

# Information Disclosure in Financial Markets

Itay Goldstein and Liyan Yang\*

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## Abstract

Information disclosure is an essential component of regulation in financial markets. In this article, we provide a cohesive analytical framework to review a few key channels through which disclosure in financial markets affects market quality, information production, efficiency of real investment decisions, and traders' welfare. We use our framework to cover four main aspects. First, we demonstrate the conventional wisdom that disclosure improves market quality in an economy with exogenous information. Second, we illustrate that disclosure can crowd out the production of private information, and that its overall market-quality implications are more subtle and depend on the specification of information-acquisition technology. Third, we review how disclosure affects the efficiency of real investment decisions when financial markets are not just a side show, as real decision makers can learn information from them to guide their decisions. Last, we discuss how disclosure in financial markets affects investor welfare through changing trading opportunities and through beauty-contest motives. Overall, our review suggests that information disclosure is an important factor for understanding the functioning of financial markets and that there are several trade-offs that need to be considered in determining its optimal level.

**Keywords:** disclosure, market quality, crowding-out effect, learning from prices, real efficiency, welfare

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\***Itay Goldstein:** Department of Finance, Wharton School, University of Pennsylvania, Philadelphia, PA 19104; Email: itayg@wharton.upenn.edu; Tel: 215-746-0499. **Liyan Yang:** Department of Finance, Joseph L. Rotman School of Management, University of Toronto, 105 St. George Street, Toronto, Ontario M5S 3E6; Email: liyan.yang@rotman.utoronto.ca; Tel: 416-978-3930. We thank the editor, Thierry Foucault, Pierre Jinghong Liang, Marco Pagano, Haresh Sapra, Joel Shapiro, and Zhuo Zhong for comments and suggestions. Yang thanks the Social Sciences and Humanities Research Council of Canada for financial support.

# 1 Introduction

Disclosure of information in financial markets is at the forefront of regulatory efforts to improve financial market quality and stability. Greenstone et al. (2006) write that: “Since the passage of the Securities Act of 1933 and the Securities Exchange Act of 1934, the federal government has actively regulated U.S. equity markets. The centerpiece of these efforts is the mandated disclosure of financial information.” These efforts have been very prominent more recently with the Sarbanse-Oxley Act of 2002 and the Dodd-Frank Act of 2010 emphasizing various aspects of improved disclosure. For example, the Sarbanes-Oxley Act was passed as an “act to protect investors by improving the accuracy and reliability of corporate disclosures made pursuant to the securities laws, and for other purposes.”

Disclosure regulation comes in different forms and affects different activities. Over time, firms are required to disclose more information about their operations and financial activities to their investors in the financial reports. Similarly, investors are required to disclose information about their holdings in firms which may pertain to activism or acquisitions intentions that ultimately affect firm value. Moreover, improved quality of public information is also achieved by increasing the reliability of credit ratings and by greater disclosure of macro-economic and industry-related information. Recently, following the financial crisis of 2008, governments increased the amount of disclosure available on banks by conducting annual stress tests and making their results publicly available. This has led to significant public debate (see, Goldstein & Sapra, 2013).

The academic literature is quite ambiguous about the effects of disclosure and its overall desirability. It is well understood that disclosure can potentially promote some important goals: By leveling the playing field in financial markets, it can increase market liquidity and market efficiency, and decrease the cost of capital for firms. However, a lot has been written about potential unintended consequences of disclosure, which occur due to the crowding out of private information production, the destruction of risk sharing opportunities, or the promotion of destabilizing beauty-contest incentives. Given the flow of new regulations related to disclosure in recent years, researchers have been delving more and more into the topic trying to understand the pros and cons and answering key questions, such as: What

is the optimal level of disclosure in terms of promoting market quality and social welfare? What types of disclosure are more beneficial? In what circumstances is disclosure more desirable?

Our goal in this review article is to present the main forces that have been put forward in the literature in the discussion on the effects of disclosure in financial markets. Since this is a review of theoretical literature, we use a workhorse model that has been used extensively in the literature on information and disclosure in financial markets, and show how the main forces are manifested within this framework. We hope this will be useful to researchers who wish to build on existing theories in developing new ones, testing existing empirical implications, or understanding ongoing policy debates. We do not attempt an all-inclusive survey of the extant disclosure literature (some excellent surveys include Dye (2001), Verrecchia (2001), Kanodia (2006), Leuz & Wysocki (2008), and Kanodia & Sapra (2017)). Instead, we aim to organize a few leading forces within a cohesive analytical framework, such that the pros and cons of disclosure can be more easily sorted out and evaluated for different environments.

The structure of the review article is as follows. Section 2 presents the basic framework for studying information and disclosure in financial markets building on the work of Grossman & Stiglitz (1980), Hellwig (1980), and Verrecchia (1982a). We show basic results demonstrating how the increased precision of public information, which is achieved via enhanced disclosure, improves common measures of market quality. That is, we show that disclosure increases liquidity and market efficiency and decreases the cost of capital and return volatility. These results capture the usual intuition that guides regulators in imposing greater disclosure.

In Section 3, we extend the basic framework to endogenize the acquisition of private information by market participants building on work by Verrecchia (1982b), Diamond (1985), and others. We demonstrate the basic argument according to which increased disclosure leads to crowding out of private information acquisition. This implies that the effect of disclosure on market quality is more nuanced once private information is endogenized, and depends on the amount of information being disclosed, on the information acquisition technology, and on the measure of market quality being considered.

While the analysis in Sections 2 and 3 considers measures of market quality, these mea-

asures do not translate easily to a clear objective function to tell how much disclosure is desirable. Section 4 extends the framework to review papers that emphasize the role of the financial market in producing information that guides the decisions in the real side of the economy. This is in the spirit of the literature on the market feedback effect, which was reviewed by Bond et al. (2012). This enables the analysis of optimal disclosure in light of its effect on the efficiency of real investment decisions (e.g., Gao & Liang, 2013; Han et al., 2016). An interesting dimension revealed by papers in this realm of work is that the type of information being disclosed is key in determining whether disclosure is desirable or not (Bond & Goldstein, 2015; Goldstein & Yang, 2016).

Finally, Section 5 considers extensions of the basic framework that allow to study the effect of disclosure on the welfare of investors' in financial markets and pin down optimal disclosure as a result. While the traditional view is that disclosure enhances the welfare of investors, a classic result by Hirshleifer (1971) shows that disclosure destroys risk-sharing opportunities, and so is welfare reducing. More recently, Kurlat & Veldkamp (2015) suggested another way by which disclosure is bad due to reduction in trading opportunities. Another common argument for which disclosure can be harmful builds on beauty-contest incentives where investors all want to do the same thing. In such a case, greater precision of public information leads them to put too much weight on it, and so might reduce welfare (Morris & Shin, 2002).

## **2 A Basic Model of Information and Disclosure**

We start by briefly introducing a basic framework that will enable us to discuss the various effects of disclosure in financial markets in a unified way. We rely on the noisy-rational-expectations-equilibrium (noisy-REE) model, which is a workhorse model that has been used extensively in the literature on information and disclosure in financial markets. The model we describe in this section builds on early contributions by Grossman & Stiglitz (1980), Hellwig (1980), and Verrecchia (1982a). The model has the traditional CARA-normal feature; that is, traders have constant absolute risk aversion (CARA) preferences and all random variables are normally distributed.

## 2.1 Setup

There are two dates,  $t = 1$  and  $t = 2$ . At date 1, two assets are traded in a competitive financial market: a risk-free asset and a risky asset. The risky asset is usually thought of as equity issued by a firm, but it can also be other assets, e.g., corporate bonds. The risk-free asset has a constant value of 1 and is in unlimited supply. The risky asset pays an uncertain cash flow at the final date  $t = 2$ , denoted by  $\tilde{v}$ . We assume that  $\tilde{v}$  is normally distributed with a mean of 0 and a precision (reciprocal of variance) of  $\tau_v$ —that is,  $\tilde{v} \sim N(0, \tau_v^{-1})$ , with  $\tau_v > 0$ .<sup>1</sup> The risky asset is traded at an endogenous price  $\tilde{p}$  and has a fixed supply  $Q \geq 0$ .

There are three types of traders in the financial market: informed traders, uninformed traders, and liquidity traders. The first two types of traders have CARA utility over their date-2 wealth with a risk aversion coefficient of  $\gamma > 0$ . They can represent individuals or institutions who trade the risky asset. The total mass of the first two types of traders is 1, with a fraction  $\mu \in [0, 1]$  being informed traders and a fraction  $1 - \mu$  being uninformed traders. Prior to trading, informed trader  $i$  observes a private signal  $\tilde{s}_i$ , which contains information about fundamental value  $\tilde{v}$  of the risky asset in the following form:

$$\tilde{s}_i = \tilde{v} + \tilde{\varepsilon}_i, \text{ with } \tilde{\varepsilon}_i \sim N(0, \tau_\varepsilon^{-1}) \text{ and } \tau_\varepsilon > 0, \quad (1)$$

where  $(\tilde{v}, \{\tilde{\varepsilon}_i\}_{i \in [0, \mu]})$  are mutually independent. For now, we take both  $\mu$  and  $\tau_\varepsilon$  as exogenous. We will endogenize them later.

A common way to introduce disclosure into this model is to add a public signal  $\tilde{y}$  as follows:<sup>2</sup>

$$\tilde{y} = \tilde{v} + \tilde{\eta}, \text{ with } \tilde{\eta} \sim N(0, \tau_\eta^{-1}) \text{ and } \tau_\eta \geq 0. \quad (2)$$

For example,  $\tilde{y}$  can be thought of as announcements made by the firm about its future prospects or as economic statistics published by government agencies, central banks, or other parties (e.g., credit rating agencies). The precision  $\tau_\eta$  controls the quality of the public signal  $\tilde{y}$ , with a high value of  $\tau_\eta$  signifying that  $\tilde{y}$  is more informative about the asset cash flow  $\tilde{v}$  (i.e., more disclosure). This can be achieved by making more frequent announcements or by

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<sup>1</sup>We use a tilde ( $\tilde{\phantom{x}}$ ) to signify an exogenous random variable and use  $\tau$  to denote its precision (i.e., for a random variable  $\tilde{z}$ , we have  $\tau_z = \frac{1}{\text{Var}(\tilde{z})}$ ).

<sup>2</sup>See, e.g., Diamond (1985), Verrecchia (2001), Morris & Shin (2002), Hughes et al. (2007), and Lambert et al. (2007).

releasing more accurate data.<sup>3</sup> Much of our analysis is concerned with how the parameter  $\tau_\eta$  affects market outcomes. Note that we focus on the effect of ex-ante disclosure quality, in the sense of an improvement in the pre-committed precision of public information. We do not cover here strategic ex-post disclosure, where firms choose whether to disclose based on their signal, and this involves a signaling effect. There is a large literature that addresses these issues.<sup>4</sup> Also note that public information in equation (2) represents disclosure about fundamental information, and so we will not discuss the literature on market transparency, which explores the effect of disclosing information about trading positions and prices.<sup>5</sup>

Liquidity traders, also called “noise traders” in the literature, demand  $\tilde{x}$  units of the risky asset, where  $\tilde{x} \sim N(0, \tau_x^{-1})$  (with  $\tau_x \in (0, \infty)$ ) is independent of other shocks in the economy. Noise trading provides the randomness that makes the rational-expectations equilibrium partially revealing, which is crucial to sustain trading in equilibrium. In the baseline model, we take the size  $\tau_x^{-1}$  of noise trading as exogenous. We will endogenize it later on.<sup>6</sup>

## 2.2 Equilibrium

The equilibrium requires that (1) informed and uninformed traders choose investments in assets to maximize their expected utility conditioning on their respective information sets including the asset price  $\tilde{p}$ , the public signal  $\tilde{y}$ , and (for the informed traders) the private signal  $\tilde{s}_i$ ; (2) the markets clear such that the demand for the risky asset equals the exogenous supply  $Q$ ; and (3) informed and uninformed traders have rational expectations in the sense that their beliefs about all random variables are consistent with the true underlying distributions and equilibrium behaviors.

