Adverse Selection, Informational Feedback Effect, and the Optimal Disclosure Policy *

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Abstract

Trading in a secondary stock market not only redistributes wealth among investors but also generates information that guides subsequent investment. We provide a positive theory of disclosure that reflects both functions of the secondary stock market. On one hand, disclosure improves firm value by ameliorating adverse selection among investors. On the other hand, disclosure reduces the private incentive to produce information and thus impedes investment efficiency. This trade-off determines the optimal disclosure policy. Our theory reconciles the disclosure practice with other prominent features of securities regulation and generates new testable predictions.

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1 Introduction

Corporate disclosure is an integral part of the broad market infrastructure and thus a positive theory of disclosure should capture the economic functions of the market. Liquidity provision is a basic function of the secondary stock market. It provides a venue where investors could take different positions based on their information and liquidity needs. In doing so the secondary stock market provides liquidity to investors and redistributes wealth among investors. Focusing on this function the prevailing theory of disclosure has exploited the insight that disclosure improves liquidity provision by leveling the playing-field in the secondary stock market. By reducing the information advantage informed investors enjoy over their counterparties, more disclosure ameliorates the adverse selection in the secondary stock market and results in a lower liquidity discount for the firm shares in the primary market (e.g., Diamond and Verrecchia (1991)). Private information acquisition by investors is the root cause of illiquidity and the motivation for the preemptive corporate disclosure.

However, more private information acquisition by investors is also viewed as a proxy for the health of a stock market (Morck, Yeung, and Yu (2000)) and thus a desirable goal pursued by firms and regulators. The legal literature has established that the tenet of securities regulation in the United States has shifted to the "efficiency enhancement model" since 1970's as part of the triumph of the Efficient Market Hypothesis (e.g, Stout (1988), Mahoney (1995)). The new doctrine is predicated on the second function of the secondary stock market, which we term as the informational feedback role of the stock price. Stock prices aggregate information from every corner of the economy and market participants look to the stock prices for information to improve their decisions. Under the guidance of this view institutions and policies have been designed to facilitate the process by which information is impounded into stock prices. Any institution that lowers the cost or improves the incentive of investors to acquire information can be potentially valuable.

We extend the disclosure theory to explicitly integrate both the liquidity provision and the informational feedback role of the secondary stock market. Investors' information acquisition that exacerbates adverse selection and illiquidity in the secondary stock market is also the ultimate source of the information market participants look to guide their decisions. A value-maximizing firm has to balance these two roles of private information acquisition in the secondary stock market when choosing its disclosure policy.

We start with a model in the spirit of Diamond and Verrecchia (1991) that captures the role of disclosure in leveling the playing-filed. A firm sets a disclosure policy when issuing shares to investors who have future uncertain liquidity needs that can only be satisfied by trading in the secondary stock market where a speculator acquires costly information and trades anonymously. Anticipating this trading disadvantage in the secondary stock market investors demand a liquidity discount for the firm shares in the primary market. Disclosure could partially preempt the speculator's information advantage and reduce the liquidity cost for the firm.

We then introduce the informational feedback role of the secondary stock market. In addition to the asset-in-place, the firm also has a growth opportunity whose value depends on an investment decision made by the firm after observing the stock price from the secondary market. We classify information into two types based on whether it is known to the firm without accessing the stock price. One is termed as Firm Information which the firm learns at no cost and could disclose to the market. The other is New Information which the firm can only learn from the stock price. The speculator acquires both Firm Information and New Information at a cost. By this design the speculator's information overlaps but is not a subset of the Firm Information. In making the investment decision, the firm uses not only the Firm Information it collects but also the New Information that is acquired by the speculator, impounded into the stock price through trading, and learned by the firm from the stock price. Preemptive disclosure reduces the profitability and thus the incentive of the speculator to acquire information. Lower private information acquisition reduces both the liquidity cost and the investment efficiency of the firm. This central tension determines the firm's optimal disclosure policy.

This extended theory of disclosure justifies why a well-functioning stock market promotes disclosure on one hand and encourages speculative information acquisition on the other hand. Since a decrease in information acquisition cost of the speculator heightens adverse selection and increases the liquidity cost for the firm, a theory of disclosure predicated only on ameliorating adverse selection would predict that the firm value increases in information acquisition cost. This prediction is inconsistent with the policy orientation and empirical results discussed above. In contrast, our extended theory predicts that lower information acquisition cost leads to both higher disclosure quality and higher firm value if the informational feedback effect is sufficiently strong.

In addition to the reconciliation with other prominent features of the broad market infrastructure, the extended theory of disclosure also generates new testable predictions. First, the model predicts that growth firms are *endogenously* more opaque than value firms in general. Because lower disclosure incentivizes speculators to acquire New Information useful for firms' investment decision, growth firms, whose value depends more on future decisions, disclose less than value firms whose future cash flows mainly emanate from asset-in-place. Among growth firms, those whose growth decisions rely more on New Information disclose less while those relying more on Firm Information disclose more.

Second, the model also predicts that a lower cost of information acquisition by the speculator always leads to higher disclosure quality. When the information acquisition cost becomes lower, the burden on disclosure to stimulate the speculator's incentive to acquire information is lessened while the benefit of the informational feedback effect is not directly affected. As a result, the firm increases disclosure. Similarly, a higher level of investors' liquidity needs favors higher disclosure quality because more liquidity trades subsidize the speculator's information acquisition. To the extent that better investor protection and financial development help to lower information acquisition cost (Morck, Yeung, and Yu (2000)) and to attract more investors to manager liquidity through the stock market, countries (regimes) with better investor protection and financial development enjoy higher disclosure quality. This prediction is often *assumed* in the literature but our model provides a micro-foundation for it.

Broadly, our paper demonstrates that the explicit consideration of the informational feedback role of the secondary stock market generates new insights on traditional financial market issues. This opens new opportunities for future research because the informational feedback role of the secondary stock market has been taken as granted in the public discourse of a wide array of prominent issues in the stock market, such as insider trading, regulation FD, short sales, program trading, and the regulation of financial institutions. The modeling device of the informational feedback effect and the novel information structure in our model are useful for the future endeavor in this direction[1].

So far we have assumed that it is the firm who learns new information from its own stock price. Theoretically, this assumption is consistent with the informational role of the stock price and the original insight of Hayek (1945). Empirically, it has been supported by a growing empirical literature reviewed in Rajan and Zingales (2003) (see also Durnev, Morck, and Yeung (2004), Chen, Goldstein, and Jiang (2007)). However, this assumption is not necessary. We extend our model to allow other market participants to make decisions based on stock price. The basic trade-off between liquidity cost and investment efficiency is preserved with one new twist. Disclosure in the new setting takes on an additional role of providing information directly to the relevant decision maker. Moreover, we also extend the model to consider a special case where it is the competitors who learn from disclosure and the stock price before making their decisions that could reduce the value of the disclosing firm (Verrecchia (1983)). With the private incentive for information production this extension adds a novel perspective to the literature on proprietary cost of disclosure that more disclosure could lower proprietary cost, a similar result to Arya and Mittendorf (2005) but through a different mechanism.

[1] Take insider trading as an example. One argument for insider trading is that it improves economic efficiency by impounding more information to stock price (Manne (1966)). However, our model implies that whether the increased informational efficiency leads to alloctional efficiency depends on the specifics of the informational feedback effect. If non-public Firm Information is the basis of the trading, the firm is served better with a policy of more disclosure and restricting insider trading. But if the insider trades on New Information which cannot be solicited otherwise, such trading might be justified on the ground of economic efficiency because the firm's investment could be improved.

