financing.[7]) Type $\theta = H$ corresponds to a high-quality firm, in which the manager chooses an unobservable investment level $\lambda \in [0, 1]$. The firm is worth $V^H = R^H + \lambda g$ at $t = 4$, where $g > 0$ parameterizes the desirability of the investment opportunity.[8] Since $g > 0$, $\lambda = 1$ is first-best optimal. The variable $R^H \geq R^L$ represents the value of a high-quality firm that does not invest.

At $t = 2$, a hard (verifiable) signal $y \equiv \{G, B, \varnothing\}$ is generated and may be publicly

[7] The model is unchanged if instead the K raised is retained by the founder rather than injected into the firm (e.g. if the motivation for the financing was a liquidity need by the founder rather than the firm). In this case, the values are exclusive of K.

[8] 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.

disclosed. An example of such a signal is earnings, and so we will sometimes refer to the signal as "earnings". With probability $1-\sigma$, the signal is the null signal $\varnothing$, which corresponds to no disclosure. With probability σ, an informative signal is generated. An L-firm always generates signal B. An H-firm generates signal B with probability $\rho\lambda^2$, and G with probability $1-\rho\lambda^2$. The variable ρ parameterizes the extent to which higher investment increases the probability of $y=B$. We will sometimes refer to a H-manager who generates signal B as "unlucky".

At $t=3$, the investor suffers a liquidity shock with probability ϕ. If she suffers a shock, with probability $\frac{1}{2}$ she is forced to buy β shares, and with complementary probability $\frac{1}{2}$ she is forced to sell β shares. With probability $1-\phi$, she suffers no shock; she will not trade voluntarily as she is uninformed. Her trade is therefore given by $I=\{-\beta,0,\beta\}$. If $y=G$, the speculator has no private information and will not trade, but if $y\in\{B,\varnothing\}$, the public signal is not fully informative and the speculator will try to take advantage of her private information on θ by trading an amount S. Similar to Dow and Gorton (1997), the market maker observes each individual trade, but not the identity of each trader. For example, if the vector of trades Q equals $(-\beta,\beta)$, he does not know which trader (speculator or investor) bought β, and which trader sold β. 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. The variable V is soft information prior to the realization of payoffs at $t=4$ and thus cannot be credibly communicated.[9] We will briefly consider a variant of the model in which V is hard information.

The manager's objective function is given by $\omega P+(1-\omega)V$. The parameter ω represents the weight that he puts on the $t=3$ stock price P compared to the $t=4$ fundamental value V. The concern for the short-term stock price is standard in the myopia literature and can arise from a number of sources introduced by prior research, such as takeover threat (Stein (1988)), termination threat (Edmans (2011)), concern for managerial reputation (Narayanan (1985), Scharfstein and Stein (1990)), or the manager expecting to sell his own shares at $t=3$ (Stein (1989)).

Before solving the model, we discuss its assumptions. The investment decision improves the firm's fundamental value but potentially lowers short-term earnings, as in the classic managerial myopia models of Stein (1988, 1989). This specification

[9]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.

captures the fact that intangible investment can be costly in the short-term before its benefits materialize. Costs incurred in improving workforce quality through employee training is expensed; outside investors cannot distinguish whether high expenses are due to desirable investment (a H-firm choosing a high λ) or low firm quality (an L-firm). Similarly, R&D and advertising are nearly always expensed. Even though these items can be separated out in an income statement, outside investors do not know whether high R&D or advertising is efficient, or stems from a low-quality manager unable to curb the waste of corporate resources. Also as in managerial myopia models, short-term earnings are verifiable but the long-run fundamental value is not (prior to the final period). This specification captures the fact that intangible investment does not pay off until the long-run, and it is very difficult for the firm to credibly certify the quality of its intangible assets (e.g. its corporate culture).

Outside investors have no information on the firm's type, and the speculator has perfect information. This seemingly stark dichotomy is purely for simplicity; we only require the speculator to have some information advantage over outside investors. Many shareholders (e.g. retail investors) are atomistic and lack the incentive to gather information about the firm, or unsophisticated and lack the expertise to do so. In contrast, speculators such as hedge funds often closely monitor firms that they do not currently have a stake in to generate trading ideas.

The liquidity-enforced selling (which occurs with probability $\frac{\phi}{2}$) occurs because the investor may suffer a sudden demand for funds, e.g. to pursue another investment opportunity. The liquidity-enforced buying occurs because the investor may have a sudden inflow of cash, e.g. due to a bonus at work (for a retail investor) or an inflow of funds (for an institutional investor). The investor will invest a disproportionate fraction of these new funds into the firm in question if she is less aware about the existence of stocks she does not currently own (e.g. Merton (1987)).[10] The results will continue to hold if the investor only faces the probability of liquidity-enforced selling. All we require is that the investor may have to trade against a more informed speculator, as in Diamond and Verrecchia (1991). We now formally define a Perfect Bayesian Equilibrium as the solution concept of the model.

Definition 1 *The founder's disclosure policy* $\sigma \in [0,1]$, *the* H*-manager's investment strategy* $\lambda : [0,1] \rightarrow [0,1]$, *the speculator's trading strategy* $S : \Theta \times [0,1] \times \{G, B, \varnothing\} \rightarrow \mathbb{R}$, *the market maker's pricing strategy* $P : [0,1] \times \{G, B, \varnothing\} \times \mathbb{R}^2 \rightarrow \mathbb{R}$, *the belief*

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

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 $\theta \in \Theta$, $\sigma \in [0,1]$, 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 founder'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.*

2 Analysis

2.1 First-Best Benchmark

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

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

This result is given in Lemma 1 below.

