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Disclosure and Dynamic Risk Sharing with a Large Shareholder

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ABSTRACT: We study the effects of disclosure in a dynamic market with imperfect competition. The supply of an asset is determined by a large shareholder with price impact, who trades slowly to diversify away from concentrated ownership. Small investors provide capital and thus risk-bearing capacity to the market. Although it is well known that disclosure impedes risk sharing by shifting risk before future trading opportunities, we show that disclosure, at the same time, can enhance risk sharing by promoting more trades. Resolving this tradeoff, an interior level of disclosure quality maximizes the small investors' surplus as well as the total surplus, but minimizes the large shareholder's surplus. Further, efficient disclosure policies feature increasing quality over time.

JEL Classifications: D80; E21; G12; L13; M41.

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I. INTRODUCTION

One of the main roles of financial markets is to facilitate risk sharing (Pagano 1993); those with excessive exposure to certain risks can sell their holdings to those who are less exposed. A typical scenario of this sort is when firms' large shareholders such as founders, venture capitalists, and private equities sell their initial stakes in the open stock market. It is found that diversification motives account for a considerable portion of all trades by corporate insiders and affiliates (Carpenter and Remmers 2001; Cohen, Malloy, and Pomorski 2012). Although the potential of disclosure to reduce information asymmetry between firms and investors is regarded as beneficial for capital allocation (Healy and Palepu 2001), the desirability of disclosure is less evident from a risk-sharing perspective. A seminal result in Hirshleifer (1971) (usually referred to as the "Hirshleifer effect") suggests that disclosure *before* any trading can happen

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is detrimental to sellers and buyers alike because, by reducing the amount of risk that they can share, disclosure prevents them from realizing gains from trade.[1]

In practice, disclosure is a dynamic process. For instance, disclosures are issued both before public offerings, through registration statements, and after public offerings, through periodic reporting. Trading also takes place dynamically. Firms start with concentrated ownership and gradually become more dispersedly held as the controlling shareholders diversify over time (Zingales 1995; Mikkelson, Partch, and Shah 1997; Coates 1998; Bodnaruk, Kandel, Massa, and Simonov 2008; Cohen et al. 2012; Dong, Slovin, and Sushka 2020).[2] Although disclosure *before* any trading takes place destroys risk-sharing opportunities (Hirshleifer 1971), can some disclosure instead facilitate risk sharing if it occurs *between* trading opportunities? In this paper, we show that this question has a positive answer when the financial market is imperfectly competitive because of the presence of large shareholders, who have market power.

We model a pure-exchange economy where a large shareholder, who has market power, trades alongside with many small investors who are price-takers. The large shareholder has a large initial stake in a firm, and seeks to diversify away from this concentrated ownership. The market for the firm's shares opens twice—once before and once after a public disclosure.[3] Because of his market power, the large shareholder faces a downward-sloping price schedule; that is, if he sells more shares, the price must decrease for the small investors to be willing to buy this larger quantity. Empirical studies documented that large shareholders' trades indeed have significant price impacts (e.g., see the survey by Vayanos and Wang 2013). Hence, the large shareholder faces a tradeoff between selling a greater fraction of the firm, to share more risk with small investors, and selling less, to reduce the impact of his sales on the price (Admati, Pfleiderer, and Zechner 1994; DeMarzo and Urošević 2006; Marinovic and Varas 2024). Despite this negative price impact of his trade, the large shareholder earns a "monopoly" rent because of his market power.

The motivation to highlight the role of imperfect competition in financial markets is two-fold. First, large shareholders are commonly present (Shleifer and Vishny 1986). A sample of publicly listed U.S. companies revealed that 96 percent of them had at least one large shareholder (Edmans and Holderness 2017); the average largest shareholder owned 26 percent of the stock, and about half of them were individuals. Further, founding families are present in one-third of the Standard & Poor's (S&P) 500 and account for 18 percent of outstanding equity (Anderson and Reeb 2003). Second, market power of large shareholders can explain the empirical pattern mentioned earlier that they sell gradually over time. Without their price impact, all the sales would take place immediately and exclusively at the very first chance to trade, and any subsequent disclosure would be irrelevant for traders' welfare (Christensen et al. 2010). By contrast, with the negative price impact of his sales, a large shareholder cannot fully diversify in his first trade. Nor can he hold a constant amount of shares after the first trade, because such a strategy is not sequentially optimal (DeMarzo and Urošević 2006). In the first period, the large shareholder internalizes the negative impact of his second-period sales on both the second-period and first-period prices. However, in the second period, the first-period price is sunk, and the large shareholder only internalizes the negative effect on the second-period price. Therefore, in the second period, the large shareholder finds it optimal to sell more shares than it would have been optimal *ex ante*. Notably, this deviation does not occur because of new private information, but rather because the large shareholder's incentives change over time.[4]

We find that disclosure quality has two opposing effects on the extent of risk sharing. On the negative side, more precise disclosure implies that relatively more uncertainty is resolved before traders have an additional opportunity to share risk in the second trading round. This destruction of risk-sharing opportunities can be viewed as a generalization of the Hirshleifer effect to a dynamic market with imperfect competition. On the other hand, the novel positive effect is that more precise disclosure increases trading volume, thereby promoting risk sharing. Intuitively, because the large shareholder sells slowly, as the quality of the disclosure between the two trading rounds increases, his sales before the disclosure increase as he faces more risk about the second-period price, which leads to him selling more overall across

[1] A discussion in Dye (1985) complements this insight: "[r]isk-averse investors must be allowed to take positions on markets [before disclosure] so as to ensure themselves against the information the manager discloses. Otherwise, they may prefer suppression of this information."