Section 2 briefly reviews the related literatures; Section 3 describes the model; Section 4 and 5 present our main result as well as extensive comparative static analysis. In Section 6 we further explore the idea that information in the stock price is not provided for free. Section 7 offers two extensions to the baseline model. Section 8 concludes and detailed proofs are presented in the Appendix.

2 Literature Review

Our paper belongs to a growing literature that explicitly model the informational feedback effect of stock price to shed new light on traditional issues, such as insider trading (Khanna, Slezak, and Bradley (1994)), public v.s. private financing (Subrahmanyam and Titman (1999)), securities design and capital structure (Fulghieri and Lukin (2001)), and ownership structure (Holmstrom and Tirole (1993)). In addition, our paper differs from a related literature that focus on the subtlety in exploiting the informational feedback effect (Sunder (1989), Dye and Sridhar (2002), Goldstein and Guembel (2008)). The modeling choice we employ to circumvent the subtlety is also useful for future research.

Our paper also relates to a vast literature on the monitoring benefit of the secondary stock market (Diamond and Verrecchia (1982), Holmstrom and Tirole (1993), Baiman and Verrecchia (1996), Kanodia and Lee (1998)). The stock price influences the manager's decisions because the firm links his compensation to stock price to exploit the informativeness of the stock price. The monitoring role is absent from our model because we assume away the agency conflict. The major difference between the monitoring role and the informational feedback role of the stock price is that each exploits a different type of information. The monitoring role relies on the backward-looking information about the past action of the manager, while the informational feedback role takes advantage of forward-looking information about the future cash flow. In fact, information about the future cash flow often impedes the monitoring role of the stock price (Paul (1992)).

This major difference between the monitoring and informational feedback role of the stock price also distinguishes our paper from Baiman and Verrecchia (1996). In their model, disclosure that ameliorates adverse selection also reduces production efficiency through less informative stock price. But they obtain the result by exploiting the conflicting information needs for monitoring v.s. trading purposes. The market maker observes the manager's past effort but for trading purpose he needs information about the firm's future cash flow. When the firm discloses more information about future cash flow, market maker relies more on firm disclosure and less on his own information. As a result, the price becomes less useful for monitoring the manager and production efficiency decreases. In contrast, in our model the driving force is that disclosure reduces the information acquisition of the speculator. Because they focus on the monitoring effect while we focus on the informational feedback effect of stock price, the two models generate other different predictions.

Our paper compliments the literature of the real effects of accounting disclosure (as reviewed by Kanodia (2007)) that emphasizes on the two-way impacts between firm decisions and capital market pricing. This two-way communication also occurs in our model. On one hand, the firm's investment decision affects firm value; on the other hand, the firm's investment decision is affected by the stock price of the firm due to its informativeness. Our paper contributes to this literature by introducing a new link from the secondary stock market to the firm's subsequent real decisions, namely, the informational feedback link. The firm's real decisions respond to the stock price because the firm learns new information from the stock price.

Our paper also adds to the literature on the interactions between public disclosure and the private incentive to acquire information (Demski and Feltham (1994), Kim and Verrecchia (1994), McNichols and Trueman (1994)). They identify conditions under which disclosure could stimulate private information acquisition. But the informational feedback to the real decisions subsequent to the trading is absent in these papers.

3 The Model

We introduce the informational feedback effect of the stock price into an otherwise standard model of disclosure ameliorating adverse selection among investors. All players are risk neutral. There are four dates and the time line is as follows.

Date 1	2	3	4
A firm chooses disclosure quality β and sells firm shares at P_1 per share	Firm discloses $\widetilde{x}$; Speculator acquires signal $\widetilde{y}$; Liquidity shocks $\widetilde{n}$ realized; Shares traded at P_2	The firm observes P_2 and chooses investment K	Cash flow $(\widetilde{A}+\widetilde{G})$ is realized

Figure 1: Time Line

At date 1, the primary market for firm shares opens. The firm, consisting of one asset-in-place (AIP) and one growth opportunity, issues equity shares to a continuum of risk neutral investors with total mass of 1. The total number of shares is normalized to be 1 share per capita and the share is perfectly divisible. Ex ante identical investors expect that they have liquidity needs at date 2 that can only be satisfied by trading in the secondary market. Together with the share issuance the firm sets a disclosure policy that commits the firm to a specified level of disclosure at date 2.

At date 2, a speculator chooses how much resources to spend on information acquisition and receives some private information about future profitability. The firm discloses according to its pre-specified disclosure policy. Then, investors who have liquidity shocks and the speculator trade anonymously in the secondary market intermediated by a market maker (Kyle (1985)).

At date 3, the firm makes an investment decision based on all available information.

At date 4, the cash flow of the firm is realized and consumption takes place.

3.1 The Informational Feedback Effect

The key element of our model is the informational feedback effect of the stock price. That is, the ex ante distribution of future cashflows can be affected by the *information* contained in the stock price of the secondary market. It is operationalized by the assumption that the investment level that affects the value of its growth opportunity is made by the firm on date 3, after the observation of the stock price on date 2. We show in Section 7 that if agents other than the firm learn information from the stock price and make decisions that affect the firm value the main results of the paper are intact.

Specifically, the firm consists of one asset-in-place (AIP) and one growth opportunity. The terminal cash flow of the asset-in-place, A, is

$$\widetilde{A} = A_0 + \widetilde{\mu}$$

where A_0 is the baseline value of the firm's cash flow from the asset-in-place. $\widetilde{\mu}$ is the future innovation in the profitability of the firm's AIP. It is normally distributed with mean zero and its variance will be specified in the next subsection.

The terminal cash flow from the growth opportunity, G, is

$$\widetilde{G} = \widetilde{\mu}K - \frac{1}{2g}K^2$$

where K is the firm's investment decision on date 3 after observing the stock price in the secondary stock market[2]. As we will see later, g captures the degree to which the firm could adapt its investment to new information and thus captures the firm's growth prospect. The higher g is, the higher the value of the grow opportunity.

[2]Note that we have assumed that the future cash flows from the growth opportunity and the AIP are affected by the exactly same sources of uncertainty ($\widetilde{\mu}$). This assumption is only for convenience and could be relaxed to allow correlated soruces of uncertainty.

Now we define the informational feedback effect in the context of our model. Compare the impact of new information arriving at date 2 on the AIP and the growth opportunity. From an ex ante (date 1) perspective, the information available at date 2 does not affect the distribution of the terminal cash flow of the AIP. In contrast, such information does affect the distribution of the terminal cash flow from the growth opportunity because the investment decision K can be adapted to the new information. By informational feedback effect of the stock price, we mean that the information in the stock price at date 2 affects the ex ante (date-1) distribution of the terminal cash flow of the growth opportunity and therefore the firm value. Next we introduce the information structure to explicitly model the informational feedback effect.

3.2 Information Structure

The information structure of our model captures two features. On one hand, stock prices convey information that is new to the firm. Thus the information set of the speculator cannot be a subset of that of the firm. On the other hand, the firm's disclosure could ameliorate adverse selection among investors in the secondary market. Thus, the information set of the speculator has to be correlated with that of the firm. We operationalize these two features.

Consider a simple additive structure for profitability variable $\tilde{\mu}$, consisting of two mutually independent factors:

$$\tilde{\mu} = \widetilde{f} + \widetilde{m}$$

where $\widetilde{f}$ and $\widetilde{m}$ are independent, normally distributed variables with mean zero and variance σ_f^2 and σ_m^2, respectively.