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

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

2.2 Trading Stage

The trading stage at $t = 3$ is a game 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 and speculator. Thus, they take their actions using their equilibrium belief $\hat{\lambda}$.

There are three cases to consider. If $y = G$, all players know that $\theta = H$, so the unique subgame-perfect equilibrium is the market maker sets $P = \widehat{V^H} = R^H + \hat{\lambda} g$. Since the speculator also values the firm at $\widehat{V^H}$ (he knows that the firm is of type H, but does not know the level of investment), he will receive no profit from trading, and thus will not trade. If the investor suffers a liquidity shock, she trades at a price of $P = \widehat{V^H}$, which equals expected firm value and so breaks even.

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

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 flow Q, the prices* *set by the market maker are given by the following table:*

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

(1)

Since y is an informative signal about firm type, financial efficiency is greater with $y = B$ than $y = \varnothing$. This can be seen by the difference in prices with an order vector of $(-\beta, \beta)$. Without a signal, the price is the unconditional expected value based on the prior probability of type H (γ), whereas with $y = B$, the probability is updated to the posterior $\frac{\gamma\rho\hat{\lambda}^2}{\gamma\rho\hat{\lambda}^2+(1-\gamma)}$.

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

$$
\begin{aligned}
P(G) &= \widehat{V^H} \\
\tilde{P}(B) &= \left[\frac{\phi}{2}P((\beta,\beta),B) + (1-\phi)P((\beta,0),B) + \frac{\phi}{2}P((\beta,-\beta),B)\right] \\
\tilde{P}(\varnothing) &= \left[\frac{\phi}{2}P((\beta,\beta),\varnothing) + (1-\phi)P((\beta,0),\varnothing) + \frac{\phi}{2}P((\beta,-\beta),\varnothing)\right],
\end{aligned}
$$

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

$$\tilde{P}(B) < \tilde{P}(\varnothing) < P(G).$$

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 and has been committed to. The manager chooses λ

to maximize his expected payoff:

$$\max_{\lambda} U_m\left(\lambda,\widehat{\lambda}\right) = \omega\mathbb{E}(P|\theta=H)+(1-\omega)V^H$$
$$= \omega\left\{\sigma(1-\rho\lambda^2)P(G)+\sigma\rho\lambda^2\tilde{P}(B)+(1-\sigma)\tilde{P}(\varnothing)\right\}+(1-\omega)(R^H+\lambda g).$$

His first-order condition is given by

$$\frac{\partial U_m\left(\lambda,\widehat{\lambda}\right)}{\partial\lambda} = \omega\sigma(-2\rho\lambda)P(G)+\omega\sigma(2\rho\lambda)\tilde{P}(B)+(1-\omega)g=0. \tag{2}$$

Since

$$\frac{\partial^2 U_m\left(\lambda,\widehat{\lambda}\right)}{\partial\lambda^2} = -2\omega\sigma\rho[P\left(G\right)-\tilde{P}\left(B\right)]<0,$$

the manager's utility function is strictly concave and so equation (2) is sufficient for a maximum.

Plugging $\lambda=\widehat{\lambda}$ into the manager's first-order condition (2) yields the quadratic function:

$$H\left(\lambda,\sigma\right)=\left(\frac{\gamma}{\Omega\left(1-\gamma\right)}-\sigma\phi\right)\lambda^2-\sigma\phi\frac{\Delta}{g}\lambda+\frac{1}{\Omega\rho}. \tag{3}$$

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. We have $H(0,\sigma)=\frac{1}{\Omega\rho}>0$.

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

Proposition 1 *(Investment): There exists an equilibrium investment level, given by:*

$$\lambda^*=\begin{cases}\lambda_1\left(\sigma\right), & \textit{if} \quad \sigma>X;\\ 1, & \textit{if} \quad \sigma\leq X,\end{cases}$$

where

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

λ_1 is the root of the quadratic $H\left(\lambda,\sigma\right)=0$ for which $H'(\lambda_1,\sigma)<0$, and $\lambda_1(\sigma)$ is strictly decreasing. The threshold X is increasing in g and γ, and decreasing in ω, ϕ, ρ, and Δ.

In addition, for the case of $\sigma \leq X$, if we also have both

$$X > \sigma > Z \equiv \frac{2g\left[\sqrt{(1-\gamma)^2 g^2 + \Delta^2\gamma\rho(1-\gamma)} - (1-\gamma)g\right]}{\phi\rho\Omega(1-\gamma)\Delta^2}$$

and

$$\sigma < W \equiv \frac{2g\gamma}{\phi\Omega(1-\gamma)[\Delta+2g]},$$

then we also have two additional equilibria, $\lambda^* = \lambda_1(\sigma)$ and $\lambda^* = \lambda_2(\sigma)$, where $\lambda_2(\sigma)$ is the root of the quadratic $H(\lambda,\sigma) = 0$ for which $H'(\lambda_2) > 0$, and $\lambda_2 > \lambda_1$.