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<sup>3</sup>We assume that traders can costlessly interpret the public signal  $\tilde{y}$ . Some studies have considered settings in which traders can only extract a noisy version of  $\tilde{y}$  and their public data processing abilities can be different (e.g., Indjejikian, 1991; Pagano & Volpin, 2012; Di Maggio & Pagano, 2017).

<sup>4</sup>See, e.g., Grossman (1981), Milgrom (1981), Dye (1985), Jung & Kwon (1988), Acharya et al. (2011), and Guttman et al. (2014).

<sup>5</sup>See, for example, Madhavan (1995), Pagano & Röell (1996), Bloomfield & O’Hara (1999), Naik et al. (1999), and Huddart et al. (2001). Di Maggio & Pagano (2017) have considered the interactions between disclosure of fundamental information and transparency of the trading process.

<sup>6</sup>There are various ways to endogenize noise trading in asymmetric information models, such as endowment shocks (e.g., Diamond & Verrecchia, 1981; Diamond, 1985) or private investment opportunities (e.g., Wang, 1994; Easley et al., 2014).

Constructing a noisy-REE boils down to solving a price function that depends on the public information  $\tilde{y}$ , informed traders' private information  $\tilde{s}_i$ , and the noise trading  $\tilde{x}$ . By the law of large numbers, the noise terms  $\tilde{\varepsilon}_i$  in the private signals  $\tilde{s}_i$  will wash out, and thus we conjecture that the price  $\tilde{p}$  is a function of  $(\tilde{y}, \tilde{v}, \tilde{x})$ . The literature focuses on a linear price function of the form:

$$\tilde{p} = p_0 + p_y \tilde{y} + p_v \tilde{v} + p_x \tilde{x}, \quad (3)$$

where the  $p$ -coefficients are endogenously determined in equilibrium. We restrict attention to this form here.

Informed trader  $i$  has an information set  $\{\tilde{y}, \tilde{s}_i, \tilde{p}\}$ . The CARA-normal setup implies that the demand function of informed trader  $i$  is  $D_I(\tilde{y}, \tilde{s}_i, \tilde{p}) = \frac{E(\tilde{v}|\tilde{y}, \tilde{s}_i, \tilde{p}) - \tilde{p}}{\gamma \text{Var}(\tilde{v}|\tilde{y}, \tilde{s}_i, \tilde{p})}$ . For trader  $i$ , the information contained in the price is equivalent to the signal  $\tilde{s}_p$ :

$$\tilde{s}_p \equiv \frac{\tilde{p} - (p_0 + p_y \tilde{y})}{p_v} = \tilde{v} + \rho^{-1} \tilde{x}, \text{ with } \rho = \frac{p_v}{p_x}, \quad (4)$$

which is normally distributed, with mean  $\tilde{v}$  and precision  $\rho^2 \tau_x$ . Applying Bayes' rule to compute the conditional moments in the demand function, we can compute

$$D_I(\tilde{y}, \tilde{s}_i, \tilde{p}) = \frac{\tau_\varepsilon \tilde{s}_i + \tau_\eta \tilde{y} + \rho^2 \tau_x \tilde{s}_p - (\tau_v + \tau_\varepsilon + \tau_\eta + \rho^2 \tau_x) \tilde{p}}{\gamma}. \quad (5)$$

Similarly, an uninformed trader has an information set  $\{\tilde{y}, \tilde{p}\}$  and we can compute his demand function for the risky asset as follows:

$$D_U(\tilde{y}, \tilde{p}) = \frac{E(\tilde{v}|\tilde{y}, \tilde{p}) - \tilde{p}}{\gamma \text{Var}(\tilde{v}|\tilde{y}, \tilde{p})} = \frac{\tau_\eta \tilde{y} + \rho^2 \tau_x \tilde{s}_p - (\tau_v + \tau_\eta + \rho^2 \tau_x) \tilde{p}}{\gamma}. \quad (6)$$

The market-clearing condition is

$$\int_0^\mu D_I(\tilde{y}, \tilde{s}_i, \tilde{p}) di + (1 - \mu) D_U(\tilde{y}, \tilde{p}) + \tilde{x} = Q. \quad (7)$$

To derive the equilibrium price function, we insert (5) and (6) into (7) to solve the price in terms of the public signal  $\tilde{y}$ , the fundamental  $\tilde{v}$ , and the noise trading  $\tilde{x}$ , and then compare with the conjectured price function in equation (3) to obtain a system defining the unknown  $p$ -coefficients.

Solving this system yields the following result: For any  $\mu \in [0, 1]$  and  $\tau_\varepsilon \geq 0$ , there exists

a unique partially revealing noisy-REE, with price function (3), where

$$\begin{aligned}
 p_0 &= \frac{-\gamma Q}{\mu\tau_\varepsilon + \tau_v + \tau_\eta + \rho^2\tau_x}, p_y = \frac{\tau_\eta}{\mu\tau_\varepsilon + \tau_v + \tau_\eta + \rho^2\tau_x}, \\
 p_v &= \frac{\mu\tau_\varepsilon + \rho^2\tau_x}{\mu\tau_\varepsilon + \tau_v + \tau_\eta + \rho^2\tau_x}, \text{ and } p_x = \frac{\rho\tau_x + \gamma}{\mu\tau_\varepsilon + \tau_v + \tau_\eta + \rho^2\tau_x},
 \end{aligned} \tag{8}$$

with  $\rho = \frac{\mu\tau_\varepsilon}{\gamma}$ .

## 2.3 Market Quality and Disclosure

The effect of disclosure is often understood by examining different measures of market quality. We now define four common measures, explain their origins, and discuss how they are affected by greater disclosure.

### 2.3.1 Market Liquidity

Market liquidity refers to a market's ability to facilitate the purchase or sale of an asset without drastically affecting the asset's price. The literature has used the coefficient  $p_x$  in price function (3) to *inversely* measure market liquidity: A smaller  $p_x$  means that liquidity trading  $\tilde{x}$  has a smaller price impact, and thus the market is deeper and more liquid. Formally,

$$\text{Liquidity} \equiv \frac{1}{p_x}. \tag{9}$$

This measure of market liquidity is often referred to as Kyle's (1985) lambda.

The *illiquidity* measure  $p_x$  can also be linked to another often used measure, bid-ask spread. Suppose that a liquidity trader comes to the market with a buying order  $\tilde{x} = +1$ . By (3), he expects that on average he could fulfill his order at an ask price quoted by the market,  $\text{Ask} \equiv E(\tilde{p}|\tilde{x} = +1) = p_0 + p_x$ . Similarly, if the liquidity trader wants to sell an order  $\tilde{x} = -1$ , then on average, he expects that he would fulfill his order at a bid price,  $\text{Bid} \equiv E(\tilde{p}|\tilde{x} = -1) = p_0 - p_x$ . As a result, the bid-ask spread is

$$\text{Bid-ask spread} = \text{Ask} - \text{Bid} = 2p_x.$$

So,  $p_x$  is indeed positively associated with the bid-ask spread.

From (8), disclosure improves market liquidity; that is,  $\frac{\partial \text{Liquidity}}{\partial \tau_\eta} > 0$ . Intuitively, more precise public information implies that there is less uncertainty about the asset value and so rational traders trade more aggressively against liquidity traders. As a result, changes in

liquidity trading are absorbed with a smaller price change.

### 2.3.2 Market Efficiency

Market efficiency, also called “price efficiency” or “informational efficiency,” concerns how informative the prevailing market prices are about the future values of the traded assets. An underlying reason for promoting market efficiency is that it is believed to be a good proxy for real efficiency, by which more information in prices about underlying values improves real investment decisions.<sup>7</sup> In Section 4, we will refine this statement. In the literature (e.g., Vives, 2008; Peress, 2010; Ozsoylev & Walden, 2011), researchers measure market efficiency using the precision of the posterior about asset fundamental conditional on its price,<sup>8</sup> that is,

$$\text{Market efficiency} \equiv \frac{1}{\text{Var}(\tilde{v}|\tilde{p})}. \quad (10)$$

Given that  $\tilde{v}$  and  $\tilde{p}$  are normally distributed,  $\frac{1}{\text{Var}(\tilde{v}|\tilde{p})}$  is positively related to the correlation coefficient  $\text{Corr}(\tilde{v}, \tilde{p})$  between  $\tilde{v}$  and  $\tilde{p}$ , that is,  $\frac{1}{\text{Var}(\tilde{v}|\tilde{p})} = \frac{\tau_v}{1 - [\text{Corr}(\tilde{v}, \tilde{p})]^2}$ . For this reason, one can also use  $\text{Corr}(\tilde{v}, \tilde{p})$  to measure market efficiency (e.g., Goldstein & Yang, 2014).

Using (8), we can show that disclosure improves market efficiency, that is,  $\frac{\partial}{\partial \tau_\eta} \frac{1}{\text{Var}(\tilde{v}|\tilde{p})} > 0$ . Intuitively, more public information before the price is formed directly injects more fundamental information into the price through updating traders’ forecasts about the asset payoff. This implies that the price tracks fundamental value more closely.

### 2.3.3 Cost of Capital

In this one-period model, the return on the risky asset is  $\tilde{v} - \tilde{p}$ , since at date 2, the uncertainty is resolved and the asset price is its fundamental value  $\tilde{v}$ . The expected return  $E(\tilde{v} - \tilde{p})$  is often interpreted as the cost of capital on the risky asset (e.g., Easley & O’Hara, 2004; Hughes et al., 2007; Lambert et al., 2007). A lower cost of capital benefits the issuer of the

<sup>7</sup>Fama & Miller (1972, p. 335) note: “...(an informationally efficient market) has a very desirable feature. In particular, at any point in time market prices of securities provide accurate signals for resource allocation; that is, firms can make production-investment decisions...”

<sup>8</sup>Equation (10) gives the most standard measure for market efficiency. In the context of learning from prices examined in Section 4, one can also measure the additional information contained in the price relative to that in the disclosure as  $\frac{1}{\text{Var}(\tilde{v}|\tilde{p}, \tilde{y})} - \frac{1}{\text{Var}(\tilde{v}|\tilde{y})}$ .

security since it enables him to sell the security at a higher price.