The firm privately learns $\widetilde{f}$ perfectly at date 2 at no cost. We call $\widetilde{f}$ Firm Information, which the firm acquires without the help of the stock market. Firm disclosure, denoted by x, is an unbiased signal of firm's private information $\widetilde{f}$:

$$\widetilde{x} = \widetilde{f} + \widetilde{\varepsilon}_x$$

where $\widetilde{\varepsilon}_x$ is a normally distributed variable with variance σ_x^2. We define the quality of the disclosure x as β

$$\beta = \frac{\sigma_f^2}{\sigma_f^2 + \sigma_x^2}$$

β is an increasing transformation of the precision of the signal x scaled by the precision of the factor $\widetilde{f}$. The higher the β, the more precise the firm's disclosure reveals about $\widetilde{f}$. We will treat β as firm's date-1 disclosure quality choice. We also assume that the firm incurs a cost $\frac{w}{2}\beta^2$ when its disclosure quality is β. This cost focuses us on the interior disclosure solution because it prevents the firm from full disclosure when w is large enough.

When making the date-3 investment decision, the firm would no doubt use Firm Information $\widetilde{f}$. Further, the firm can improve its investment decision if the stock price contains information about $\widetilde{m}$, the other underlying profitability factor. We assume that the speculator has a competitive advantage over the firm in collecting information about factor $\widetilde{m}$. Through trading, speculator's information is transmitted to stock price P_2. We use the term New Information to label what the firm can potentially learn about future profitability from observing the stock price. Thus, $\widetilde{f}$ is Firm Information, and $\widetilde{m}$ is New Information.

Specifically, the speculator incurs cost $C(\gamma) = \frac{c}{2}\gamma^2$ to acquire a signal y. With probability γ, the signal reveals $\widetilde{\mu}$ perfectly to the speculator; but with probability $1-\gamma$, the signal is not informative at all. In other words,

$$\widetilde{y} = \begin{cases} \tilde{\mu} & \text{with probability } \gamma \\ \varnothing & \text{with probability } 1-\gamma \end{cases}$$

Thus, γ characterizes the quality of the speculator's information acquisition[3].

This completes the information structure. On one hand, Firm Information $\widetilde{f}$ and disclosure x are correlated with the speculator's information y. On the other hand, there is New Information $\widetilde{m}$ the speculator acquires that could be learned by the firm.

The private information acquisition affords the speculator information advantage and leads to adverse selection among investors in the secondary market at date 2. To reduce the dimension of information asymmetry, we assume that the only information advantage of the speculator is the private observation of $\tilde{\mu}$. It is common knowledge that whether the speculator has received an informative signal or not.

We digress from the description of the model to illustrate the information structure of our model. We adapt the following example from Rajan and Zingales (2003). Consider an automobile manufacturer contemplating on investing in a new car model. The firm has Firm Information $\widetilde{f}$. Moreover, each of its dealers has some valuable information about the popular characteristics of existing car models through their interactions with customers. Collectively some of their information is even new to the firm and is an important input to the investment decision. That is, dealers own some information about $\widetilde{m}$. How could the firm's top management tap into this information? One solution is to rely on the corporate bureaucracy in which each dealer reports his information to a regional sales manager, who reports it to the national sales manager, who then reports to the headquarter. This system could be fraught with incentive problems. For example, collecting the feedbacks from customers and organizing them to usable information is privately costly to the dealers. If there is no sufficient or correct incentive in place, dealers will under-report or mis-report the information. For another instance, when the message a dealer receives from his customers is that they really like the cars but hate the service the dealer provides, the dealer has much less incentive to report the message truthfully. Further, the system

[3] An equivalent way to model the speculator's information y is $\widetilde{y} = \tilde{\mu} + \widetilde{\varepsilon}_y$. We then define $\gamma = \frac{\sigma_m^2 + \sigma_f^2}{\sigma_m^2 + \sigma_f^2 + \sigma_y^2}$. This choice will capture the two features of our information structure but renders the model not tractable for some comparative statics.

may not be compatible to the incentives of sales representatives involved in the reporting hierarchy. For example, a sales manager who has invested human capital heavily and has succeeded in selling a few particular models would be reluctant to report information that favors other models. The same incentive problems could also plague other mechanisms to generate the information, such as hiring a consultant. The bottom line is that all information about $\widetilde{m}$ is not directly collected by the firm.

This opens the possibility for the secondary stock market to aggregate the information. In contrast to the corporate bureaucracy the market pricing system could overcome some of these incentive issues. When they could trade in the stock market and profit from their information, everyone who stumbles on some valuable information, such as customers, suppliers, dealers and employees, are mobilized to "report" their information to the market through trading. When the information acquisition is motivated by pure trading profit, traders have all the incentive to produce the most accurate information in the least expensive way.

3.3 Trading in the Secondary Stock Market

The trading in the secondary market both impounds the speculator's information into the stock price and enables the speculator to generate trading profit based on their information advantage. A simple way to capture these two features is to adopt a trading mechanism similar to Kyle (1985).

There are three types of players in the secondary market at date 2: investors, the speculator, and the market maker. Investors who bought the firm's stocks at date 1 experience liquidity shocks and trade to meet these needs. The shock requires each investor i, $i \in [0,1]$, to place a market order of $\widetilde{n} + \widetilde{\varepsilon}_i$ where $\widetilde{n}$ represents the market-wide shock and is common to all investors and $\widetilde{\varepsilon}_i$ represents non-systematic, mean-zero *iid* shocks. The market-wide shock $\widetilde{n}$ is normally distributed with mean zero and variance σ_n^2. The idiosyncratic shocks across investors sum to zero ($\int_i \widetilde{\varepsilon}_i = 0$ with probability one). Thus, the total order from investors sums to $\widetilde{n}$.

When the speculator receives an uninformative signal (with probability $1 - \gamma$), she does not trade and expects a zero trading profit. When the speculator does receive an informative signal $y = \mu$ (with probability γ), she submits an order of d to maximize her expected trading profit $dE[FirmValue - P_2|x, y = \mu]$. We also denote π the trading profit the speculator expects to receive before information acquisition,

$$\pi = \gamma E_{\widetilde{\mu}}[dE[FirmValue - P_2|x, y = \mu]]$$

The market maker observes the total order flow of $D = d + \widetilde{n}$ but cannot differentiate the two components. He then sets a price to clear the market and to break even. The market maker earns zero profit because he is assumed to operate in a competitive market.

$$P_2 = E[FirmValue|x, D]$$

The informational feedback effect complicates the trading model. In a pure exchange economy model, the firm only has AIP whose terminal cash flow is pre-determined and cannot be affected by the stock price. In contrast, the total firm value in our model is the sum of two values: the AIP and the growth opportunity. The value of the growth opportunity in turn depends on the information in the stock price. Thus, the stock price not only *reflects* but also *affects* the firm value and the determination of the stock price becomes a fixed-point problem (e.g., Sunder (1989), Dye and Sridhar (2002)). In any such a fixed-point equilibrium, the value of the growth opportunity and thus the firm value are non-linear in the realization of the signals. As a result, the price of the firm is not normally distributed, making it not tractable to study its informational properties directly.

Because we focus on the interaction between disclosure and the informational feedback effect, this complexity itself is of no interest to us and we use a modeling device from Subrahmanyam and Titman (1999) to circumvent it. As in their model, we assume that the firm issues two claims: one on the cash flow from AIP and the other on the cash flow from the growth opportunity. Since the terminal cash flows of the AIP and the growth opportunity are subjective to the same sources of uncertainty ($\widetilde{\mu}$), the prices of the two claims are related to each other in a deterministic manner and share the identical informational properties. Therefore, there is no loss of generality to use the informational properties of the AIP to infer the informational properties of the price of the entire firm. This technique thus allows us to reach closed-form solutions and to characterize the information content of stock prices explicitly[4].