Here, X is the value of σ such that $\lambda = 1$ is a solution to the equation $H(\lambda, X) = 0$; if $\sigma < X$, $H(1,\sigma) > 0$. Z is the threshold of σ such that, if and only if $\sigma \geq Z$, $H(\lambda,\sigma)$ has real roots. W is the threshold of σ such that, if and only if $\sigma < W$, $H'(1,\sigma) > 0$.

The intuition behind Proposition 1 is as follows. The cost of investment (from the manager's perspective) is that it increases the probability of a bad signal and thus reduces the expected stock price. This cost is particularly high if the signal is likely to be disclosed, i.e. if σ is high. Thus, disclosure increases the cost of investment, and so 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 (i.e. full investment is more likely to be undertaken) if ω, or $\Omega = \frac{\omega}{1-\omega}$, 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, it is also 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 firm quality θ. The price becomes more reflective of quality θ rather than the noisy signal y. Thus, the manager is less concerned about emitting the bad signal. Full investment is also likelier if the prior probability of $\theta = H$, γ, is high, as this means that signal B is more likely to be generated by a H-firm and so leads to a less negative inference. Finally, it is likelier if $\Delta \equiv R^H - R^L$, the difference in the values of a high- and low-quality firm, is low, as this reduces the incentive to be revealed as a high-quality firm by delivering $y = G$.

When $\sigma > X$, disclosure is sufficiently high that the manager reduces investment below the first-best optimum. Moreover, further increases in σ cause investment to fall further, since λ_1 is decreasing in σ. Thus, while a rise in σ augments financial efficiency, since the signal y is partially informative, it reduces real efficiency.

Note that when $\sigma < X$, we have a boundary solution. The manager's first-order condition (2), and thus the equilibrium condition $H(\lambda, \sigma)$ is positive. The manager would like to increase λ further, but cannot since λ is bounded above by 1. When $\sigma \geq X$, the manager's first-order condition and the equilibrium condition $H(\lambda, \sigma)$ are both zero.

For the case in which $\sigma > Z$ and $\sigma < W$ in addition to $\sigma < X$, we have multiple equilibria. When $\sigma > Z$, the quadratic $H(\lambda, \sigma)$ has two real roots. In addition, $\sigma < W$ is equivalent to $H'(1, \sigma) > 0$. Since $\sigma < X$ is equivalent to $H(1, \sigma) > 0$, $H'(1, \sigma) > 0$ implies that both roots λ_1 and λ_2 lie in $[0, 1]$ and are thus valid equilibria. Since $H(1, \sigma) > 0$, $\lambda^* = 1$ is also an equilibrium. In contrast, if $\sigma > W$, then $H'(1, \sigma) < 0$, in which case $H(1, \sigma) > 0$ implies that both roots λ_1 and λ_2 exceed 1 and are thus not valid equilibria. Note that $W > Z \Rightarrow W > X$, so the only two possible orderings are $0 < Z < X < W$ or $0 < W < Z < X$. Multiple equilibria can only exist if $0 < Z < \sigma < X < W$.

The intuition behind the existence of multiple equilibria is as follows. The worst outcome for a H-manager who invests is that he emits a bad signal and the speculator's purchase of β shares is canceled out by the investor selling β shares. In this case, $P = P((\beta, -\beta), B) = \frac{\gamma\rho\hat{\lambda}^2}{\gamma\rho\hat{\lambda}^2 + (1-\gamma)} V^H + \frac{1-\gamma}{\gamma\rho\hat{\lambda}^2 + (1-\gamma)} R^L$. The equilibrium of $\lambda^* = 1$ is feasible because, if the market conjectures that the H-firm invests fully ($\widehat{\lambda} = 1$), then $P((\beta, -\beta), B)$ is relatively high: the market attaches a high posterior to signal y being generated by a H-manager who has invested but became unlucky. Thus, a H-manager is indeed willing to select $\lambda = 1$ since, even if $y = B$ and $I = -\beta$, he will not suffer too low a price. In contrast, an equilibrium with a lower λ (λ_1 or λ_2) is also feasible because, when the market conjectures a low level of investment, $P((\beta, -\beta), B)$ is low and so the manager indeed underinvests because he is fearful of becoming unlucky and suffering a low stock price.

We can now define two sets. First, we define

$$\Lambda = \{\lambda \in [0, 1] : \exists \sigma \in [0, 1] \, \text{s.t.} \; H(\lambda, \sigma) = 0.\}$$

The set Λ contains all possible λ's that are interior equilibrium investment levels in the subgame following the announcement of a particular σ. Note that $1 \in \Lambda$ if $X \leq 1$: if the founder chooses $\sigma = X$, the manager's first-order condition (2) is zero at $\lambda = 1$. Also note that by Proposition 1, $\Lambda = \varnothing$ if and only if $0 < W < Z < X$ and $X > 1$. Then, since $H(\lambda, \sigma) \neq 0$, we have a boundary solution and $\lambda = 1$.

Second, for any equilibrium, we define:

$$\Sigma = \{\sigma : \lambda^*(\sigma) = 1 \text{ in the subgame following } \sigma\}.$$

Thus, Σ is the set of σ's that induce full investment in an equilibrium. (We later show that an equilibrium to the full game, which includes the founder's choice of disclosure policy, always exists.) The set Σ is non-empty, because when $\sigma \in (0, Z)$, the following subgame has a unique equilibrium with $\lambda^*(\sigma) = 1$. Furthermore, if $X \leq 1$ and $\lambda^*(X) = 1$, $X \in \Sigma$.