From (8), we have

$$E(\tilde{v} - \tilde{p}) = \frac{\gamma Q}{\mu\tau_\varepsilon + \tau_v + \tau_\eta + \left(\frac{\mu\tau_\varepsilon}{\gamma}\right)^2 \tau_x}. \quad (11)$$

Thus, the cost of capital  $E(\tilde{v} - \tilde{p})$  is positively affected by risk aversion  $\gamma$  and asset supply  $Q$  in the numerator. This is because traders are willing to pay a lower price when they are more risk averse and have to hold more of the asset on average, so the risk they have to bear is higher. The expression in the denominator is equal to  $\left[\frac{\mu}{\text{Var}(\tilde{v}|\tilde{y}, \tilde{s}_i, \tilde{p})} + \frac{1-\mu}{\text{Var}(\tilde{v}|\tilde{y}, \tilde{p})}\right]$ , which is inversely related to the average risk perceived by traders per unit of the security. When the perceived risk goes up, the cost of capital also increases. Disclosure affects the cost of capital only through affecting the perceived risk: A higher level of disclosure lowers the cost of capital by lowering traders' average risk; that is,  $\frac{\partial E(\tilde{v}-\tilde{p})}{\partial \tau_\eta} < 0$ .

### 2.3.4 Return Volatility

Return volatility  $\sigma(\tilde{v} - \tilde{p}) = \sqrt{\text{Var}(\tilde{v} - \tilde{p})}$  is another measure that attracts a lot of attention from academics and regulators. Using (8), we can show that disclosure lowers return volatility; that is,  $\frac{\partial \sigma(\tilde{v}-\tilde{p})}{\partial \tau_\eta} < 0$ . This is because more public information improves market efficiency, which thus brings the asset price  $\tilde{p}$  closer to the fundamental  $\tilde{v}$ .

### 2.3.5 Summary

To summarize the results discussed thus far, we can see that for a given size of informed-traders population  $\mu$  and a given precision of their information  $\tau_\varepsilon$ , disclosure improves all typical measures of market quality. It increases market liquidity and market efficiency and decreases the cost of capital and return volatility. This is the conventional wisdom that is often put forward to argue for greater disclosure with the intent of improving the functioning of the financial market. This is consistent with many academic papers (e.g., Diamond & Verrecchia, 1991; Verrecchia, 2001; Easley & O'Hara, 2004; Hughes et al., 2007; Lambert et al., 2007; Gao, 2008) and with the logic behind recent regulatory acts, such as the Sarbanes-

Oxley Act (2002) and the Dodd-Frank Act (2010).<sup>9</sup>

### 3 Information Acquisition and Crowding-Out Effect

In the previous section, both the fraction  $\mu$  of informed traders and the precision  $\tau_\varepsilon$  of informed traders' private information were exogenous. In this setup, disclosure was shown to improve various measures of market quality, as it enabled more information to get into prices, improving market liquidity, market efficiency, etc. However, a natural question is how changes in disclosure will affect private information production, which is central to financial markets. Starting to think about the effect of disclosure more broadly, various papers endogenized the variables  $\mu$  and  $\tau_\varepsilon$  that capture the amount of private information in the market (e.g., Verrecchia, 1982b; Diamond, 1985; Kim & Verrecchia, 1994; and more recently, Gao & Liang, 2013; Colombo et al., 2014). One key finding in these studies is that more public information can weaken the incentives of traders to become informed and/or to acquire more precise information. In other words, public information crowds out the production of private information. This can weaken and potentially reverse the direct effect of disclosure on some market-quality variables. In this section, we augment the baseline model in Section 2 with information acquisition to illustrate the crowding-out effect.

#### 3.1 The Setup

We add an information-acquisition date,  $t = 0$ , to the baseline model in Section 2. The information-acquisition technology closely follows Grossman & Stiglitz (1980) and Verrecchia (1982a). At date 0, there exist a unit mass of identical CARA traders. Trader  $i$  can become informed by paying a cost to acquire a private signal  $\tilde{s}_i$  in the form of (1), which has a trader-specific precision  $\tau_{\varepsilon i}$ . The information-acquisition cost  $C(\tau_{\varepsilon i})$  has two parts:<sup>10</sup> a

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<sup>9</sup>For example, in its final ruling on shortening the reporting deadline for insider trading to two business days, the Securities and Exchange Commission (SEC, 2002) argues that “making this information available to all investors on a more timely basis should increase market transparency, which will likely enhance *market efficiency* and *liquidity*.”

<sup>10</sup>Although the information-acquisition cost is measured in terms of traders' date-0 wealth, it can represent both the monetary cost and the time cost. Recently, Dugast & Foucault (2017) and Kendall (2017) have explicitly modeled the time cost of information.

fixed cost  $c_F \geq 0$  and a variable cost  $c_V(\tau_{\varepsilon i})$ , where  $c_V(\cdot)$  is an increasing, smooth, and convex function, satisfying  $c_V(0) = 0$ . For instance, we can think of traders as financial institutions and their information-acquisition activities typically involve both a fixed cost (such as the overhead cost of establishing a research department) and a variable cost (such as hiring analysts to produce financial reports). In equilibrium, an endogenous fraction  $\mu$  of traders decide to acquire private information, and these traders become the informed traders in the date-1 financial market. We can show that the informed traders choose the same precision level  $\tau_\varepsilon$  in equilibrium, and thus, the economy at dates 1 and 2 is the same as in the baseline model.

The equilibrium in this extended economy consists of an information-acquisition equilibrium at date 0 and a noisy-REE at date 1. The date-1 noisy-REE is still characterized by (3) and (8). The date-0 information-acquisition equilibrium is characterized by: a) Intensive margin,  $\tau_\varepsilon^*$ : How precise is the information that informed traders acquire?; b) Extensive margin,  $\mu^*$ : How many traders decide to become informed? In the literature, researchers have either fixed  $\mu^* = 1$  and considered the crowding-out effect of disclosure on  $\tau_\varepsilon^*$  (e.g., Verrecchia, 1982b), or fixed the value of  $\tau_\varepsilon^*$  and considered the crowding-out effect on  $\mu^*$  (e.g., Diamond, 1985). As we will show below, both settings can naturally emerge endogenously in our setup and they may have different implications.

Let us consider a particular trader  $i$ . Suppose that a fraction  $\mu$  of the traders are informed and acquire signals with precision  $\tau_\varepsilon$ . When trader  $i$  stays uninformed, we use  $CE_U(\tau_\varepsilon, \mu)$  to denote his ex-ante expected utility (certainty equivalent) at the trading stage. When trader  $i$  decides to become informed and acquire a private signal with precision  $\tau_{\varepsilon i}$ , we use  $CE_I(\tau_{\varepsilon i}; \tau_\varepsilon, \mu)$  to denote his ex-ante expected utility. Note that in  $CE_I(\tau_{\varepsilon i}; \tau_\varepsilon, \mu)$ , trader  $i$  can only choose  $\tau_{\varepsilon i}$  and will take  $(\tau_\varepsilon, \mu)$  as given. Following an argument similar to that of Grossman & Stiglitz (1980), we can compute  $CE_U(\tau_\varepsilon, \mu)$  and  $CE_I(\tau_{\varepsilon i}; \tau_\varepsilon, \mu)$  and analyze equilibrium outcomes.

Three types of information-acquisition equilibrium arise. First, when  $c_F$ , the fixed cost in information acquisition, is sufficiently small, all traders become informed, that is  $\mu^* = 1$ ; a case that mimics Verrecchia (1982b). Here,  $CE_U(\tau_\varepsilon^*, 1) \leq CE_I(\tau_\varepsilon^*; \tau_\varepsilon^*, 1)$ , so that traders choose to become informed when all others are informed, and the precision of information

$\tau_\varepsilon^*$  is pinned down by the first-order condition:  $\frac{\partial CE_I(\tau_\varepsilon^*; \tau_\varepsilon^*, 1)}{\partial \tau_{\varepsilon i}} = 0$ . Second, when  $c_F$  takes an intermediate value, an interim proportion of the traders choose to become informed:  $\mu^* \in (0, 1)$ . The equilibrium is pinned down by a condition that makes traders indifferent between producing the equilibrium amount of information and remaining uninformed:  $CE_U(\tau_\varepsilon^*, \mu^*) = CE_I(\tau_\varepsilon^*; \tau_\varepsilon^*, \mu^*)$  and by a first-order condition that guarantees that the level of precision is chosen optimally:  $\frac{\partial CE_I(\tau_\varepsilon^*; \tau_\varepsilon^*, \mu)}{\partial \tau_{\varepsilon i}} = 0$ . It turns out that in equilibrium, the precision of information produced  $\tau_\varepsilon^*$  is independent of disclosure quality  $\tau_\eta$ , and thus this case mimics the one studied by Diamond (1985). Finally, when  $c_F$  is sufficiently large, no trader chooses to become informed, which is guaranteed by the condition  $CE_U(\tau_\varepsilon, 0) \geq \max_{\tau_{\varepsilon i}} CE_I(\tau_{\varepsilon i}; \tau_\varepsilon, 0)$ .

Figure 1 graphically illustrates these equilibrium outcomes. For this illustration, we assume that the variable cost function takes a quadratic form,  $c_V(\tau_{\varepsilon i}) = \frac{k}{2}\tau_{\varepsilon i}^2$ , and that the parameter values are  $\tau_v = \tau_x = \gamma = Q = 1$  and  $k = 0.1$ . The figure plots the regimes of equilibrium types in the parameter space of  $(c_F, \tau_\eta)$ . Generally speaking, as  $c_F$  and  $\tau_\eta$  become larger, an equilibrium with a lower  $\mu^*$  is more likely to prevail. The last feature is a reflection of the crowding out effect, which we now turn to explain in more detail.

[INSERT FIGURE 1 HERE]

## 3.2 The Effect of Disclosure

### 3.2.1 The Crowding-Out Effect on Private Information

The following results follow directly from the equilibrium analysis above and demonstrate the crowding-out effect. First, when all traders are informed,  $\mu^* = 1$ , the equilibrium precision of information  $\tau_\varepsilon^*$  decreases in the quality of public information  $\tau_\eta$ . Second, when an intermediate fraction of traders choose to become informed,  $\mu^* \in (0, 1)$ , this fraction decreases in the quality of public information  $\tau_\eta$  (in this case the precision  $\tau_\varepsilon^*$  is unaffected). These two results reproduce the crowding-out effect studied by Verrecchia (1982b) and Diamond (1985), respectively. Intuitively, when both public information and private information are about the same random variable  $\tilde{v}$ , they are substitute, and thus additional public information motivates traders to cut back on their costly private acquisition activities either in the form of producing less precise private information or in the form of becoming uninformed.

In Figure 1, we could see how an increase in disclosure makes it more likely that we move to an equilibrium with a smaller fraction of informed traders. Figure 2 continues this example with the same parameters to illustrate more directly the crowding-out effect. We now also set  $c_F = 0.07$ . We plot the equilibrium fraction  $\mu^*$  of informed traders and the equilibrium precision  $\tau_\varepsilon^*$  of private information as functions of the precision  $\tau_\eta$  of public information. We see that globally, both  $\mu^*$  and  $\tau_\varepsilon^*$  weakly decrease with  $\tau_\eta$ . Starting from low disclosure, all traders choose to become informed, and an increase in disclosure reduces the precision of their information. Then, at some point, the fraction of informed traders starts decreasing as disclosure continues to improve, eventually drying up all the information produced privately in the market. Hence, public disclosure clearly crowds out private information. We now examine the effect that this will have on the measures of market quality studied in the previous section.