4 The Main Results

At date 1 the firm maximizes its share price P_1 by choosing a disclosure policy β.

$$\max_{\beta} \quad P_1 \equiv E[A] + E[G(\beta)] - \pi(\beta) - \frac{w}{2}\beta^2 \tag{1}$$

$E[A]$ is the expected value of the AIP that is independent of β. $E[G(\beta)]$ is expected value of the growth opportunity. It relates to β through the firm's learning from the stock price. $\pi(\beta)$ is the liquidity loss investors expect to incur when they trade with the speculator's in the secondary market to satisfy their liquidity needs at date 2. It is equal to the speculator's expected trading profit. Since investors break even, the firm bears the full consequences of investors' expected liquidity loss. Finally, $\frac{w}{2}\beta^2$ is the direct cost of disclosure.

We show in two steps the main result that the firm's optimal disclosure policy trades off the effects of disclosure on liquidity cost and on investment efficiency of the firm. First, disclosure levels the playing-field and reduces the incentive of the speculator to acquire information. Second, the leveled playing-field reduces both the firm's liquidity cost and investment efficiency.

[4] In an earlier version of the paper, we examined the informational properties of the price of the claim to the entire firm value. The main results and the signs of all the comparative statics were the same but we had to to use a much less richer inforamtion structure (binary signals).

Lemma 1 *Higher disclosure quality leads to lower information acquisition by the speculator in equilibrium, that is,* $\frac{d\gamma^*(\beta)}{d\beta} < 0$.

This is the rationale for the argument of disclosure leveling the playing-field. As we show in Appendix, the optimal information acquisition policy by the speculator is $\gamma^*(\beta) = \frac{\sigma_n Q}{2c}$, where $Q = \sqrt{\sigma_m^2 + (1-\beta)\sigma_f^2}$. Given β, Q captures the information advantage of the speculator created by her information acquisition and provides a private incentive for the speculator to engage in costly information acquisition. The firm disclosure reduces Q and preempts some of the information the speculator will acquire, resulting in a lower level of information acquisition by the speculator and a more leveled playing-field.

Lemma 2 *Higher disclosure quality and thus lower information acquisition by the speculator reduce the liquidity cost the firm pays in equilibrium, that is,* $\frac{d\pi(\beta)}{d\beta} < 0$.

This result is in the same spirit of Diamond and Verrecchia (1991). At date-1 the firm reimburses the price-protected investors for their expected date-2 liquidity loss in the form of a discount of the share price P_1 relative to the expected cash flow of the firm. Disclosure improves share price P_1 because it reduces this liquidity cost by discouraging information acquisition by the speculator (Lemma 1).

At this stage the speculator's information acquisition only redistributes wealth since the expected trading profit of the speculator is equal to the liquidity cost of the firm. As a result, the resources spent on information acquisition by the speculator is socially wasteful. However, the next lemma introduces a positive view on the information acquisition by the speculator and provides one justification for the enormous resources involved in the operation of the secondary stock market.

Lemma 3 *Higher disclosure quality and thus lower information acquisition by the speculator reduce the ex ante value of the growth opportunity, that is,* $\frac{dE[G]}{d\beta} < 0$.

We sketch the proof of this Lemma. At date 3, the firm chooses an investment level conditional on its information set (Ω) to maximize the expected value of the growth opportunity $E[G|\Omega]$. The optimal investment level is $K = gE[\mu|\Omega]$ and the conditional expected value of the growth opportunity valued at the optimal investment policy is $E[G|\Omega] = \frac{g}{2}\left(E[\mu|\Omega]\right)^2$.

Some algebra shows that if the information set Ω consists of normally distributed signals the unconditional expected value of the growth opportunity (viewed from date 1) is $E[G] = \frac{g}{2}(Var[\mu] - Var[\mu|\Omega])$. Notice, Ω consists of the Firm Information $\widetilde{f}$ as well as New Information in the stock price P_2 (about $\widetilde{m}$) the firm could learn. More New Information in stock price P_2 leads to a smaller $Var[\mu|\Omega]$, which in turn leads to a higher value of the growth opportunity. As a result, more information acquired by the speculator (i.e., higher $\gamma^*(\beta)$) leads to a higher firm value. More precisely, we show that

$$E[G] = \frac{g}{2}\left(\frac{\sigma_m^2}{2}\gamma^*(\beta) + \sigma_f^2\right) \tag{2}$$

While the firm always fully enjoys the benefit of Firm Information (measured by σ_f^2), the firm only infers New Information with noise from price P_2. As a result, only half of the New Information acquired by the speculator is utilized by the firm in its investment decision (measured by $\sigma_m^2/2$). The term $\gamma^*(\beta)$ in equation (2) reflects the fact that the speculator only learns New Information with probability $\gamma^*(\beta)$.

Combined with Lemma 1, we reach the result in Lemma 3.

$$\frac{dE[G]}{d\beta} = \frac{g\sigma_{\widetilde{m}}^2}{4}\frac{d\gamma^*(\beta)}{d\beta} < 0. \tag{3}$$

Equation (3) describes how disclosure affects the firm's investment efficiency through the informational feedback effect of the stock price. Disclosure reduces investment efficiency because it reduces the information acquisition by the speculator (Lemma 1) and thus reduces the learning from the stock price by the firm.

Equation (3) also reveals that two parameters capture the intensity of the informational feedback effect of the stock price in our model. First, recall g captures the relative importance of the growth opportunity to the firm. The larger g is, the more valuable the growth opportunity is. Setting $g = 0$ means that the firm does not have a growth opportunity. As a result, the informational feedback effect is absent and disclosure does not affect the ex ante value of growth opportunity of the firm ($\frac{dE[G]}{d\beta} = 0$ when $g = 0$). Second and similarly, σ_m^2 captures how much the firm can learn about profitability (μ) from the stock price. The higher σ_m^2 is, the more the firm relies on the stock price to make its investment decision. Setting $\sigma_m^2 = 0$ means that the firm has nothing to learn from the stock prices and thus the informational feedback effect disappears. Again, disclosure has no effect on the value of the growth opportunity ($\frac{dE[G]}{d\beta} = 0$ when $\sigma_m^2 = 0$).

We are ready to state the main result of the paper by collecting the results in Lemma 2 and 3.

Proposition 1 *The optimal disclosure policy trades off the two countervailing effects of disclosure on the liquidity cost and on the investment efficiency, in addition to the direct disclosure cost. That is, the optimal disclosure policy is determined by the following first order condition.*

$$\frac{d}{d\beta}P_1(\beta) = \underbrace{(-\frac{d\pi(\beta)}{d\beta})}_{\text{marginal benefit of disclosure}} - \underbrace{(-\frac{dE[G(\beta)]}{d\beta} + \beta w)}_{\text{marginal cost of disclosure}} \tag{4}$$

The significance of Proposition 1 could be understood from two perspectives. From the perspective of the firm's learning from the stock price, Proposition 1 makes the point that the informational feedback role of the stock price is not provided to the firm for free. Even though the stock price is public information, its informativeness is ultimately sustained by the private incentive of the speculator in equilibrium. This point extends the main insight in Grossman and Stiglitz (1980) and Verrecchia (1982) because we explicitly model how the information in the stock price improves allocational efficiency. With this refined model we show that it is the New Information in the price that improves the investment efficiency. When the firm discloses its own information to the secondary market, the stock price could become more informative to outsiders. But this increase in the informational efficiency of the stock price does not necessarily improve the firm's investment efficiency because the firm does not learn anything new. Therefore, the relation between the informational efficiency and allocational efficiency of the stock price depends on the specifics of the decision problems and should not be taken as granted.

The other perspective on Proposition 1 is that disclosure or a leveled playing-filed has an endogenous consequence. When the information acquisition by the speculator has positive social value, the value maximizing disclosure policy is pulled back from fully addressing the liquidity concern in order to stimulate the speculator's informative acquisition. Interpreting "investor protection" narrowly as leveling the playing-ground could have an unintended consequence for disclosure policies.