2.4 Disclosure Stage

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

$$\begin{aligned}\max_{\sigma} \Pi(\sigma) &= (1 - \alpha(\sigma))\, \mathbb{E}\left[V^{\theta}\right] \\ &= (1 - \alpha(\sigma))[\gamma V^{H}(\sigma) + (1 - \gamma) V^{L}]. \end{aligned} \tag{5}$$

When choosing σ, the founder takes into account two effects of σ. First, it affects α, because the investor's stake must be sufficient to compensate for her trading losses. Second, it affects λ and thus V^H, as shown in Proposition 1. Lemma 3 addresses the first effect, demonstrating how α depends on the disclosure policy.

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

$$\alpha(\sigma) = \frac{K + \beta\phi(1 - \gamma)\left(V^H - R^L\right)\left[(1 - \sigma)\gamma + \sigma\frac{\gamma\rho\lambda^2}{\gamma\rho\lambda^2 + (1-\gamma)}\right]}{\gamma V^H + (1 - \gamma) R^L}. \tag{6}$$

It is decreasing in σ and increasing in β, ϕ, Δ, λ, ρ and g.

The second term in the numerator is the investor's expected trading losses. Since $\frac{\gamma\rho\lambda^2}{\gamma\rho\lambda^2+(1-\gamma)} < \gamma$, these are strictly decreasing in σ. Greater disclosure increases price informativeness and thus reduces the investor's losses. A greater stake corresponds to a higher cost of capital; thus, the cost of capital is decreasing in disclosure, but increasing in the frequency ϕ and magnitude β of liquidity shocks, as well as the difference in value between a high- and low-quality firm $(\Delta + g\lambda)$. It is also increasing in ρ, the extent to which investment worsen the signal, as this reduces the informativeness of the public signal y and thus increases the speculator's information advantage. Plugging (6) into (5) yields

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

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

We solve for the founder's choice of disclosure policy in two steps. First, we solve for the optimal disclosure policy in Σ and in $\neg\Sigma$ (Lemmas 4 and 5). Second, we solve for the optimal disclosure policy overall, which (depending on the parameter constellation) may involve comparing the founder's payoff under the optimal disclosure policy in Σ with his payoff under the optimal disclosure policy in $\neg\Sigma$.

We first analyze the optimal disclosure policy in Σ in an equilibrium (if exists). By the definition of Σ, in the equilibrium, $\lambda^*(\sigma) = 1$ for all $\sigma \in \Sigma$. Thus, for $\sigma \in \Sigma$, the founder's payoff becomes

$$\begin{aligned}\Pi(\sigma) = &\left[\gamma\left(R^H + g\right) + (1-\gamma) R^L - K\right] \\ &- \beta\phi(1-\gamma)(\Delta + g)\left[(1-\sigma)\gamma + \sigma\frac{\gamma\rho}{\gamma\rho + (1-\gamma)}\right],\end{aligned} \tag{7}$$

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

Lemma 4 *In an equilibrium with the set Σ, the optimal disclosure policy in Σ is*

$$\sigma^* = \max\Sigma,$$ [11]

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

Intuitively, if the firm wishes to implement $\lambda^* = 1$, it should choose the highest possible σ that supports full investment, which is $\max\Sigma$.

We next turn to the optimal disclosure policy in $\neg\Sigma$. For any $\sigma' \in \neg\Sigma$, the equilibrium in the following subgame is λ' where $H(\lambda', \sigma') = 0$. Thus, if $\sigma' \in \neg\Sigma$, then

[11] Here, we assume $\max\Sigma$ exists in the equilibrium. As we will show later, however, $\max\Sigma$ does not exist in some equilibria. In such a case, full investment will not appear on the equilibrium path; that is, the equilibrium disclosure policy does not belong to Σ.

$\lambda' \in \Lambda$. The founder's maximization problem becomes

$$\max_{\sigma \in \neg\Sigma} \Pi(\sigma) = \left[\gamma\left(R^H + \lambda g\right) + (1-\gamma) R^L - K\right]$$
$$- \beta\phi(1-\gamma)(\Delta + \lambda g)\left[(1-\sigma)\gamma + \sigma\frac{\gamma\rho\lambda^2}{\gamma\rho\lambda^2 + (1-\gamma)}\right] \tag{8}$$
$$\text{s.t.} \quad H(\lambda, \sigma) = 0.$$

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

$$\sigma = \frac{g\left(\gamma\rho\lambda^2 + (1-\gamma)\right)}{\lambda\Omega\phi\rho(1-\gamma)(\Delta + \lambda g)}, \tag{9}$$

and is decreasing and convex in λ. Increased disclosure reduces investment; however, since investment cannot fall below zero, it does so at a decreasing rate.