[INSERT FIGURE 2 HERE]

### 3.2.2 The Effect on Market Quality

In Section 2, disclosure had an unambiguous effect on four measures of market quality—market liquidity, market efficiency, cost of capital, and return volatility—increasing the first two and decreasing the other two. However, things ought to be more complicated once we consider the crowding-out effect on private information. We use Figure 3 to demonstrate the overall effect of disclosure on these measures once private information adjusts endogenously based on the analysis above. The figure uses the same parameter values as in Figure 2. It turns out that the effect of disclosure is by and large non-monotone and that the results depend on whether crowding out happens in the extensive margin (as in Diamond, 1985) or intensive margin (as in Verrecchia, 1982b) and on which measure of market quality we inspect.

[INSERT FIGURE 3 HERE]

Let us consider the effect of disclosure  $\tau_\eta$  on the cost of capital  $E(\tilde{v} - \tilde{p})$ . Recall that without considering private information to be endogenous, disclosure has a direct negative effect on the cost of capital. The figure shows that, in the presence of endogenous private

information, there are three different regimes. First, when  $\tau_\eta$  is small,  $E(\tilde{v} - \tilde{p})$  decreases in  $\tau_\eta$ . In this regime,  $\mu^*$  is fixed at 1 and  $\tau_\varepsilon^*$  decreases in  $\tau_\eta$ , which corresponds to Verrecchia (1982b). Here, the crowding out of private information happens in the intensive margin. The decrease in private information following an increase in disclosure increases the risk faced by traders on average pushing up the cost of capital, but this is not strong enough to overturn the direct negative effect that disclosure has on the cost of capital. Second, when  $\tau_\eta$  takes intermediate values,  $E(\tilde{v} - \tilde{p})$  starts to increase with  $\tau_\eta$ . Here,  $\mu^* \in (0, 1)$  decreases with  $\tau_\eta$  and  $\tau_\varepsilon^*$  is fixed, which corresponds to Diamond (1985), where the crowding out happens in the extensive margin. Now, the decrease in private information as a result of an increased disclosure is sufficiently strong so that overall the cost of capital increases in disclosure; in opposite direction to the direct effect. Hence, the indirect effect via the crowding out on the extensive margin turns out to be more powerful. Third, when  $\tau_\eta$  is high,  $E(\tilde{v} - \tilde{p})$  decreases in  $\tau_\eta$  again. Here,  $\mu^* = 0$ , and so disclosure no longer affects private information, and only the direct negative effect of disclosure on the cost of capital is present.<sup>11</sup> Overall, we see that the fact that public information crowds out private information implies that disclosure no longer has a uniformly negative effect on the cost of capital, and so the total effect has to be evaluated more carefully and depends on the exact information structure in place.

Considering the effect of disclosure on market efficiency and return volatility, we can see very similar effects as those described above for the cost of capital. The exception is the measure of liquidity, which is monotonically increasing in disclosure. Here, the crowding-out effect of private information does not interfere with the positive direct effect that disclosure has on liquidity. This is because the crowding-out effect partly benefits market liquidity since it weakens adverse selection induced by private information.

## 4 Disclosure and Real Efficiency

The above analysis has shown the effect that disclosure has on four commonly mentioned variables that capture different dimensions of market quality. We first showed how disclosure

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<sup>11</sup>Tang (2014) uses a figure similar to Figure 3 to explain the non-monotone relation between the cost of capital and disclosure, but her model follows Diamond (1985) and so her analysis does not recognize the contrasting implications of extensive versus intensive margins.

unambiguously improves these measures when we consider only its direct effect, but then showed that disclosure tends to crowd out private information production and as a result ends up having a more nuanced effect on the different measures. One issue with the above analysis is that these measures do not translate easily to a clear objective function that will help us tell when disclosure is desirable and when it is not.

In this section we tackle this issue and extend our basic framework to review papers that attempted to pin down optimal disclosure policy with a clear objective function in mind. The papers reviewed here emphasize the role of the financial market in producing information and guiding the decisions in the real side of the economy; e.g., investment decisions made by firm managers. This idea goes back to Hayek (1945), who argued that prices are an important source of information because they aggregate information from many market participants. There is a vast recent literature exploring the implications of this market feedback effect; a recent survey is provided by Bond et al. (2012). The papers reviewed here explore the optimal disclosure policy taking into account how disclosure affects the information provided by the market and the efficiency of the investment decisions that are guided by the market. This is of course related to the concept of market efficiency discussed in Section 2. However, as should be clear from the analysis here, market efficiency and real efficiency are not always aligned. The latter refers to the efficiency of the market in revealing information needed for decisions on the real side of the economy. Real efficiency is what the models here feature, based on an objective function developed from first principles.<sup>12</sup>

## 4.1 Crowding-Out Effect and Optimal Disclosure Policy

The crowding-out effect reviewed in Section 3 suggests that disclosure can reduce the amount of private information in the price. So, if a firm manager tries to learn information from the price, this crowding-out effect tends to harm their learning quality. On the other hand, as we reviewed in Section 2, disclosure can benefit the firm by lowering the cost of capital when information is exogenous. Gao & Liang (2013) study the resulting trade-off to examine the optimal disclosure policy of a firm. We now present an extension of our CARA-normal setup

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<sup>12</sup>For a broader discussion, see Bond et al. (2012) and the distinction they make between forecasting price efficiency (FPE) and revelatory price efficiency (RPE).

that captures their trade-off.

We extend the model in Section 3 to include another active player (the firm) and an intermediate date ( $t = 1\frac{1}{2}$ ). We interpret the traded risky asset as the asset-in-place of a firm. The firm is endowed with information  $\tilde{s}_F = \tilde{v} + \tilde{\varepsilon}_F$  with  $\tilde{\varepsilon}_F \sim N(0, \tau_F^{-1})$  and  $\tau_F > 0$ . At the beginning of date 0, the firm chooses a disclosure policy which commits it to disclose a noisy version of  $\tilde{s}_F$  to the date-1 financial market in the following form:

$$\tilde{y} = \tilde{s}_F + \tilde{\delta} \text{ with } \tilde{\delta} \sim N(0, \tau_\delta^{-1}) \text{ and } \tau_\delta \in [0, \infty]. \quad (12)$$

All of the underlying random variables ( $\tilde{v}, \tilde{\varepsilon}_F, \tilde{\delta}, \{\tilde{\varepsilon}_i\}_i, \tilde{x}$ ) are mutually independent. We can rewrite  $\tilde{y}$  in (12) in the form defined in (2) by writing  $\tilde{\eta} \equiv \tilde{\varepsilon}_F + \tilde{\delta}$ , where  $\tilde{\eta} \sim N(0, \tau_\eta^{-1})$  with  $\tau_\eta = (\tau_F^{-1} + \tau_\delta^{-1})^{-1} \in [0, \tau_F]$ . Parameter  $\tau_\eta$  still controls the disclosure quality. In particular, when  $\tau_\eta = 0$ , the firm does not disclose any information, and when  $\tau_\eta = \tau_F$ , the firm discloses its information  $\tilde{s}_F$  without error.

The firm also has a growth opportunity whose productivity is related to  $\tilde{v}$ . The firm invests in the growth opportunity at  $t = 1\frac{1}{2}$ , and so it can look into the asset price  $\tilde{p}$  to extract information about  $\tilde{v}$ . The growth opportunity's cash flow  $\tilde{G}$  is realized at date 2, and it takes the following form:

$$\tilde{G} = \sqrt{\Phi} \tilde{v} I - \frac{I^2}{2}, \quad (13)$$

where  $I$  is the investment made by the firm at  $t = 1\frac{1}{2}$  and parameter  $\Phi > 0$  captures the size of the growth option. As in Subrahmanyam & Titman (1999) and Foucault & Gehrig (2008), we assume that the growth opportunity is separate from the asset-in-place and non-tradable to keep the model tractable. In this extended economy, the firm makes two decisions: a disclosure-policy decision at  $t = 0$  and a real-investment decision at  $t = 1\frac{1}{2}$ . We assume that the firm is risk-neutral and cares about both the asset-in-place and the growth opportunity. To simplify things relative to Section 3, we assume that private information acquisition does not incur a fixed cost and the variable cost function is  $c_V(\tau_{\varepsilon i}) = \frac{k}{2} \tau_{\varepsilon i}^2$  with  $k > 0$ . All the other features of the model are the same.

The noisy-REE in the date-1 financial market is still characterized as in Section 2 and the date-0 information-acquisition equilibrium is still characterized as in Section 3. We now examine the two decisions of the firm. At  $t = 1\frac{1}{2}$ , the firm has an information set

$\{\tilde{s}_F, \tilde{p}, \tilde{y}\} = \{\tilde{s}_F, \tilde{s}_p\}$ , where  $\tilde{s}_p$  is the market signal given by (4). The firm's optimal investment policy maximizes the expected value of the growth opportunity in (13) given the information available, implying that:  $I(\tilde{s}_F, \tilde{s}_p) = \sqrt{\Phi}E(\tilde{v}|\tilde{s}_F, \tilde{s}_p)$ . Inserting  $I(\tilde{s}_F, \tilde{s}_p)$  back into the growth opportunity and taking unconditional expectation yields the expected growth value:

$$E(\tilde{G}) = \frac{\Phi}{2} \left[ \frac{1}{\tau_v} - \frac{1}{\tau_v + \tau_F + \left(\frac{\tau_\varepsilon}{\gamma}\right)^2 \tau_x} \right]. \quad (14)$$

We can see that the expected growth value increases in the precision  $\left(\frac{\tau_\varepsilon}{\gamma}\right)^2 \tau_x$  of the price signal  $\tilde{s}_p$ . This is a result of the feedback effect. The firm benefits from having more precise information in the price about the fundamental  $\tilde{v}$  because then it can make a more efficient investment decision. By the crowding-out effect, additional disclosure lowers the precision  $\tau_\varepsilon$  of private information produced and so makes the price signal  $\tilde{s}_p$  less accurate. As a result, disclosure can harm the firm by reducing the value of the growth option.

At  $t = 0$ , the firm chooses an optimal disclosure policy  $\tau_\eta$ . Following Langberg & Sivaramakrishnan (2010), we assume that the firm's date-0 objective is a weighted average of the expected price of the asset-in-place and its expected growth opportunity value,  $\alpha E(\tilde{p}) + (1 - \alpha) E(\tilde{G})$ , with  $\alpha \in (0, 1)$ .<sup>13</sup> Here, the expected price of the assets in place  $E(\tilde{p})$  is derived from (3) and (8) and the expected value of the growth option  $E(\tilde{G})$  is given by (14). Then, the optimal disclosure policy  $\tau_\eta^{opt}$  balances two forces. On the one hand, greater disclosure increases  $E(\tilde{p})$  by reducing the uncertainty faced by financial-market traders and so reducing the cost of capital they impose on the firm.<sup>14</sup> On the other hand, greater disclosure crowds out private-information production and so deprives valuable information from the firm, thereby reducing the efficiency of its investment decision and the value of its growth option. As a result, one can show that when  $\frac{\Phi}{Q}$  is relatively high, that is, when the firm's growth opportunity is large relative to its asset-in-place, the negative effect of disclosure dominates and thus the firm chooses to disclose less. This model therefore implies

<sup>13</sup>For instance, the firm is balancing the interests of its short-term shareholders, who sell the shares at a price  $\tilde{p}$ , and its long-term shareholders, who care about the firm's terminal cash flows  $\tilde{v} + \tilde{G}$ .