Before we characterize the optimal disclosure policy in next section, we highlight how our extended theory of disclosure reconciles corporate disclosure policy with other institutional features of the stock market. For example, our theory justifies why a well-functioning stock market promotes disclosure on one hand and encourages speculative information acquisition on the other hand. If the adverse selection were the *only* concern in the secondary stock market, a positive theory of disclosure would predict two categories of solutions. One is to use disclosure to directly reduce the informed investors' information advantage; the other is to *increase* the cost of information acquisition so as to indirectly discourage investors from seeking informative advantage. The latter is not consistent with the practice of corporate policy and securities regulation. This inconsistency is reconciled by our model.

Corollary 1 *Assume that the firm's optimal disclosure policy is interior, that is,* $0 < \beta^* < 1$*. Firm value increases in the cost of information acquisition if and only if the informational feedback effect is sufficiently small. That is, there exists a cutoff value* g^*

(or σ_m^*) such that

$$\frac{d}{dc}P_1 > 0 \quad \textit{if } g < g^* \textit{ (or } \sigma_m < \sigma_m^*\textit{)}$$
$$\frac{d}{dc}P_1 < 0 \quad \textit{if } g > g^* \textit{ (or } \sigma_m > \sigma_m^*\textit{)}$$

From the perspective of the liquidity provision role of the secondary stock market, the trading-profit-driven information acquisition by the speculator is a social waste. It merely redistributes wealth among investors at some cost and the cost is eventually borne by the firm. This explains why firm value increases in c when liquidity cost is the primary concern to the firm (i.e., g or σ_m are sufficiently small).

In contrast, from the perspective of the informational feedback role of the secondary stock market, the same information acquisition by the speculator generates unintended social benefit by improving the firm's investment efficiency. As a result, the firm value decreases in the information acquisition cost when the informational feedback role of the stock price is sufficiently strong. Further, as we will discuss in detail in Section 6, even as private information acquisition increases firm value over the high g (or σ_m) range, the equilibrium information acquired by the speculator is still lower than the socially desirable level.

5 Determinants of the Optimal Disclosure Policy

The main trade-off firms face in determining optimal disclosure policy (captured by equation 4) reveals two types of factors determine the optimal disclosure quality. First, factors that increase the value of the growth opportunity or the value of the informational feedback effect create incentives for firms to reduce disclosure quality, in order to preserve the speculator's incentive to acquire New Information. Second, factors that improve the speculator's incentive to acquire information release the burden on firm disclosure, resulting in higher disclosure quality to address the adverse selection problem. Next, we analyze these two types of factors in turn.

5.1 Growth and Disclosure Quality

We first turn to the notion of firm growth and disclosure. Consider a commonly used empirical growth metric: market-to-book ratio. In our model, a close theoretical counterpart is

$$GROWTH \equiv \frac{E[A]+E[G]}{E[A]} = 1 + \frac{g^2(\frac{\sigma_m^2}{2}\gamma + \sigma_f^2)}{A_0}$$

The denominator, the value of the asset in place, is best proxied by book value, and the numerator, the value of the entire firm, is proxied by the market values of both AIP and growth opportunity. The liquidity cost is excluded from the numerator to avoid the endogeneity problem. Intuitively, variable $GROWTH$ measures the importance of growth opportunity relative to the value of the AIP. The following proposition relates independent variables affecting the $GROWTH$ measure (i.e., g, σ_m^2, and σ_f^2) to endogenous corporate disclosure policy (β).

Proposition 2 *Assume that the firm's optimal disclosure policy is interior, that is,* $0 < \beta^* < 1$. *Ceteris paribus,*

1. *firms with more growth prospect (higher g) disclose less than firms with less growth prospect (lower g).*
2. *firms whose growth depends more on New Information $\widetilde{m}$ (higher σ_m^2) disclose less than firms whose growth depends less on $\widetilde{m}$;*
3. *firms whose growth depends more on Firm Information $\widetilde{f}$ (higher σ_f^2) disclose more than firms whose growth depends less on $\widetilde{f}$.*

While growth prospect g does not directly affect the speculator's trading profit given her information acquisition, but as g increases, New Information $\widetilde{m}$ becomes more valuable for the firm. Thus, firms reduce disclosure quality to make the information acquisition by the speculator more profitable and thus induce her to acquire more information. This result uses informational feedback effect to explain why growth firms are generally less transparent than value firms cross-sectionally.

Variable σ_m^2 affects both the value of New Information to the firm and the trading profit of the speculator. On one hand, as σ_m^2 increases, the speculator's information acquisition becomes more profitable because her information gives her a bigger informational advantage ($\frac{\partial Q}{\partial \sigma_m^2} > 0$). This leads to a higher liquidity cost for the firm and induces the firm to improve disclosure quality. On the other hand, an increase in σ_m^2 also increases the marginal benefit of learning by the firm and induces the firm to reduce disclosure quality to encourage more information acquisition. In equilibrium, the second effect dominates. An increase in σ_m^2 leads to lower disclosure quality. The overall firm value is improved even though disclosure quality and equilibrium liquidity of the firm are lower.

Variable σ_f^2 presents a different picture. As with an increase in σ_m^2, an increase in σ_f^2 gives the speculator a larger informational advantage and thus induces the firm to disclose more. Unlike the σ_m^2 case, the firm already possesses Firm Information and need not re-learn $\widetilde{f}$ from stock price. As a result, the firm commits to higher disclosure policy when σ_f^2 increases.

Proposition 2 adds new predictions for the relation between growth and disclosure policy. Two often cited factors that relate growth to disclosure policy are future financing needs and the nature of its information. Growth firms have incentive to disclose more because they expect to access the market for financing more often in the future, but their disclosure quality might be low because the information about growth firm is inherently more difficult to collect and disclose. We hold constant the financing needs and the quality of information the firm could collect and provide new predictions on the subtle disclosure tendencies motivated by the informational feedback effect. Our model predicts that different characteristics of growth leads to different types of disclosure policy. Both σ_m^2 and σ_f^2 indicate higher growth prospect of the firm but they prescribe opposite disclosure policy. It is crucial to understand the source of a firm's growth in order to specify the relation between growth and disclosure quality correctly. Finally, our model points out that the endogenous nature of growth itself as the value of the growth opportunity depends on firms' disclosure policy through firms' learning from the stock price.

5.2 Financial Development, Investor Protection, and Disclosure Quality

Optimal disclosure policy is also affected by environmental factors which affect the speculator's incentive to acquire information. Now we examine the impact of model parameters c and σ_n^2 on the equilibrium disclosure quality.

Proposition 3 *Assume that the firm's optimal disclosure policy is interior, that is,* $0 < \beta^* < 1$*. Ceteris paribus,*

1. *equilibrium disclosure quality (β^*) is decreasing in information acquisition cost c;*
2. *equilibrium disclosure quality (β^*) is increasing in liquidity demand variance σ_n^2.*

As discussed earlier, lowering information acquisition cost increases the speculator's incentive to acquire information, leading to larger information advantage and thus a more severe adverse selection problem in the secondary market. At the same time, lowering does not affect the marginal benefit of firms learning (for a given γ). So more information acquisition makes it more likely for the firm to learn New Information from the stock price. Overall, the shift in the firm's trade-off releases its burden to distort disclosure policy to incentivize the speculator to acquire information. As a result, the firm raises disclosure quality to better address the more severe adverse selection problem. Similarly, an increase in the size of liquidity trade (σ_n^2) in a market reduces the speculator's price impact and makes her information acquisition more profitable. Thus, the speculator's incentive enhanced by a higher σ_n^2 substitutes for the incentive provided the distortion in the disclosure policy. From the firm's perspective, a higher σ_n^2 subsidizes the production cost of New Information. Therefore, firm also raises disclosure quality in response to a higher σ_n^2.