Equation (8) shows that there are four effects of a larger λ on the founder's objective function. The first is the "value creation effect", the positive effect of investment on firm value, which can be seen by λ entering the first term of equation (8). The second is the "variance" effect, which is negative. A higher λ augments the difference in value, $\Delta + \lambda g$, between the high- and low-quality firms. This in turn increases the investor's information disadvantage relative to the speculator, her trading loss, and thus her equity stake α. The effect can be seen by λ appearing in the first part of the second term. The third is the "disclosure effect". Implementing higher investment λ requires less disclosure σ (equation (9)), augmenting the cost of capital. Since $\frac{\gamma\rho\lambda^2}{\gamma\rho\lambda^2+(1-\gamma)} < \gamma$, a reduction in σ lowers the founder's payoff and so the disclosure effect is also negative. The fourth is the "signal distortion effect". Higher investment means that the signal y is less informative about firm type, because $y = B$ is more likely to be generated by a H-firm. Thus, the investor (who observes y) suffers a greater information disadvantage relative to the speculator. This effect can be seen by λ appearing in the term $\frac{\gamma\rho\lambda^2}{\gamma\rho\lambda^2+(1-\gamma)}$. This term affects the price set by the market maker upon seeing $y = B$ and $Q = (\beta, -\beta)$ (see Lemma 2): a rise in λ augments $P((\beta, -\beta), B)$ since $((\beta, -\beta), B)$ is more likely to be generated by a H-firm. On the one hand, this higher price reduces the investor's losses if she is forced to sell and the speculator buys, because in reality $\theta = H$. On the other hand, it increases the investor's losses if she is forced to buy and the speculator sells, because in reality $\theta = L$, as she now has to buy at a higher price. The second effect is dominant, because when $y = B$, it is more likely that $\theta = L$, and so overall a rise in λ augments the investor's loss through changing the price set by the market maker.

Equation (8) can be rewritten:

$$\Pi(\lambda,\sigma) = \left[\gamma\left(R^H + \lambda g\right) + (1-\gamma) R^L - K\right] - \beta\phi\gamma(1-\gamma)(\Delta + \lambda g) \\ + \beta\phi\gamma(1-\gamma)(\Delta+\lambda g)\,\sigma \frac{(1-\gamma)(1-\rho\lambda^2)}{\gamma\rho\lambda^2 + (1-\gamma)}. \tag{10}$$

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

Plugging equation (9) into the objective function (10) yields firm value now as a function of investment alone:

$$\Pi(\lambda) = \left[\gamma\left(R^H + \lambda g\right) + (1-\gamma) R^L - K\right] - \beta\phi\gamma(1-\gamma)(\Delta + \lambda g) \\ + \frac{\beta\gamma(1-\gamma)g}{\rho\Omega}\left[\frac{1}{\lambda} - \rho\lambda\right]. \tag{11}$$

The loss mitigation term contains a linear component (the $-\rho\lambda$ term) and a convex component (the $\frac{1}{\lambda}$ term). Combining the terms in λ, in $\frac{1}{\lambda}$, and independent of λ yields

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

where

$$D \equiv R^H - (1-\gamma)(1+\beta\phi\gamma)\Delta - K > 0, \tag{13}$$

$$E \equiv g\left[1 - (1-\gamma)(1+\beta\phi\gamma) - \frac{(1-\gamma)\beta\gamma}{\Omega}\right] \lesseqgtr 0, \tag{14}$$

$$F \equiv \frac{(1-\gamma)\beta\gamma g}{\rho\Omega} > 0. \tag{15}$$

F contains the convex component of the loss mitigation term; E contains the linear component of this term as well as of the expected value and maximum trading losses terms. Differentiating (12) yields

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

Since $\Pi(\lambda)$ is globally convex (which follows from the convexity of F), the solution to $\Pi'(\lambda) = 0$ is a minimum. The maximal value of $\Pi(\lambda)$ is attained at a boundary: we will either have $\lambda^* = \max\Lambda\ (= 1)$ or $\lambda^* = \min\Lambda\,(= \lambda_1(1))$. The intuition behind the boundary solution is as follows. The benefits of increasing investment to the founder are linear in the level of investment. One of the costs, the maximum trading losses, is also linear in investment. However, the loss mitigation term contains both linear and convex components. As investment rises, disclosure must fall in order to support the higher level of investment, and this reduces the loss mitigation brought about by disclosure. Due to the convexity, increases in investment reduce loss mitigation at a decreasing rate. Intuitively, since σ is convex in λ (equation (9), the negative effect of disclosure on investment decreases as disclosure rises. Thus, if it is optimal for the founder to increase disclosure by a small amount, thus reducing investment from 1 to $1-\varepsilon$, it is optimal for him to increase disclosure all the way to 1, thus reducing investment all the way to $\lambda_1(1)$.

Lemma 5 *Suppose $\sigma' \in \neg\Sigma$. Then $\lambda(\sigma') \in \Lambda$ and so $\Lambda \neq \varnothing$. The optimal investment in the set Λ for the founder is either* $\min\Lambda$ *or* $\max\Lambda$*. In particular,*

1. *If $X < 1$, the optimal investment level is either $\lambda^* = \lambda_1(1)$, in which case the optimal disclosure policy is $\sigma^* = 1$, or $\lambda^* = 1$, in which case the optimal disclosure policy is $\sigma^* = X$;*

2. *If $X \geq 1$, the optimal investment level is either $\lambda^* = \lambda_1(1)$ or $\lambda^* = \lambda_2(1)$. In both cases, the optimal disclosure policy is $\sigma^* = 1$.*

We now move to the second step. Having found the optimal disclosure policy in Σ and in $\neg\Sigma$, we now solve for the optimal disclosure policy overall (given a set of parameters), which may involve comparing the founder's payoff across Σ and $\neg\Sigma$. In doing so, we formally prove existence of an equilibrium in the model and characterize it.