<sup>14</sup>Recall that, for simplicity, we assumed here that information acquisition does not have a fixed cost. Then, based on the results in the previous section, the crowding-out effect of disclosure only happens in the intensive margin, and the cost of capital decreases in the level of disclosure.

that growth firms are endogenously more opaque than value firms.

## 4.2 Liquidity-Chasing Noise Trading

Another negative effect of disclosure on real efficiency is studied in Han et al. (2016). They follow the approach of modeling discretionary liquidity traders in the market microstructure literature (e.g., Admati & Pfleiderer, 1988; Foster & Viswanathan, 1990) and show that greater disclosure attracts more noise trading. We now modify the model presented in the previous subsection to illustrate this mechanism.

We shut down the information-acquisition activities of the CARA-traders at date 0 and endow each of them with a private signal  $\tilde{s}_i$  with precision  $\tau_\varepsilon$ . There is also a large mass of discretionary liquidity traders who are risk neutral, uninformed, and ex-ante identical.<sup>15</sup> These traders are “discretionary” in the sense that at date 0, each chooses whether to participate in the date-1 market by optimally balancing the expected loss from trading against informed CARA-traders versus an exogenous liquidity benefit  $B$  of market participation. If discretionary liquidity trader  $l$  decides to trade, he has to trade  $\tilde{u}$  units of risky asset, where  $\tilde{u} \sim N(0, 1)$  and is perfectly correlated across the liquidity traders. The equilibrium mass  $L^*$  of liquidity traders participating in the market determines the noise trading active in the market:  $\tilde{x} \equiv L^* \tilde{u}$  and  $\tau_x^{-1} = L^{*2}$ . All the other features of the model in Subsection 4.1 are unchanged.

We now characterize the market-participation equilibrium of discretionary liquidity traders at date 0. At that point, discretionary liquidity trader  $l$  faces the following trade-off. First, trading generates an exogenous benefit of  $B > 0$ , which represents the exogenous liquidity needs. Second, because liquidity traders are trading against informed CARA-traders, they will incur endogenous trading losses on average. Then, the expected utility of participating in the market for discretionary liquidity trader  $l$  is

$$W(L; \tau_\eta) = B + E[\tilde{u} \cdot (\tilde{v} - \tilde{p})] = \underbrace{B}_{\text{liquidity benefit}} - \underbrace{p_x(L; \tau_\eta) \times L}_{\text{trading cost}}. \quad (15)$$

Here,  $L$  is the mass of liquidity traders choosing to participate in the market and  $p_x(L; \tau_\eta)$

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<sup>15</sup>In practice, these traders can represent institutional traders—e.g., index funds or ETFs—who need to rebalance portfolios around index recompositions or when receiving flow shocks.

is given by (8) with  $\tau_x^{-1} = L^2$ . Note that expected trading losses are increasing in  $L$  because when more liquidity traders participate they exert stronger price pressure given that they trade in the same direction. In equilibrium, an endogenous mass  $L^*$  of liquidity traders choose to participate in the market, while the rest choose not. Hence,  $L^*$  is determined by the indifference condition:  $W(L^*; \tau_\eta) = 0$ .

Expression (15) shows that discretionary liquidity traders have incentives to chase market liquidity. That is, if a change in the trading environment improves market liquidity (i.e.,  $p_x$  decreases), then, other things being equal, expected trading losses decrease and discretionary liquidity traders are more likely to participate in the market. Since disclosure promotes market liquidity, releasing public information induces more discretionary liquidity traders to choose to participate in the market. That is,  $\frac{\partial L^*}{\partial \tau_\eta} > 0$ .

Disclosure affects real efficiency still through affecting the firm's learning from the price. By observing the price  $\tilde{p}$ , the firm obtains a signal  $\tilde{s}_p$  with a precision of  $\left(\frac{\tau_\varepsilon}{\gamma}\right)^2 \tau_x$ . Recall that in this economy, the precision of noise trading is given by  $\tau_x = \frac{1}{L^{*2}}$ , which implies that the precision of the information in the price decreases in the level of disclosure:  $\frac{\partial}{\partial \tau_\eta} \left(\frac{\tau_\varepsilon}{\gamma L^*}\right)^2 < 0$ . That is, more public information attracts additional liquidity trading and, as a result, the price reveals less fundamental information, thereby reducing real efficiency.

### 4.3 Multiple Dimensions of Disclosure

The models discussed in the previous two subsections highlight the negative real-efficiency effects of disclosure. Two recent papers—Bond & Goldstein (2015) and Goldstein & Yang (2016)—point out that in the presence of multiple dimensions of information, real-efficiency implications of disclosure might be different depending on what dimension of information is disclosed.

Bond & Goldstein (2015) show that a decision maker on the real side of the economy should disclose information about issues on which he knows more than the market and keep silent on issues on which he wants to learn from the market. They cast their idea in a trading model where the decision maker is the government that makes an intervention decision. We now extend the baseline model in Section 2 to illustrate the mechanism. Suppose that the firm's date-2 cash flow  $\tilde{v}$  is given by  $\tilde{v} = T + \tilde{v}_B$ , where  $\tilde{v}_B \sim N(0, \tau_B^{-1})$  with  $\tau_B > 0$ .

The component  $T$  is the result of endogenous government intervention based on its private information and the asset price  $\tilde{p}$ . For example, one can think of government bailouts of AIG and Citigroup in the recent financial crisis. Specifically, we add an additional date,  $t = 1\frac{1}{2}$ , at which the government chooses  $T$  to maximize  $E \left[ -\frac{(T-\tilde{v}_A)^2}{2} + cT \middle| \mathcal{I}_G \right]$ , where  $\tilde{v}_A \sim N(0, \tau_A^{-1})$  (with  $\tau_A > 0$ ),  $c > 0$  is a constant, and  $\mathcal{I}_G$  is the government's information set. As discussed in Bond & Goldstein (2015), this objective function qualitatively captures many government motives, such as promoting social surplus and maintaining financial sector stability.

Note that in this setting, the asset cash flow  $\tilde{v}$  is ultimately driven by two underlying random variables,  $\tilde{v}_A$  and  $\tilde{v}_B$ . We assume that the government wants to learn from the market element  $\tilde{v}_A$  more than element  $\tilde{v}_B$ . For example,  $\tilde{v}_A$  determines the benefit from intervention as it reflects the spillover effect from an individual bank's failure, and this is something the government needs to learn from the market about. On the other hand,  $\tilde{v}_B$  is information about the bank's expected direct cash flows, which is information that the government has direct access to. For simplicity, suppose that the government knows  $\tilde{v}_B$  perfectly and only receives a private signal  $\tilde{s}_G$  on  $\tilde{v}_A$ , where  $\tilde{s}_G = \tilde{v}_A + \tilde{\varepsilon}_G$  with  $\tilde{\varepsilon}_G \sim N(0, \tau_G^{-1})$  and  $\tau_G > 0$ . Traders have private information on  $\tilde{v}_A$  in the form of (1) but know nothing about  $\tilde{v}_B$ . That is, trader  $i$  receives a signal  $\tilde{s}_i = \tilde{v}_A + \tilde{\varepsilon}_i$  with  $\tilde{\varepsilon}_i \sim N(0, \tau_\varepsilon^{-1})$  and  $\tau_\varepsilon > 0$ . So, the asset price  $\tilde{p}$  will aggregate private signals  $\tilde{s}_i$  and convey information on  $\tilde{v}_A$ . The government can use disclosure to affect the information aggregation process of the price. Specifically, at date 1 before the financial market opens, the government discloses two public signals,  $\tilde{y}_A = \tilde{s}_G + \tilde{\eta}_A$  and  $\tilde{y}_B = \tilde{v}_B + \tilde{\eta}_B$ , where  $\tilde{\eta}_A \sim N(0, \tau_{\eta A}^{-1})$  (with  $\tau_{\eta A} \in [0, \infty]$ ) and  $\tilde{\eta}_B \sim N(0, \tau_{\eta B}^{-1})$  (with  $\tau_{\eta B} \in [0, \infty]$ ). All the underlying random variables ( $\tilde{v}_A, \tilde{v}_B, \tilde{\varepsilon}_G, \tilde{\eta}_A, \tilde{\eta}_B, \{\tilde{\varepsilon}_i\}_i$ ) are mutually independent.

The price function in the date-1 financial market takes the form of  $\tilde{p} = p_0 + p_{yA}\tilde{y}_A + p_{yB}\tilde{y}_B + p_v\tilde{v}_A + p_x\tilde{x}$ , where the  $p$ -coefficients are endogenous. At  $t = 1\frac{1}{2}$ , the government has an information set  $\mathcal{I}_G = \{\tilde{s}_G, \tilde{y}_A, \tilde{y}_B, \tilde{v}_B, \tilde{p}\}$ . To the government, the price is still equivalent to the signal  $\tilde{s}_p$  as in (4), i.e.,

$$\tilde{s}_p = \frac{\tilde{p} - p_0 - p_{yA}\tilde{y}_A - p_{yB}\tilde{y}_B}{p_v} = \tilde{v}_A + \rho^{-1}\tilde{x} \text{ with } \rho = \frac{p_v}{p_x}.$$

Thus, the government's intervention policy is

$$\begin{aligned} T(\tilde{s}_G, \tilde{s}_p) &= \arg \max_T E \left[ -\frac{(T - \tilde{v}_A)^2}{2} + cT \middle| \tilde{s}_G, \tilde{y}_A, \tilde{y}_B, \tilde{v}_B, \tilde{p} \right] \\ &= E(\tilde{v}_A | \tilde{s}_G, \tilde{s}_p) + c = \frac{\tau_G}{\tau_A + \tau_G + \rho^2 \tau_x} \tilde{s}_G + \frac{\rho^2 \tau_x}{\tau_A + \tau_G + \rho^2 \tau_x} \tilde{s}_p + c. \end{aligned} \quad (16)$$

The precision  $\rho^2 \tau_x$  of signal  $\tilde{s}_p$  still captures the extra information that the government learns from the market. As in Section 4.1, in equilibrium, the government's utility increases with precision  $\rho^2 \tau_x$ , since a higher  $\rho^2 \tau_x$  means that the government is making a more informed intervention decision. In this sense,  $\rho^2 \tau_x$  is a measure for real efficiency.

Financial trader  $i$  has information set  $\{\tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{p}\}$ , which is equivalent to  $\{\tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{s}_p\}$ . The CARA-normal setup implies that trader  $i$ 's demand for the risky asset is

$$D(\tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{p}) = \frac{E[T(\tilde{s}_G, \tilde{s}_p) + \tilde{v}_B | \tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{s}_p] - \tilde{p}}{\gamma \text{Var}[T(\tilde{s}_G, \tilde{s}_p) + \tilde{v}_B | \tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{s}_p]}. \quad (17)$$

Using the expression of  $T(\tilde{s}_G, \tilde{s}_p)$  in (16) and the market-clearing condition,  $\int D(\tilde{s}_i, \tilde{y}_A, \tilde{y}_B, \tilde{p}) di + \tilde{x} = Q$ , we can solve for  $\tilde{p}$  in terms of  $(\tilde{y}_A, \tilde{y}_B, \tilde{v}_A, \tilde{x})$ . Comparing this solved price with the conjectured price function, we then form a system in terms of the  $p$ -coefficients, which characterizes the noisy-REE in the financial market.