We interpret these two results as providing an endogenous link between disclosure quality to the financial development or investor protection at the country-level. Consider parameter c first, this parameter reflects the difficulty for market participants to acquire information and to profit from acquired information. A large literature has established that a lower cost of information acquisition (thus higher level of information acquisition) is a measure of better respect for private properties and investor protection (Morck, Yeung, and Yu (2000)).[5] Under this interpretation, legal protection improves the incentive of the speculator to acquire costly information and serve as a substitute for using the distorted disclosure policy to provide incentive for the speculator. Thus, this result supports often-claimed assertion that higher country-level disclosure quality is associated with stronger investor protection.

Now consider parameter σ_n^2, this parameter measures the investors' liquidity needs, which can serve as a proxy for the financial development of an economy because a developed market with better investor protection attracts investors to rely more on the stock market for their liquidity needs. Under this interpretation, our result is also consistent with the observed higher disclosure quality in countries with higher financial development or investor protection. Combined, these two model predictions are consistent with the country-level empirical analysis linking disclosure quality and investor protection.

[5] When the respect for properties rights by the government is poor, market participants have less incentive to acquire information about the fundamentals for at least two reasons. First, in an economy with poor respect for property rights the value of an asset or a firm is influenced by political risk more than by the fundamentals. Often as outsiders the market participants' competative advantage is in producing information about the fundamentals rather than about the polictical risk. Second, the market participants are more uncertain about whether they will be able to generate profit on their inforamtion acquisition or they will be able to keep the profit from trading on their information acquisition. When such trading profit is at odds with the interest of the entrenched parties, the risk of losing the trading profit becomes even higher. Investor protection works in the same way except that now the policital risk is created by the uncontained opportunisim of the corporate insiders. When corporate insiders could appropriate firm resources, the correlation between the information about the firm fundamentals and about the future return to outsider investors become weaker and thus the value of information acquisition is diminished. At the firm level, the investors protection could also be interpreted as corporate govenance.

6 Who is the most Efficient Information Provider?

We have made the point that the information production by the stock price is not for free. Eventually the firm pays for the information it learns from the stock price in the form of a higher liquidity cost. To understand better the mechanism of information production by the secondary stock market we compare it with two other hypothetical mechanisms of information production. First, the firm produces information about $\widetilde{m}$ with the same technology as the speculator. Second, the firm hires a consultant who has the same technology but the firm cannot contract with the consultant directly on the information production. These two cases are hypothetical because we have assumed in our baseline model that the speculator has monopoly in producing information about $\widetilde{m}$.

Proposition 4 *If the firm could use the same technology the speculator has to acquire information about $\widetilde{m}$, the firm chooses γ^{FB}. Compared with this first best case the information production in our baseline model is either too low or too high.*

This stark result reveals the second-best nature of the information production through the secondary stock market. The efficiency loss originates from the misalignment of the speculator's private incentive with the firm's. The speculator's interest in trading profit is not congruent with the firm's interest of improving investment efficiency. As a result, there is a wedge between the marginal benefit of information production for the firm (the social value) and for the speculator (private value). Since we focus on the price of the claim to the terminal cash flow from the asst-in-place, the private value of the information about $\widetilde{m}$ for trading purpose in our model is kept constant for a disclosure quality. However, the social value of information about $\widetilde{m}$ depends on the importance of the growth opportunity. Since the private value of the information about $\widetilde{m}$ is invariant to its social value, the private incentive produces too little information when it is needed and too much information when it is not needed.

Second, if the firm could hire a consultant with the same information production technology but the information production by the consultant is not contractible, we obtain a typical agency problem. Even without the detail of the contractual relationship the agency theory predicts that the equilibrium production of information is lower than the first-best level in Proposition 4. The wedge stems from the agency cost in the employment relationship. The comparison with our baseline case depends on the available technology for contracting. This comparison reveals that the market mechanism through which the speculator is incentivized to acquire information could be viewed as a special agency mechanism where the contracting instrument is limited only to the trading profit.

Given the constraint that the firm does not have competitive advantage in producing certain types of information for its investment decision, whether the firm relies on the market to produce information through the disclosure policy or relies on direct contracting depends on the specifics of these two mechanisms. For example, the advantage of the market mechanism is to provide a venue for whoever good at information production to supply her talents to the firm. In other words, the market could find the firm the best "consultant" without extra search cost. For another instance, information production that suffers severe moral hazard problem is more likely to be produced by the market. The use of prediction market to generate forward looking information, like those employed at large, decentralized firms such as Hewlett-Packard, Microsoft, and Google, is a good example. The relative competitive advantage of different mechanisms of information production warrants further investigation.

7 Extension: Does it Matter that Who Learns?

In this section, we expand the discussion on the informational feedback effect. We emphasize that the basic trade-off between the informational feedback effect and level-the-playing-field effect exists even if it is not the firm who learns the information in the stock price. As long as the information in the stock prices influnces any decisions that affect firm value, the informational feedback effect exists and the firm's disclosure policy will consider the effect of disclosure on the production of information in the stock price. Examples of such decisions include:

- New equity investors decide how much they are willing to pay in a Seasoned-Equity-Offering that determines the cost of capital and affects the investment level the firm could take;
- Competitive lenders decide how much additional capital to provide or withdraw (to call an existing loan);
- Employees decide their private investment in firm-specific human capital;
- Supplier and custmors decide their relationship investment with the firm.

A common feature of these examples is that more information available at date 3 improves the firm value through these decisions. In the first example, the stock price directly affects the investment level of the firm and thus the firm value. Thus it is difficult to differentiate the informational feedback effect from the financial constraint of the firm. In the second example the firm value is improved not directly by the lower cost of equity implied by the higher stock price, but it is still related to the financial constraint of the firm. More broadly, the capital needs of the firm is not necessary for the informational feedback effect. In the third and fourth examples, the firm value reponds to the information in the stock price because it affects the decisions of employees and other stakeholders, not because information relaxes the financial constraint of the firm.

The main intuition that the firm's disclosure policy faces a trade-off remains for these examples. The main difference in details is that disclosure takes on an additional role. When the decision maker is the firm, disclosure reduces the information advantage of the speculator. The firm does not learn any new information from the disclosure because the firm could use undisclosed information in its investment decision. When the decision maker is not the firm, disclosure itself provides new information to the decision maker. While the firm knows $\widetilde{f}$ regardless of disclosure quality and stock price informativeness, the outside decision maker learns about $\widetilde{f}$ both from the disclosure x and the stock price.

Moreover, we can extend the model to consider a special case where it is the competitors who learn from disclosure and stock price before making their decision which could reduce the value of the disclosing firm (Verrecchia (1983), Dye (1986) and Gigler (1994)). With the private incentive for information production this extension adds a novel perspective to the literature on proprietary cost of disclosure. That is, more disclosure could lower proprietary cost, a similar result to Arya and Mittendorf (2005) but with a different mechanism. Even though disclosure provides information to the competitors, it also reduces the speculator's incentive to acquire information that the competitors could learn from the stock price. There are conditions under which the overall information learned by the competitors is lower with more disclosure by the firm.

8 Conclusion

In this paper, we present a positive theory of corporate disclosure policy which balances the concerns for reducing adverse selection and the concerns for encouraging information production, both in the secondary stock market. The key feature is the informational feedback effect of the stock price. The main insight from our analyses is that such an effect generates an endogenous cost to corporate disclosure. The many comparative statics results correspond to the institutional features and empirical results in the literature.