As discussed previously, there are two possible orderings of the cutoffs: $0 < W < Z < X$ (where the equilibrium is unique) and $0 < Z < X < W$. In the former case we have a unique equilibrium; in the latter case, we have multiple equilibrium investment levels if $Z < \sigma < X$ (see Proposition 1). We choose the equilibrium investment level that maximizes the founder's payoff (note that this does not imply choosing the highest investment level). This selection criterion echoes the concept of "forward induction". When committing to a disclosure policy for which there are multiple possible investment levels, the founder will wish to implement the investment level that maximizes his payoff. The stake α will be chosen so that the investor breaks even given the investment level that the founder intends to implement. Thus, by observing the stake α, the market maker and manager can infer the investment level that the founder intends to implement. Thus, the observed stake α serves as a public coordination device to ensure that the market maker and manager coordinate on this equilibrium investment level, rather than another equilibrium.

For each of the two orderings, we have two subcases to consider, depending on whether $X \lesseqgtr 1$. We thus have a total of four subcases. We start with the subcase of $0 < W < Z < X$ and $X \geq 1$. Here, we have $\Lambda = \varnothing$, and so the investment level following any $\sigma \in [0, 1]$ is $\lambda^* = 1$. Then Lemma 4 immediately implies Proposition 2.

Proposition 2 *(Full disclosure and full investment). If $0 < W < Z < X$ and $X \geq 1$, the model has a unique equilibrium, in which the optimal disclosure policy is $\sigma^* = 1$ and the equilibrium investment level is $\lambda^* = 1$.*

Since either $0 < Z < X < W$ or $0 < W < Z < X$, we have $0 < W < Z < X$ if and only if $X > W$, i.e.

$$\frac{1}{2}\left[1 + \frac{g}{\Delta + g}\right] > \frac{\gamma\rho}{\gamma\rho + (1-\gamma)}, \tag{16}$$

and $X \geq 1$ is equivalent to

$$\frac{1-\omega}{\omega} \geq \phi \frac{(1-\gamma)\,\rho}{\gamma\rho + (1-\gamma)} \frac{\Delta + g}{g}, \tag{17}$$

we can see that the set of parameters that leads to $\Lambda = \varnothing$ is nonempty. An increase in g and a decrease in ω or $R^H - R^L$ makes both conditions more likely to be satisfied, and a fall in ϕ helps satisfy (17) and has no effect on (16). As per the discussion of Proposition 1, all of these changes make it more likely that the manager invests efficiently even with full disclosure. There is no trade-off between disclosure and investment, and so full disclosure and full investment can be implemented simultaneously.

We now move to cases in which $\Lambda \neq \varnothing$. First, we continue to consider $X \geq 1$, but now analyze the ordering $0 < Z < X < W$, which yields multiple equilibria if $\sigma \in [Z, 1]$

(see Lemma 1). In particular, when $\sigma = 1$, the investment levels $\lambda_1(1)$, $\lambda_2(1)$, and 1 are all possible equilibria. The equilibrium is given in Proposition 3 below:

Proposition 3 *(Full disclosure, multiple equilibrium investment levels). If* $0 < Z < X < W$ *and* $X \geq 1$*, the model has a unique equilibrium, in which the optimal disclosure policy is* $\sigma^* = 1$ *and the equilibrium investment level is* $\lambda^* = \arg\max \{\Pi(\lambda_1(1), 1), \Pi(\lambda_2(1), 1), \Pi(1, 1$

The proof of Proposition 3 shows that the founder will never choose $\sigma^* < 1$, and thus chooses between the three equilibrium investment levels that can be sustained when $\sigma^* = 1$. Interestingly, even though there is no disclosure effect, because the founder can implement $\lambda^* = 1$ without having to reduce σ^* below 1, the founder may still choose to underinvest (select $\lambda^* = \lambda_1(1)$ or $\lambda_2(1)$). The variance and signal distortion effects alone can be strong enough to outweigh the value creation effect and lead to $\lambda^* < 1$ being optimal for the founder.

We have $0 < Z < X < W$ if and only if $X < W$, i.e.

$$\frac{1}{2}\left[1 + \frac{g}{\Delta + g}\right] < \frac{\gamma\rho}{\gamma\rho + (1-\gamma)}. \tag{18}$$

In turn, inequality (18) is satisfied if g is sufficiently small. If the investment opportunity is highly profitable, the founder will wish to implement full investment and so we are in the case of Proposition 2. Only if g is small will he consider implementing partial investment to reduce the investor's trading loss. Similarly, if Δ is high, trading losses are large and so the founder may wish to induce partial investment. If γ is high, then high investment augments the signal distortion effect: if there are many H-firms, investment means that a bad signal becomes less informative about firm type, and so the investor's information asymmetry and thus trading losses widen. As is standard, a high ρ increases the bias in the signal caused by investment, and may mean that partial investment is optimal.