The key results can be summarized as follows: Disclosing information about  $\tilde{v}_A$  harms the government through impairing its learning quality from the price, while disclosing information about  $\tilde{v}_B$  benefits the government. To see the intuition, consider the extreme cases where the government fully discloses one of the signals.<sup>16</sup> First, if the government fully discloses its signal on  $\tilde{v}_A$  so that  $\tilde{y}_A = \tilde{s}_G$  and  $\tau_{\eta A} = \infty$ , then,  $T(\tilde{s}_G, \tilde{s}_p)$  is perfectly known by financial traders, and so they will no longer put any weight on their own private signals  $\tilde{s}_i$ . As a result, the price does not aggregate  $\tilde{s}_i$  anymore and the government learns nothing from the price. Effectively, there is a crowding-out effect, whereby disclosing information about something the traders know makes them trade less on this information and reduces the ability of the government to learn from their information. Interestingly, this crowding out does not operate through the incentives to produce information, as we saw previously in this survey, but through the ability to trade on existing information. It is captured by the numerator of traders' demand function (17), as the availability of public information reduces

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<sup>16</sup>The intuition is similar also for intermediate cases, but more difficult to convey.

the speculative value of their private information and causes them to trade less aggressively. Second, suppose that the government fully discloses its information on  $\tilde{v}_B$  so that  $\tilde{y}_B = \tilde{v}_B$  and  $\tau_{\eta B} = \infty$ . Then, financial traders no longer need to forecast  $\tilde{v}_B$ , which lowers the risk they face, making traders trade more aggressively on  $\tilde{s}_i$ . This uncertainty-reduction effect, originating from the fact that traders are risk averse, is reflected by the denominator of their demand function (17), as the reduction in risk incentivizes them to trade more on their information. In consequence, the price will aggregate more of traders' private information, benefiting the government's learning from the price.

The mechanism in Goldstein & Yang (2016) is different and does not rely on risk aversion as they study an environment in which all players are risk neutral. In their model, what matters for determining which information will be reflected by prices is the relative intensity in which agents trade on different pieces of information. Assuming again two dimensions of information, which in the context of a regular firm could represent the demand for firms' products and the quality of its production technology, and assuming that agents have access to signals on both, they show that revealing more precise information on the dimension the firm already knows about will cause traders to trade more aggressively on the dimension the firm wants to learn and will enable the firm to learn more from the price. The opposite will be true if more precise public information is revealed on what the firm is trying to learn; this will crowd out valuable private information from being incorporated into the price and reduce the ability of the firm to learn from the price.

There is another important distinction in this paper relative to the literature. In most models discussed above, such as Gao & Liang (2013) and Bond & Goldstein (2016), public information is disclosed by the real decision maker and so he does not directly learn from the disclosed information. In some scenarios, this may not be the case. For example, a firm manager can benefit directly from public information disclosed by the government or other agencies. In these scenarios, disclosure has both a direct effect of providing new information to the decision maker and an indirect effect of affecting price informativeness. Goldstein & Yang's (2016) analysis considers both effects. Paradoxically, for the reason discussed above, more disclosure about the variable that the real decision maker wants to learn can backfire as it interferes with the ability of the market to reveal this type of information attenuating

the positive direct effect of better disclosure. In cases where the market is very effective in processing information, the indirect effect can be stronger than the direct effect, implying that better disclosure can reduce the overall quality of information available to the decision maker and harm real efficiency, even though the decision maker directly learns from the public information.<sup>17</sup>

The analysis of multiple dimensions of information can be linked to the debate on the optimal disclosure of stress test results (see Goldstein & Sapra (2013) for a survey). The stress-test results are useful for the regulator to make intervention decisions and for creditors to determine whether to rollover their debt or extend more credit to financial institutions. However, one has to keep in mind that disclosure of these results will crowd out information from the financial market. Based on the papers described here, disclosure will be undoubtedly beneficial when the stress-test result is about issues for which the regulator or creditors have a relative informational advantage over the financial market. However, when the stress-test result is about something that the regulator or creditors know relatively less than the financial market, disclosing such information makes market prices less informative, which can lead to negative efficiency outcomes.

## 5 Investor Welfare

The previous section described the various effects of disclosure on the efficiency of real investment decisions. Another important issue that has to be considered in evaluating the effects of disclosure is the implication for the welfare of traders in the financial market. As mentioned in Section 2, the usual argument invoked in favor of disclosure is that it improves market quality which is perceived to have positive effects for investors in financial markets. However, as we discuss in this section, several models in the literature have shown that disclosure can have negative effects on investors' welfare. Hence, it is not always warranted to implement "investor protection" regulations that improve disclosure. In the next two

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<sup>17</sup>Amador & Weill (2010) construct a monetary model and show that disclosure about monetary and productivity shocks can lower welfare through reducing the informational efficiency of the good price system. This effect is similar to the indirect price-informativeness effect discussed by Goldstein & Yang (2016), although Amador & Weill (2010) do not explore the different implications of different types of disclosure.

subsections, we discuss two families of models that develop ideas along these lines.

## 5.1 Destruction of Trading Opportunities

The well known ‘‘Hirshleifer effect’’ (Hirshleifer, 1971) is a powerful argument against public disclosure of information. The idea is that when traders face idiosyncratic risks, say due to heterogeneous endowment shocks, public disclosure decreases welfare by reducing the risk-sharing opportunities available to traders. More recently, Kurlat & Veldkamp (2015) study a related channel through which disclosure harms investors. In their setting, investors benefit when they have access to assets with a higher risk and a higher return, and these opportunities are eliminated by public disclosure of information. The common theme of both channels is that disclosure harms investors through destroying trading opportunities. We now extend the baseline model in Section 2 to illustrate these channels.

For the Hirshleifer effect to arise, we assume that traders trade to share risks rather than to speculate on private information. Specifically, we assume that at date 2, trader  $i$  receives an endowment of labor income,  $\tilde{q}_i\tilde{v}$ , where  $\tilde{q}_i \sim N(0, \sigma_q^2)$  with  $\sigma_q \geq 0$ , and  $\tilde{q}_i$  is independent of  $\tilde{v}$  and also independent across traders. When trading at date 1, trader  $i$  knows his exposure  $\tilde{q}_i$  to the risky asset but has no private information about the asset value  $\tilde{v}$ . To simplify things further, we assume that there are no noise traders in the model. The other features of the model are unchanged, and in particular, the public signal  $\tilde{y}$  is still given by equation (2). In this economy, trader  $i$ ’s demand for the risky asset is

$$D_i(\tilde{y}, \tilde{p}) = \frac{E(\tilde{v}|\tilde{y}, \tilde{p}) - \tilde{p}}{\gamma \text{Var}(\tilde{v}|\tilde{y}, \tilde{p})} - \tilde{q}_i. \quad (18)$$

In equation (18), the first term is the demand of a CARA trader without endowment shocks, attempting to make a profit on the deviations of prices from expected fundamental value, and the second term is the hedging term capturing trader  $i$ ’s attempt to reduce the endowment risk. Combining equation (18) with the market-clearing condition, we can compute the asset price  $\tilde{p}$  as

$$\tilde{p} = E(\tilde{v}|\tilde{y}) - \gamma \text{Var}(\tilde{v}|\tilde{y}) Q. \quad (19)$$

Since there is no private information or noise trading, the price only depends on the public signal  $\tilde{y}$ .

Inserting equation (18) into trader  $i$ 's objective function yields the indirect utility at the trading stage as follows:

$$U_i(\tilde{y}, \tilde{p}, \tilde{q}_i) = -\exp\left(-\underbrace{\frac{[E(\tilde{v}|\tilde{y}) - \tilde{p}]^2}{2\text{Var}(\tilde{v}|\tilde{y})}}_{\text{trading gains}} - \underbrace{\gamma \tilde{p}\tilde{q}_i}_{\text{wealth}}\right). \quad (20)$$

In (20), the term  $\tilde{p}\tilde{q}_i$  simply captures the fact that each unit of labor income increases trader  $i$ 's wealth by the price  $\tilde{p}$  of the risky asset, since it has the same cash flow as the risky asset. The term  $\frac{[E(\tilde{v}|\tilde{y}) - \tilde{p}]^2}{2\text{Var}(\tilde{v}|\tilde{y})}$  represents the benefit from trading the risky asset given the trading behavior in (18). This term essentially captures the effect highlighted in Kurlat & Veldkamp (2015).

We can use the certainty equivalent  $CE \equiv -\frac{1}{\gamma} \log(-E[U_i(\tilde{y}, \tilde{p}, \tilde{q}_i)])$  to study the ex-ante utility of trader  $i$ . To see formally the effect in Kurlat & Veldkamp (2015), let us turn off the Hirshleifer effect, by dropping traders' idiosyncratic endowments and saying that they just trade the quantity put on the market by the issuer, that is,  $\sigma_q = 0$  and  $Q > 0$ . Using (19), the first term in the utility function in (20) can be expressed as:

$$\frac{[E(\tilde{v}|\tilde{y}) - \tilde{p}]^2}{2\text{Var}(\tilde{v}|\tilde{y})} = \frac{\gamma^2 Q^2}{2} \text{Var}(\tilde{v}|\tilde{y}) = \frac{\gamma^2 Q^2}{2} \frac{1}{\tau_v + \tau_\eta}. \quad (21)$$

Then,  $CE = \frac{\gamma Q^2}{2} \frac{1}{\tau_v + \tau_\eta}$ , which is decreasing in disclosure quality  $\tau_\eta$ . The intuition is as follows: Greater disclosure brings the asset price closer to its fundamental, and so traders cannot enjoy the benefit of trading a risky asset. In the limit, if  $\tilde{y}$  perfectly reveals  $\tilde{v}$ , then the risky asset becomes riskless, and traders lose all access to risk in their portfolio. The argument is very simple: If traders trade the risky asset in equilibrium, then we can infer that they derive utility from it, and this utility is lost if we shut down risk by revealing the information publicly. Note that this model takes the perspective of the investors by pointing out that they can be worse off by greater disclosure quality. One has to remember that the issuer could be better off by disclosure for several reasons. For example, if the issuer is risk neutral and cares about the average selling price of the security, then as we discussed in Section 2.3.3, disclosure leads to a lower cost of capital, which in turn benefits the issuer. Since the model is not a zero-sum game, the welfare loss of the investors and the welfare gain of the issuer do not cancel out in general.

Now, let us turn off the effect in Kurlat & Veldkamp (2015) and demonstrate the Hir-

shleifer Effect, that is, suppose that  $\sigma_q > 0$  and  $Q = 0$ . In this case, the asset is no longer provided by the issuer and traders trade among themselves to hedge against their endowment shocks. We can compute  $CE = \frac{1}{2\gamma} \log \left( 1 - \gamma^2 \sigma_q^2 \frac{\tau_\eta}{\tau_v(\tau_v + \tau_\eta)} \right)$ , which again decreases with  $\tau_\eta$ . Intuitively, since traders are risk averse, they benefit from trading risk-sharing contracts that insure against their exposure to idiosyncratic shocks. Disclosure reduces risk-sharing opportunities, because once the asset value is known, it is no longer possible to insure against its realization.