The main conclusion of the study is that market can serve an irreplaceable role of information production and transmission in an economy and as such, it is a strength of a market-based economic system. Further, this particular role is more prominent and more valuable in an economy where cost of information acquisition is low (better legal protection of property right or corporate governance) and the growth of the economy depends more on information outside the firm (an open and entrepreneurial economy). Finally, corporate disclosure is critically important in how market serves this information role because disclosure policies affect and are affected by the information production and transmission by the market.

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Appendix

8.1 Proof of Lemma 1 and 2

First, we solve for the secondary-market trading game at date 2. It is a standard Kyle model with one speculator, one market-maker, and one liquidity trader. The terminal value of the claim is

$$\widetilde{A} = A_0 + \widetilde{f} + \widetilde{m}$$

The speculator's private information is

$$\widetilde{y} = \begin{cases} \varnothing & \text{with probability } 1-\gamma \\ \widetilde{f} + \widetilde{m} & \text{with probability } \gamma \end{cases}$$

Public disclosure, known to both market-maker and speculator, is

$$\tilde{x} = \widetilde{f} + \tilde{\varepsilon}_x$$

All three random variables, $\widetilde{f}$, $\widetilde{m}$, and $\tilde{\varepsilon}_x$, are zero-mean, normal and independent of each other with variances σ_f^2, σ_m^2 and σ_x^2, respectively.

Using standard solution techniques for Kyle-model, we arrive at the following results (details available upon request).

- When the speculator receives an informative signal, the market-maker, for a given public disclosure x and total order flow D, sets market price as $P_1 = E[\mu|D] = \beta x + \lambda D$

  After solving the model,

$$\lambda = \frac{1}{2}\frac{Q}{\sigma_n}, Q \equiv \sqrt{\sigma_m^2 + (1-\beta)\sigma_f^2} \tag{5}$$

- For a given quality of her private information γ, the speculator's expected profit is

$$\pi(\gamma) = \frac{\sigma_n}{2}\gamma Q + (1-\gamma) * 0 = \frac{\sigma_n}{2}\gamma Q$$

- Ex Ante, the above expected profit is a transfer from the liquidity traders to the speculators (given market-maker breaks even). As a result, the expected loss to the liquidity traders is also equal to $\pi(\gamma)$.

Second, we derive the optimal private information acquisition by the speculator. The speculator chooses γ to maximize $\pi - \frac{c}{2}\gamma^2$, resulting in a first-order-condition (FOC):

$$\frac{\sigma_n}{2}Q - c\gamma^*(\beta) = 0 \Rightarrow \gamma^*(\beta) = \frac{\sigma_n}{2c}Q$$

with the second-order-condition (SOC), $-c < 0$, satisfied. Note that $\gamma^*(\beta)$ is always non-negative. We also need to make sure that $\gamma^* \leq 1$. A sufficient condition is that $\frac{\sigma_n}{2c}\sqrt{\sigma_f^2 + \sigma_m^2} \leq 1$.

Lemma 1 is proved because $\frac{\partial \gamma^*(\beta)}{\partial \beta} = -\frac{\sigma_n}{2c}Q_\beta < 0$.

Lemma 2 is proved because $\frac{d\pi}{d\beta} = \frac{\sigma_n}{2}Q\frac{\partial \gamma^*(\beta)}{\partial \beta} + \frac{\sigma_n}{2}\gamma\frac{\partial Q}{\partial \beta} < 0$

8.2 Proof of Lemma 3

Now we analyze the firm investment decision on date 3. The firm chooses K to maximize expected value of G given information available to the firm Ω, resulting in the first-order-condition (FOC):

$$E[\mu|\Omega] - K/g = 0 \Rightarrow K = gE[\mu|\Omega] \Rightarrow E[G|\Omega] = \frac{g}{2}\left(E[\mu|\Omega]\right)^2$$

with the second-order-condition (SOC), $\frac{\partial}{\partial K}(E[G|\Omega]) < 0$, satisfied. Notice

$$\Omega = \begin{cases} \Omega_1 \equiv \widetilde{f} & \text{with probability } 1 - \gamma^*(\beta) \\ \Omega_2 \equiv \{\widetilde{f}, \widetilde{P_1}(D)\} & \text{with probability } \gamma^*(\beta) \end{cases}$$

When the speculator does not receive an informative signal and thus the stock price contains no speculator's information (i.e., $\Omega = \Omega_1$), which happens with probability $1 - \gamma^*(\beta)$, the value of the growth option is

$$E_{\Omega_1}[E[G|\Omega_1]] = \frac{g}{2} E_{\widetilde{f}}[\left(E[\mu|\widetilde{f}]\right)^2] = \frac{g}{2}\sigma_f^2$$

When the speculator does receive an informative signal and thus the stock price contains speculator's information (i.e., $\Omega = \Omega_1$), which happens with probability $\gamma^*(\beta)$, the value of the growth option is

$$E_{\Omega_2}[E[G|\Omega_2]] = \frac{g}{2} E_{\widetilde{f}}[\left(E[\mu|\widetilde{f}, P_1]\right)^2] = \frac{g}{2}\left(\frac{\sigma_m^2}{2} + \sigma_f^2\right)$$

Combined, the unconditional expected value of the growth option at date 0 is

$$E[G] = \frac{g}{2}\left(\frac{\sigma_m^2}{2}\gamma^*(\beta) + \sigma_f^2\right)$$

Lemma 3 is proved because

$$\frac{dE[G]}{d\beta} = \frac{g\sigma_m^2}{4}\frac{d\gamma^*(\beta)}{d\beta} < 0.$$

8.3 Proof of Proposition 1 and Corollary 1

For notation, we define $X_Y \equiv \frac{\partial X}{\partial Y}, X_{YY} \equiv \frac{\partial^2 X}{\partial Y^2}$.

Proposition 1 collects the results from Lemma 2 and 3.

We now analyze the firm disclosure choice (β) at date 1. The date-1 expected payoff to the firm is

$$\begin{aligned} P_1(\beta) &= E[A] + E[G(\beta)] - \pi(\beta) - \frac{w}{2}\beta^2 \\ &= A_0 + \frac{g\sigma_f^2}{2} + \frac{g\sigma_m^2\sigma_n}{8c}Q(\beta) - \frac{\sigma_n^2}{4c}Q^2(\beta) - \frac{w}{2}\beta^2 \end{aligned}$$

Maximizing $P_1(\beta)$ produces a FOC,

$$P_\beta \equiv \frac{\partial P_1}{\partial \beta} = \frac{\sigma_n \sigma_f^2}{16cQ}(4\sigma_n Q - g\sigma_m^2) - w\beta \tag{6}$$

The second order condition is always satisfied because

$$P_{\beta\beta} \equiv \frac{\partial^2 P_1}{\partial \beta^2} = \frac{g\sigma_m^2 \sigma_n}{8c} Q_{\beta\beta} - w < 0 \tag{7}$$

Since $\frac{\partial^2 P_1}{\partial \beta^2} < 0$, to make sure β be interior, we need

$$P_1|_{\beta=0} > 0, \quad \text{and } P_1|_{\beta=1} < 0$$

which are equivalent to the following two Regularity Conditions:

$$\begin{aligned} g\sigma_m^2 &< 4\sigma_n\sqrt{\sigma_m^2 + \sigma_f^2} && \text{(Regularity: Beta>0)} \\ w &> \frac{\sigma_n \sigma_f^2}{16c}(4\sigma_n - g\sqrt{\sigma_m^2}) && \text{(Regularity: Beta<1)} \end{aligned}$$

When these two regularity conditions are satisfied, the first-order condition is equal zero and β is interior. Rewriting the first-order condition, we have an expression for $g\sigma_m^2$

$$g\sigma_m^2 = 4\sigma_n Q - w\beta \frac{16cQ}{\sigma_n \sigma_f^2} \tag{8}$$

Now we compute comparative statics of P_1 with respect to c. By envelope theorem and equation 8,

$$\frac{dP_1}{dc} = \frac{\sigma_n Q}{8c^2}(2\sigma_n Q - g\sigma_m^2) = \frac{\sigma_n^2 Q^2}{4c^2}\left(\frac{8wc}{\sigma_n^2 \sigma_f^2}\beta - 1\right)$$

Thus, $Sign[\frac{dP_1}{dc}] = Sign[\frac{8wc}{\sigma_n^2\sigma_f^2}\beta - 1]$

As we will show in the proof of Proposition 2, $\beta_g < 0, \beta_{\sigma_m^2} < 0$. Thus, $\frac{8wc}{\sigma_n^2\sigma_f^2}\beta - 1$ is decreasing in g or σ_m^2.