We now move to the case of $X < 1$. The equilibrium does not depend on whether we are in the subcase of $0 < W < Z < X$ or $0 < Z < X < W$, and is given by Proposition 4 below:

Proposition 4 *(Full disclosure or full investment). If* $X < 1$*, the model has a unique equilibrium selected. In particular,*

1. *If* $\Pi(\lambda_1(1), 1) > \Pi(1, X)$*, the founder chooses full disclosure (*$\sigma^* = 1$*) and the manager underinvests (*$\lambda^* = \lambda_1(1) < 1$*)*

2. If $\Pi(\lambda_1(1), 1) < \Pi(1, X)$, *the founder chooses partial disclosure* ($\sigma^* = X$) *and the manager fully invests* ($\lambda^* = 1$).

The condition $X < 1$ *is equivalent to*

$$\frac{1-\omega}{\omega} < \phi \frac{1-\gamma}{\gamma} \frac{\gamma\rho}{\gamma\rho + (1-\gamma)} \frac{\Delta + g}{g}$$

and the condition $\Pi(\lambda_1(1), 1) > \Pi(1, X)$ *is equivalent to*

$$\beta > \widetilde{\beta} = \frac{1 - \lambda_1(1)}{\phi(1-\gamma)\frac{\Delta+g}{g} - \Omega^{-1}\left[(1-\gamma)\left(\frac{1}{\rho} - 1\right) + \lambda_1\right]} > 0 \tag{19}$$

The partial investment level $\lambda_1(1)$ *is increasing in* g *and* γ, *decreasing in* ω, ϕ, ρ, *and* Δ, *and independent of* β.

The threshold β *is increasing in* g *and* γ, *decreasing in* ϕ, ρ, *and* Δ, *and decreasing in* ω *when* ω *is small, but increasing in* ω *when* ω *is large.*

When $X < 1$, the manager underinvests if $\sigma = 1$, and so the founder must choose between either full disclosure or full investment. He chooses the former if and only if the magnitude of the liquidity shock β is sufficiently high (above a threshold $\widetilde{\beta}$), as this means that cost of capital considerations dominate the trade-off. Importantly, the partial investment level $\lambda_1(1)$ on the right-hand side is independent of β, which is why we use β as the cut-off parameter.

To understand the determinants of the threshold $\widetilde{\beta}$, we make the following observations. First, as shown in equation (4) in Proposition 1, the maximum amount of disclosure X that can implement full investment is increasing in g and γ, and decreasing in ω, ϕ, ρ, and Δ. Second, the partial investment level $\lambda_1(1)$ that is implemented by full disclosure is increasing in g and γ, and decreasing in ω, ϕ, ρ, and Δ, for the same intuition. Third, as g and γ rise, investment becomes more important relative to the cost of capital. A rise in g means that the growth opportunity is more productive, and a rise in γ increases the probability that the firm is of type H and has the growth opportunity. As ϕ, ρ, and Δ rise, the cost of capital becomes relatively more important relative to investment.

Thus, overall, as g and γ rise, and ϕ, ρ, and Δ fall, there are three effects. First, the founder's payoff under full investment rises, since full investment can be sustained with a higher cost of capital. Second, the founder's payoff under full disclosure also rises, since full disclosure does not lead to as much underinvestment. These two effects work in opposite directions, and alone would lead to an ambiguous effect of changes in these parameters on the cutoff $\widetilde{\beta}$. This ambiguity is resolved through the presence of a third effect: a rise in g and γ, and a fall in ϕ, ρ, and Δ , make investment more important relative to the cost of capital. Thus, they augment the cutoff $\widetilde{\beta}$, thus tightening the condition for the full disclosure policy to be optimal (inequality (19)).

In contrast, a fall in ω only has the first two effects: it reduces the partial investment level $\lambda_1(1)$ (making the full disclosure policy less attractive) and reduces the partial disclosure level X (making the full investment policy less attractive). Since ω does not affect the expected value of the investment opportunity, nor the cost of capital, the third effect is absent. Since the combination of the first two effects is ambiguous, ω has an ambiguous effect on $\widetilde{\beta}$.

In sum, increases in g and γ, and decreases in ϕ, ρ, and Δ, not only augment the partial investment level $\lambda_1(1)$ but also make it likelier that the full-investment policy will be chosen. Thus, such changes have monotonic effects on investment. Fix β such that $\beta > \widetilde{\beta}$, so that the founder chooses partial investment. The above changes will augment $\lambda_1(1)$. After a point, they will reduce $\widetilde{\beta}$ below β and so investment jumps to 1. In contrast, ω can have a non-monotonic effect on investment. Fix β such that $\beta > \widetilde{\beta}$, so that the founder chooses partial investment. Increases in ω reduce investment $\lambda_1(1)$. However, when ω becomes sufficiently high, we may jump to full investment. Investment is so low under the full disclosure regime that the founder switches to full investment.

3 Voluntary Disclosure

The analysis of Section 2 shows that, even if the actual act of disclosing information is costless, a high-disclosure policy has real costs in terms of inducing underinvestment. Thus, if the founder is able to commit to a disclosure policy (as assumed by the literature on mandatory disclosure), he may commit to partial disclosure even though full disclosure would reduce his cost of capital.

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

We can easily see that the manager will choose to disclose the signal if it turns out to be good. Since $\widetilde{P}(G) > \widetilde{P}(\varnothing)$, the manager will always disclose if $y = G$. Thus, the absence of a disclosure means that the signal must be $y = B$. No disclosure is tantamount to the disclosure of a bad signal, and so the manager is indifferent between them. The manager cannot choose not to disclose and claim that he is doing so because the founder pre-announced a low-disclosure policy, because the market knows that he would have reneged on the policy and chosen to disclose if the signal was good. No news is bad news.