The Hirshleifer effect suggests that disclosure is unambiguously bad. This is true when there is enough capital in risk-sharing markets to allow them to work. However, this is not always the case. Consider the interbank market for example, as it is used to share risk among banks. During the recent financial crisis, when aggregate conditions were bleak, this market was not able to function as too many banks suffered shortages. This arguably led to market breakdown. Goldstein & Leitner (2015) study a model to consider a trade-off between the negative Hirshleifer effect and a positive effect of disclosure to prevent market breakdown. They find that in good times, disclosure is undesirable because of the Hirshleifer effect. However, in bad times, some disclosure is necessary to get the market for risk sharing to work. They characterize optimal disclosure schemes in the spirit of the Bayesian Persuasion literature following Kamenica & Gentzkow (2011). Importantly, full disclosure is not desirable, and optimal disclosure is just enough to restart the risk-sharing market by separating traders into different groups and excluding some of them from risk-sharing arrangements.

## 5.2 Coordination and Beauty Contests

Keynes (1936) argues that stock markets share the essence of a beauty contest because the actions of traders are not only governed by their expectations about the true value of traded assets, but also by their expectations about what other traders believe. There are many other environments, such as currency attacks or bank runs, in which agents have not only fundamental concerns but also strategic concerns. In these contexts, public disclosure provides more than just information about fundamentals, as it plays a coordination role of informing agents of what other agents know and so helping each agent to predict the actions of others. This coordination role can be detrimental to efficiency and welfare in the sense

that agents place too much weight on the public signal relative to weights that would be used by a social planner. An example is the paper by Scharfstein & Stein (1990) where investors' coordination motive originates from a reputation concern—they want to appear smart by following the same information that others are following—but ends up harming the quality of investment and monitoring decisions.

The coordination mechanism and its general implications are best demonstrated by Morris & Shin (2002). We now review their model. To keep consistency, we adopt similar notations as our baseline model in Section 2. The underlying state is given by  $\tilde{v}$ , which is drawn from an improper uniform prior over the real line (i.e.,  $\tau_v = 0$ ). There is a continuum  $[0, 1]$  of agents. Agent  $i$  chooses action  $D_i$  and we use  $\mathbf{D}$  to denote the action profile over all agents. Agent  $i$  has access to both a private signal  $\tilde{s}_i$  and a public signal  $\tilde{y}$ , given by equations (1) and (2), respectively.

In Morris & Shin (2002), the beauty-contest motive is directly built into agents' preferences. Specifically, the utility for agent  $i$  is given by

$$u_i(\tilde{v}, \mathbf{D}) = -(1 - b)(D_i - \tilde{v})^2 - b(L_i - \bar{L}) \quad (22)$$

where  $b \in (0, 1)$  is a constant,  $L_i = \int_0^1 (D_j - D_i)^2 dj$ , and  $\bar{L} = \int_0^1 L_j dj$ . Hence, the agent has an incentive (with weight  $b$ ) to take an action close to the fundamentals (e.g., buy more of the asset when the fundamentals are high) and an incentive (with weight  $1 - b$ ) to take an action close to others' actions (e.g., buy when others are buying). Then, the action taken by agent  $i$  is given by

$$D(\tilde{s}_i, \tilde{y}) = \arg \max_{D_i} E[u_i(\tilde{v}, \mathbf{D}) | \tilde{s}_i, \tilde{y}] = (1 - b)E(\tilde{v} | \tilde{y}, \tilde{s}_i) + bE(\bar{D} | \tilde{y}, \tilde{s}_i), \quad (23)$$

where  $\bar{D}$  is the average action in the population, i.e.,  $\bar{D} = \int_0^1 D(\tilde{s}_i, \tilde{y}) di$ . Hence, the agent makes a decision based on the expected level of the fundamental  $\tilde{v}$  and the expectation of what other agents will do. Parameter  $b$  controls the intensity of the beauty-contest motive.

We consider a linear equilibrium in which each agent follows a linear strategy of the form,  $D(\tilde{s}_i, \tilde{y}) = \kappa_s \tilde{s}_i + \kappa_y \tilde{y}$ , where  $\kappa_s$  and  $\kappa_y$  are endogenous coefficients. Inserting this conjectured strategy into equation (23), we can find the expression of  $D(\tilde{s}_i, \tilde{y})$ . We then compare coefficients in this computed expression with those in the conjectured linear strategy

to compute  $\kappa_s$  and  $\kappa_y$  as follows:

$$\kappa_s = \frac{\tau_\varepsilon(1-b)}{\tau_\varepsilon(1-b) + \tau_\eta} \text{ and } \kappa_y = \frac{\tau_\eta}{\tau_\varepsilon(1-b) + \tau_\eta}. \quad (24)$$

When there is no beauty-contest motive (i.e., when  $b = 0$ ), the weight  $\kappa_y$  that is put on the public signal is based on the precision of the two signals as in Bayesian updating. When the beauty-contest motive arises and strengthens (i.e., when  $b > 0$  and increases), the weight  $\kappa_y$  on the public signal increases. The reason is that while both signals provide information about the fundamental, the public signal carries additional weight given that it also provides information about what other agents know and hence it helps predicting their actions.

In Morris & Shin (2002), the excessive weight on the public signal harms social welfare, which is defined as the (normalized) average of individual utilities. By (22), social welfare is

$$W(\tilde{v}, \mathbf{D}) \equiv \frac{1}{1-b} \int_0^1 u_i(\tilde{v}, \mathbf{D}) di = - \int_0^1 (D_i - \tilde{v})^2 di. \quad (25)$$

A social planner would seek to keep all agents' actions close to  $\tilde{v}$ . This is because the beauty contest motive cancels out across individuals and so does not enter the social welfare. Thus, if the social planner can specify the weight that each agent puts on the public signal  $\tilde{y}$ , that weight would be  $\kappa_y^{opt} = \frac{\tau_\eta}{\tau_\varepsilon + \tau_\eta}$ , which is lower than the equilibrium weight  $\kappa_y$  on  $\tilde{y}$ . Thus, the coordination role of public information is welfare reducing.

The implication is that greater disclosure might harm agents' welfare. Formally, using equations (24) and (25), we can compute the expected welfare in equilibrium as

$$E[W(\tilde{v}, \mathbf{D}) | \tilde{v}] = - \frac{\tau_\eta + \tau_\varepsilon(1-b)^2}{[\tau_\eta + \tau_\varepsilon(1-b)]^2}.$$

Direct computation shows that  $E[W(\tilde{v}, \mathbf{D}) | \tilde{v}]$  is U-shaped in the precision  $\tau_\eta$  of public information. Intuitively, releasing public information has two effects on welfare. The positive effect is due to the informational role; that is, more public information helps agents to predict the state  $\tilde{v}$  more accurately. The negative effect is due to the coordination role; that is, agents put too much weight on the public information and this is exacerbated when the public information is more precise. The overall result is that when the public information is sufficiently coarse, the negative effect dominates, while when the public information is sufficiently accurate, the positive effect dominates. Hence, increasing the precision of disclosure is desirable when disclosure is already quite precise.

We point out that the negative welfare effect of coordination is not general. It follows here because the beauty-contest element in individual utility is of a zero-sum nature. Angeletos & Pavan (2007) show that in other settings coordination is socially valuable, and so welfare necessarily increases with the precision of public information. One such example is investment complementarity, in which the production of one firm positively depends on the aggregate production of all firms in the same industry. Colombo et al. (2014) extend Angeletos & Pavan (2007) to allow for endogenous acquisition of private information.

While Morris & Shin (2002) take the beauty-contest motive as given, an important question to ask is where this motive would come from. After all, most traditional models of financial markets, built from first principles, do not predict that traders would like to do what other traders do. Allen et al. (2006) and Cespa & Vives (2015) endogenize the beauty-contest motive using short horizons of financial traders. A short-horizon trader has to close his investment positions in an asset before its fundamental value is realized, and so his payoff depends on how much other traders would like to pay, rather than on how much he expects the fundamental value of the asset will be. As in Morris & Shin (2002), public information again plays two roles in affecting trading: an informational role because it conveys information about the unknown fundamental value; and a coordination role, because it is common to the information sets of all traders and helps a short-horizon trader to predict the future liquidation value when he closes positions.

Gao (2008) uses the setting of Allen et al. (2006) to examine the market-efficiency implications of disclosure. The setting is an extension of our baseline model in Section 2 with one more date ( $t = 0$ ) and hence with two trading periods ( $t = 0$  and  $t = 1$ ). The risky asset still pays off  $\tilde{v}$  at date 2. Traders' short horizons are characterized by an overlapping-generations assumption. Gao (2008) focuses his analysis on the implication of disclosure for the date-0 market efficiency. He shows that greater disclosure always drives stock prices closer to the fundamental value and hence improves market efficiency. The reason lies in an endogenous link between the two roles of public information in affecting the trading of date-0 traders. The coordination role occurs because short-horizon traders correctly believe in the first place that future traders will use public information due to its information value. When the information value becomes thinner, date-0 traders overuse it less because they

again correctly believe that others will be using it less. Thus, the coordination role is always secondary to the information role in terms of market efficiency in the setting of Gao (2008). Note that this result does not directly speak to traders' welfare, because as we discuss in Subsection 5.1, a more informative price may actually harm traders.

Goldstein et al. (2011) endogenize the beauty-contest motive using a model in which the aggregate trading of currency speculators reveals new information to the central bank and affects its policy decision. The beauty-contest motive arises in their setting because speculators know that a large speculative currency attack has the potential of convincing the central bank that the fundamentals are weak and so each speculator would like to second guess other speculators' actions to better coordinate. As a result, speculators put an excessive weight on signals that are correlated with other speculators' information. In this setting, the central bank may inadvertently strengthen the coordination motive by releasing more information that becomes common to speculators, which backfires by reducing the informational content that the central bank learns from the attack, leading the bank to make more policy mistakes.

## 6 Conclusion

The analysis provided in this article demonstrates key insights from the literature on how information disclosure in financial markets affects market quality, information production, real efficiency, and traders' welfare. As the analysis shows, there are many aspects to consider when evaluating the effects of disclosure and the optimal regulation of the level and form of disclosure. We showed here how many of these effects can be manifested in a cohesive analytical framework that has been proven useful in understanding trading and information in financial markets. As disclosure is being used more and more as a tool by regulators to increase market quality, it is important to consider the different implications it has. We hope that our review will be useful for researchers interested in advancing the theoretical and empirical work in the area and for policy analysis as regulations of market disclosure continue to evolve.