Further, as $g\sigma_m^2 -> 0$ from above, $\frac{8wc}{\sigma_n^2\sigma_f^2}\beta - 1 = \frac{\frac{dP_1}{dc}}{\frac{\sigma_n^2 Q^2}{4c^2}} \to 1 > 0$;

As $g\sigma_m^2 -> 4\sigma_n\sqrt{\sigma_m^2 + \sigma_f^2}$ from below, $\frac{8wc}{\sigma_n^2\sigma_f^2}\beta - 1 = \frac{\frac{dP_1}{dc}}{\frac{\sigma_n^2 Q^2}{4c^2}} \to 1 - \frac{2\sqrt{\sigma_m^2 + \sigma_f^2}}{Q} < 0$.

By the Intermediate Value Theorem, there exists a cutoff value g^* (or σ_m^*) such that

$$\begin{aligned}\frac{d}{dc}P_1 &> 0 \quad \text{if } g < g^* \text{ (or } \sigma_m < \sigma_m^*) \\ \frac{d}{dc}P_1 &< 0 \quad \text{if } g > g^* \text{ (or } \sigma_m > \sigma_m^*)\end{aligned}$$

This proves Corollary 1.

8.4 Proof of Propositions 2 and 3

We return to the FOC

$$P_\beta = \frac{\sigma_n \sigma_f^2}{16cQ}(4\sigma_n Q - g\sigma_m^2) - w\beta^* = 0$$

Now we compute the comparative statics result on optimal disclosure quality (β) by differentiating the above FOC with respect to exogenous variables.

$$\begin{aligned}\frac{d\beta^*}{dg} &= \frac{\frac{\sigma_n\sigma_m^2}{8c}Q_\beta}{w - \frac{g\sigma_n\sigma_m^2}{8c}Q_{\beta\beta}} < 0 \\ \frac{d\beta^*}{d\sigma_f^2} &= \frac{\frac{\sigma_n^2}{4c}}{w - \frac{g\sigma_n\sigma_m^2}{8c}Q_{\beta\beta}} > 0 \\ \frac{d\beta^*}{d\sigma_m^2} &= \frac{\frac{g\sigma_n\sigma_f^2}{32cQ^3}(\sigma_m^2 - 2(\sigma_m^2 + (1-\beta^*)\sigma_f^2)}{w - \frac{g\sigma_n\sigma_m^2}{8c}Q_{\beta\beta}} < 0\end{aligned}$$

The same denominator is positive because the SOC (expression 7) is satisfied. In addition, the numerator of $\frac{d\beta^*}{dg}$ is negative because $Q_\beta < 0$. This proves Proposition 2.

On c and σ_n,

$$\frac{d\beta^*}{dc} = \frac{\frac{\sigma_n\sigma_f^2}{16Qc^2}(g\sigma_m^2 - 4\sigma_n Q)}{w - \frac{g\sigma_n\sigma_m^2}{8c}Q_{\beta\beta}} < 0$$

The numerator is negative due to the regularity condition (Regularity: Beta>0) that ensures $\beta > 0$.

$$\frac{d\beta^*}{d\sigma_n} = \frac{\frac{4w\beta^*}{\sigma_n} + \frac{\sigma_n\sigma_f^2}{c}}{w - \frac{g\sigma_n\sigma_m^2}{8c}Q_{\beta\beta}} > 0$$

This proves Proposition 3.

8.5 Proof of Propositions 4

We label it the First-Best case when the firm has access to the same information technology as the speculator. In this case optimal γ is chosen to maximize

$$E[G^{FB}] - c\gamma = \frac{g}{2}\sigma_f^2 + \gamma\frac{g}{2}\sigma_m^2 - \frac{c}{2}\gamma^2$$

The first-order condition is:

$$\gamma^{FB} = \frac{g}{2c}\sigma_m^2 \tag{9}$$

Compare this with the equilibrium information in our baseline model

$$\gamma^* = \frac{\sigma_n Q}{2c}$$

The difference in the information acquisition after substituting equation 6 is

$$\gamma^* - \gamma^{FB} = \frac{1}{2c}\left(\sigma_n Q - g\sigma_m^2\right) = \frac{g\sigma_m^2}{8c\left(1 - \frac{4c\beta w}{\sigma_n^2\sigma_f^2}\right)}\left(\frac{16cw}{\sigma_n^2\sigma_f^2}\beta - 3\right)$$

Since $\sigma_n Q = \frac{g\sigma_m^2}{4(1-\frac{4c\beta w}{\sigma_n^2\sigma_f^2})} > 0$, $Sign[\gamma^* - \gamma^{FB}] = Sign[\frac{16cw}{\sigma_n^2\sigma_f^2}\beta - 3]$.

Since $\beta_g < 0$ and $\beta_{\sigma_m} < 0$, $\frac{16cw}{\sigma_n^2\sigma_f^2}\beta - 3$ is decreasing in $g\sigma_m^2$.

Consider the two extremes on $g\sigma_m^2$:

As $g\sigma_m^2 \to 0$, $\frac{16cw}{\sigma_n^2\sigma_f^2}\beta - 3 = \frac{8c\left(1-\frac{4c\beta w}{\sigma_n^2\sigma_f^2}\right)}{g\sigma_m^2}\frac{1}{2c}\left(\sigma_n Q - g\sigma_m^2\right) \to \frac{8c\left(1-\frac{4c\beta w}{\sigma_n^2\sigma_f^2}\right)}{g\sigma_m^2}\frac{1}{2c}\sigma_n Q > 0.$

As $g\sigma_m^2 \to 4\sigma_n\sqrt{\sigma_m^2+\sigma_f^2}$, $\frac{16cw}{\sigma_n^2\sigma_f^2}\beta - 3 = \frac{8c\left(1-\frac{4c\beta w}{\sigma_n^2\sigma_f^2}\right)}{g\sigma_m^2}\frac{1}{2c}\left(\sigma_n Q - g\sigma_m^2\right) \to \frac{8c\left(1-\frac{4c\beta w}{\sigma_n^2\sigma_f^2}\right)}{g\sigma_m^2}\frac{1}{2c}(Q - 4\sqrt{\sigma_m^2+\sigma_f^2}) < 0.$

By the Intermediate Value Theorem, there exists a threshold g^{**} (or σ_m^{**}) such that

$$\begin{aligned} \gamma^* - \gamma^{FB} &< 0 \quad \text{if } g > g^{**} \text{ or } \sigma_m > \sigma_m^{**}; \\ \gamma^* - \gamma^{FB} &> 0 \quad \text{if } g < g^{**} \text{ or } \sigma_m < \sigma_m^{**}. \end{aligned}$$

This completes the proof of Proposition 4.