Since the manager knows that he will always disclose the signal y at $t = 2$ (either literally, by disclosing $y = G$, or effectively, by not disclosing and the market inferring that $y = B$), he will make his $t = 1$ investment decision assuming that $\sigma = 1$, i.e. choose $\lambda^* = \lambda_1(1)$ irrespective of the founder's preannounced policy. In short, the voluntary disclosure model is equivalent to the mandatory disclosure model with $\sigma = 1$. As a result, the only disclosure policy that the founder can commit to is $\sigma = 1$. Even if $\Pi(1, X) > \Pi(\lambda_1(1), 1)$, and so the founder would like to commit to low disclosure ($\sigma = X$), he is unable to do so. An announcement of $\sigma = X$ will not induce the manager to choose $\lambda = 1$ (or the market maker to conjecture $\lambda^* = 1$) as in the mandatory disclosure model: since the manager knows that he will always disclose at $t = 2$, he will invest $\lambda_1(1)$ to increase the probability of generating the good signal. 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 subgame perfect equilibrium involves $\lambda^* = \lambda_1(1)$ and $\sigma^* = 1$.*

Proposition 5 implies that, even if the founder would like to implement the $(\lambda^* = 1, \sigma = X)$ equilibrium, because it maximizes his objective function $(\Pi(1, X) > \Pi(\lambda_1(1), 1))$, he is unable to. Thus, there may be a 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 government either bans disclosure, or audits disclosure sufficiently intensely that the manager now chooses not to disclose. Now, when making his $t = 1$ investment decision, he knows that he will disclose at $t = 2$ with probability ζ: if disclosure is not banned, he will always disclose (either directly through releasing $y = H$, or indirectly through the market making inferences from non-disclosure). He will thus choose an investment level $\lambda^* = \lambda(\zeta)$.

Therefore, if the government's goal is to maximize firm value to existing shareholders (i.e. the founder's payoff), it will choose a disclosure policy $\zeta = X$, thus implementing the $(\lambda^* = 1, \sigma = X)$ equilibrium. Such a policy implements a lower level of disclosure than the one that managers will voluntarily choose themselves. This conclusion contrasts some existing models (e.g. Foster (1979), Coffee (1984), Dye (1990), Admati and Pfleiderer (2000)) which advocate that regulators should set a floor for disclosure, because firms have insufficient incentives to release information. It also contrasts recent increases in disclosure regulation (Sarbanes-Oxley), and is consistent with concerns that such regulation may reduce investment

However, government regulation may not maximize firm value. First, the policy that maximizes the founder's payoff varies from firm to firm. Even if all founders wish to implement the full-investment policy, the disclosure policy $\zeta = X \equiv \frac{g(\gamma\rho+(1-\gamma))}{\Omega\phi\rho(1-\gamma)(\Delta+g)}$ depends on firm characteristics. Regulation is typically economy-wide, rather than at the individual firm level. A policy of ζ will induce suboptimally low disclosure in a firm for which $X > \zeta$: disclosure only needs to be as low as X to implement full investment, so a policy of $\zeta < X$ leads to an excessively high cost of capital with no additional improvement in investment. In contrast, a policy of ζ will not constrain disclosure enough in a firm for which $X < \zeta$ and lead to the manager investing only $\lambda_1(\zeta) < 1$, although it will still improve investment compared to the benchmark of no regulation. Moreover, some founders will not wish to implement the full-investment policy if $\Pi(1, X) < \Pi(\lambda_1(1), 1)$ for their firm. Thus, a regulation aimed at inducing full investment will be inefficient.

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

to implement $\lambda^* = 1$. Such a policy will be suboptimal if $\Pi(1, X) < \Pi(\lambda_1(1), 1)$.

Third, the government may have distributional considerations and aim to minimize informed trading profits and losses, which benefit one set of investors at the expense of another. One example is the SEC's focus on "leveling the playing field" between investors. Under this objective function, it will minimize the investor's trading losses[12] and ignore investment, which is achieved with $\zeta = 1$. Thus will reduce firm value if $\Pi(1, X) > \Pi(\lambda_1(1), 1)$.

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* $\Pi(1, X) > \Pi(\lambda_1(1), 1)$ *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* $\lambda^* = \lambda_1(1)$*.*

4 Conclusion

This paper has shown that, even if the actual act of disclosing information is costless, a high-disclosure policy may be costly. While increasing the disclosure of hard information augments the total amount of information available to investors, and thus reduces the cost of capital, it also increases the amount of hard information disclosed relative to soft information. This change causes the manager to distort his real decisions in favor of those that produce favorable hard information, even at the expense of soft information, such as cutting investment. Thus, real efficiency is non-monotonic in financial efficiency. If fundamental value could be disclosed, both real and financial efficiency would be maximized with full disclosure. However, if fundamental value is soft information, then increased disclosure of hard information augments financial efficiency but reduces real efficiency.

If the founder can commit to a disclosure policy, his optimal policy will vary according to the importance of growth opportunities versus the potential losses new investors may suffer from liquidity shocks. If he 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 the manager will opportunistically disclose a good signal, regardless of the

[12] 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.

preannounced policy. Thus, there may be a role for government regulation to reduce disclosure.

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