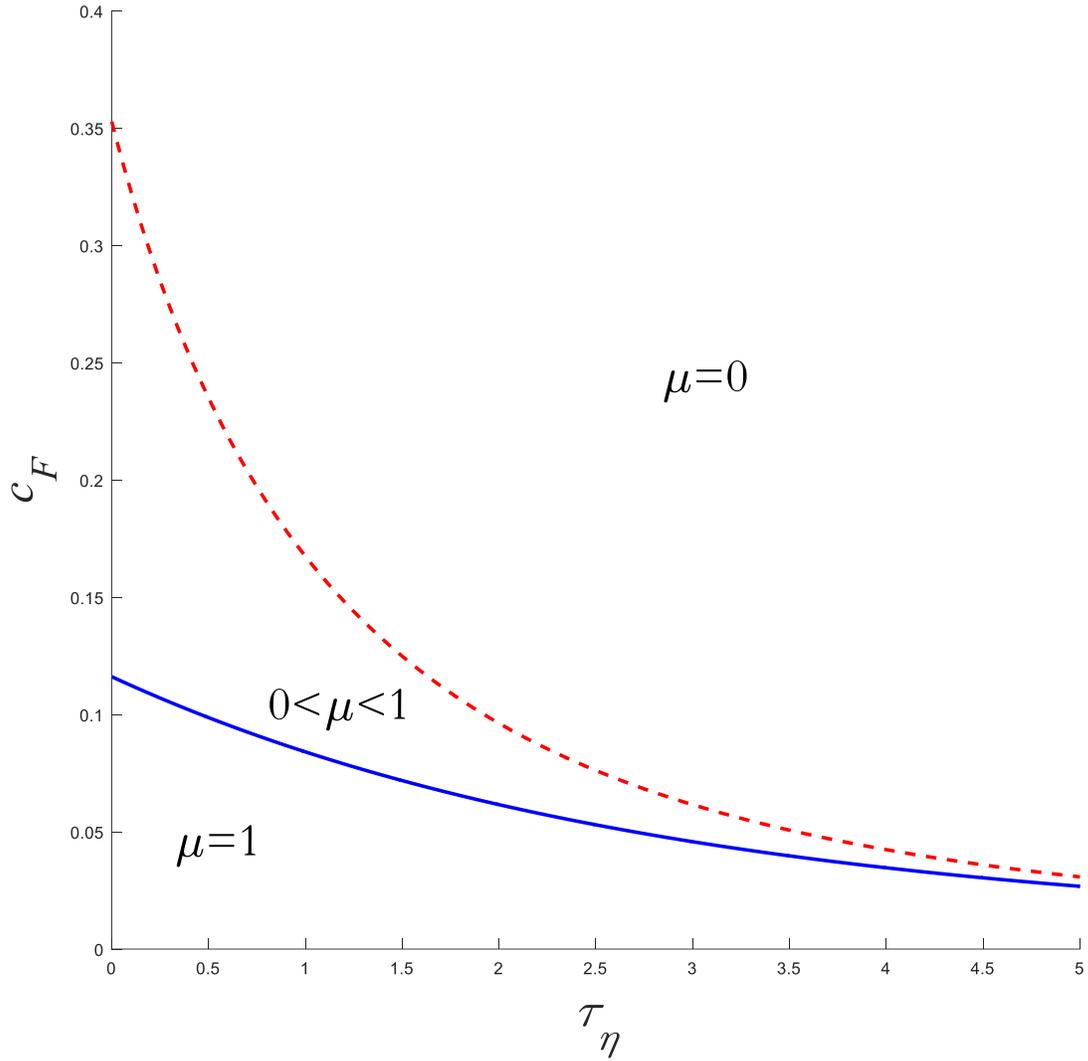
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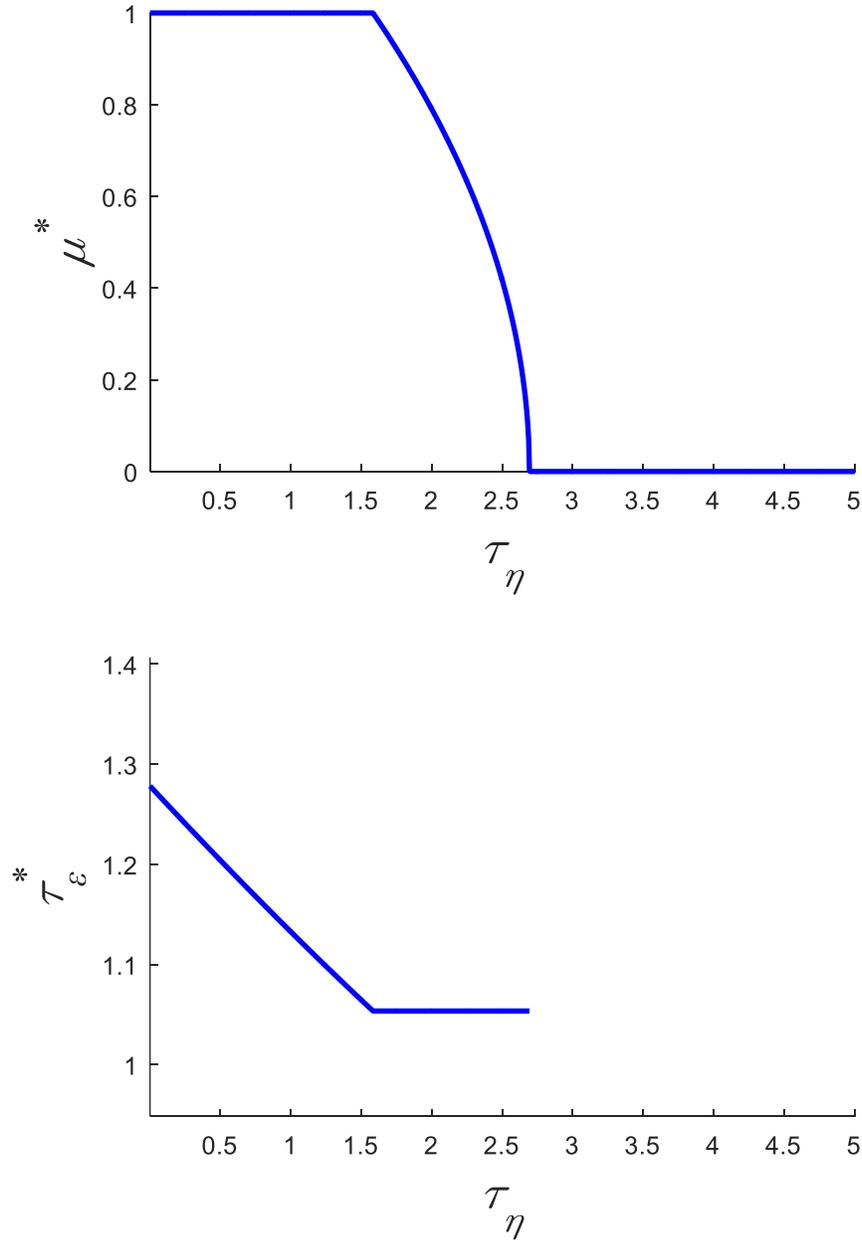
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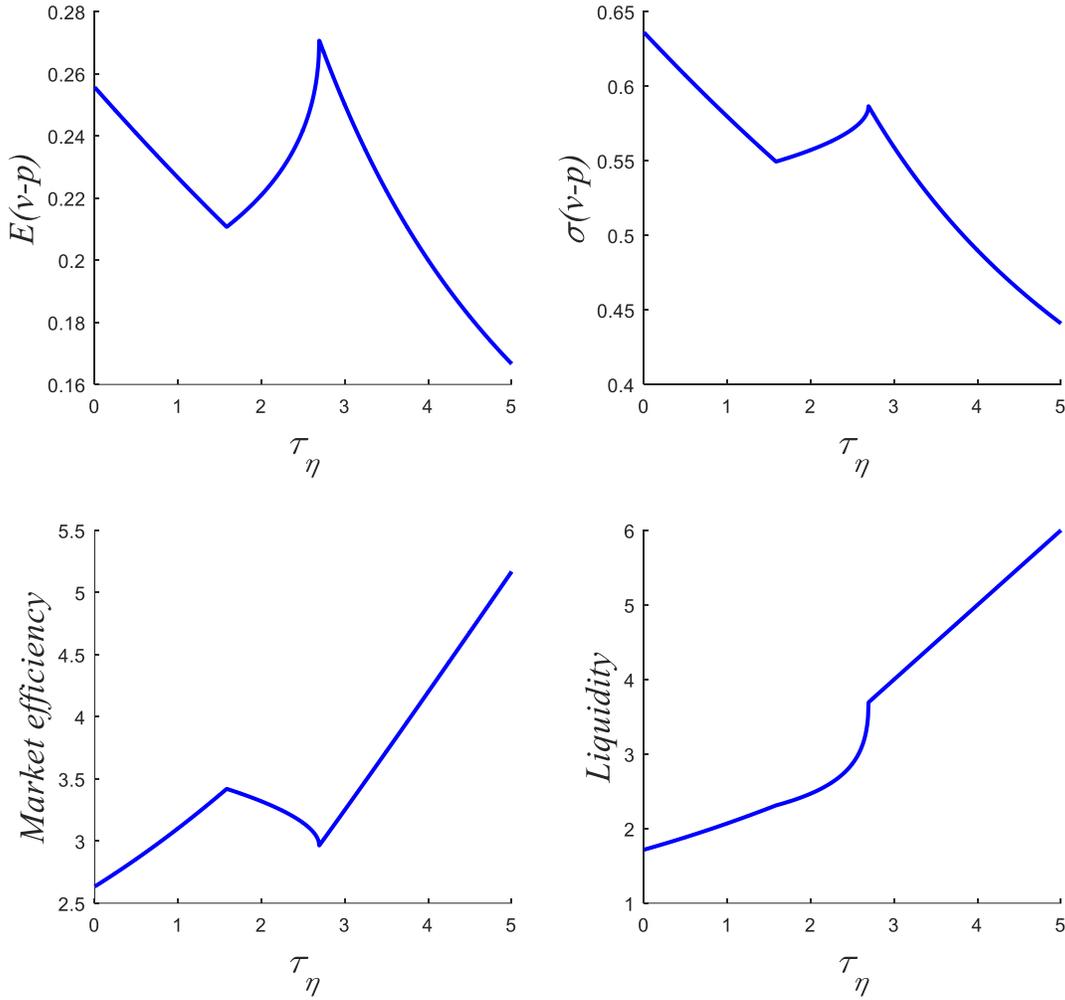
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**Figure 1: Equilibrium types in the economy with endogenous information acquisition.** This figure plots the equilibrium types in the space of  $(\tau_\eta, c_F)$ , where parameter  $\tau_\eta$  controls the disclosure quality and parameter  $c_F$  denotes the fixed cost of information acquisition. The variable cost of information acquisition takes a quadratic form,  $c_V(\tau_{\varepsilon i}) = \frac{k}{2}\tau_{\varepsilon i}^2$ . The parameter values are:  $\tau_v = \tau_x = \gamma = 1$  and  $k = 0.1$ .



**Figure 2: Crowding-out effect.** This figure plots the equilibrium fraction  $\mu^*$  of informed traders and the equilibrium precision  $\tau_\varepsilon^*$  of informed traders' private information against the disclosure quality  $\tau_\eta$ . The variable cost of information acquisition takes a quadratic form,  $c_V(\tau_{\varepsilon i}) = \frac{k}{2}\tau_{\varepsilon i}^2$ . The parameter values are:  $\tau_v = \tau_x = \gamma = 1$ ,  $c_F = 0.07$ , and  $k = 0.1$ .



**Figure 3: Effect of disclosure in the economy with endogenous information acquisition.** This figure plots cost of capital  $E(\tilde{v} - \tilde{p})$ , return volatility  $\sigma(\tilde{v} - \tilde{p})$ , market efficiency  $1/\text{Var}(\tilde{v}|\tilde{p})$ , and market liquidity  $1/p_x$  as functions of the disclosure quality  $\tau_\eta$ . The variable cost of information acquisition takes a quadratic form,  $c_V(\tau_{ei}) = \frac{k}{2}\tau_{ei}^2$ . The parameter values are:  $\tau_v = \tau_x = \gamma = Q = 1$ ,  $c_F = 0.07$ , and  $k = 0.1$ .