[2] For example, Mikkelson et al. (1997) find that top officers' stakes in U.S. companies decrease from 67 percent before the IPO to 43 percent immediately after, to 28 percent after five years, and to 17 percent after ten years.

[3] Assuming two trading periods is a common modeling choice in the literature and it makes the analysis tractable without significant loss of generality (e.g., Christensen, de la Rosa, and Feltham 2010; Friedman and Heinle 2016; Verrecchia 2019). See Section VI for an extension with more trading and disclosure rounds. We also formally show that no trader prefers any disclosure before the first trading opportunity, precisely because of the Hirshleifer effect.

[4] A modified version of the Coase (1972) conjecture holds here: being unable to commit not to sell more shares later, the large shareholder is effectively in competition with his future self, which drives down his monopoly rent. Commitment power is limited in reality. Rule 10b5-1 plans enable corporate insiders and large blockholders to preplan future trades as an affirmative defense against potential charges of insider trading. However, trading at any point when not in possession of material nonpublic information (MNPI) is always permissible (Gelfond and Katzman 2015). Further, the lack of a requirement to publicly disclose 10b5-1 plans allows insiders, in principle, to covertly cancel or trade outside of such plans (Larcker, Lynch, Quinn, Tayan, and Taylor 2021). For these reasons, deviations are not particularly costly, especially for insiders without MNPI (as in our main model). Therefore, 10b5-1 plans might be ineffective as a commitment device to preplan routine trades.

the two periods. By increasing the sales volume and moving the holdings closer to the competitive benchmark, more precise disclosure effectively incentivizes risk sharing.

The tension between destruction and creation of risk-sharing opportunities determines how disclosure quality affects traders' surplus. The small investors have the role of bearing the risk that the large shareholder diversifies. The more risk the small investors bear, the higher the surplus that they earn. As a result of the tradeoff above, the small investors' surplus is hump-shaped in disclosure quality. Further, disclosure policies that increase the small investors' surplus decrease the large shareholder's surplus, which is then U-shaped in disclosure quality. This occurs because the large shareholder acts as a monopolist in the asset market and, hence, disclosure policies that make the buyers better off reduce the large shareholder's rent. Total surplus as a function of disclosure quality follows the same pattern as small investors' surplus, because imperfect competition leads to a deadweight loss (Tirole 1988); any disclosure that decreases (increases) the large shareholder's market power is more than offset by an increase (decrease) in the small investors' surplus.

The literature identified other rationales for disclosure without assuming that information is used for productive decisions. Pre-trade disclosure can be beneficial in pure-exchange economies if traders are asymmetrically informed and acquiring private information is costly (Diamond 1985). Under those circumstances, public information improves risk sharing by discouraging private information acquisition, thus making traders' beliefs more homogeneous and, consequently, reducing the magnitude of their speculative positions. Further, Verrecchia (2019) shows that, when trading can occur both before and after a disclosure, some public information can improve traders' surplus if they are heterogeneously informed. In his model, disclosure improves risk sharing by reducing the speculative trades caused by the heterogeneous precisions. The literature also showed that some public information can be welfare-improving when markets are incomplete (e.g., Green 1981; Hakansson, Kunkel, and Ohlson 1982; Gottardi and Rahi 2014). For a study on the welfare effects of disclosure in a production economy, see Gao (2010). As in Verrecchia (2019), we examine a pure-exchange setting, but we focus on the distortion due to the market power of a seller who trades dynamically. In our setting, some disclosure improves the small investors' surplus as well as total surplus by increasing the extent of risk sharing (and decreases the large shareholder's rent derived from his market power). To our knowledge, this positive effect of disclosure quality on risk sharing is new to the literature.

An important feature of our setting is that there is positive trading volume after the disclosure, even though traders can form portfolios before the disclosure. In the literature, a similar feature arises when investors are differentially informed (Verrecchia 2019), have heterogeneous preferences (Friedman and Heinle 2016), or have heterogeneous prior beliefs (Christensen and Qin 2014). In our setting, post-disclosure trading occurs because the seller's market power prevents immediate efficient risk sharing in one trading round. Such a slow trading is also present in Rostek and Weretka (2015), who consider a dynamic asset market with multiple large traders. They show that maximizing traders' surplus requires postponing disclosure as much as possible. We reach a different conclusion that disclosure can allow some traders to realize more gains from trade. In our model, this occurs because greater disclosure induces the large shareholder to supply more shares to small investors. By contrast, all traders are large in their model; some buy whereas others sell, but in the aggregate they supply the same quantity of risk.

To highlight the salient implications of the large shareholder's market power, our main model focuses on an economy with risk-averse traders and in which the large shareholder's sales are "routine," that is, not driven by private information.[5] To distinguish the implications of risk sharing from those of asymmetric information, we also study an alternative dynamic model, with risk-neutral traders, where the large shareholder profits from trading on private information. In such a setting without risk-sharing incentives, by contrast, disclosure only has the effect of eroding the large shareholder's informational advantage and, thus, his surplus, at the benefit of liquidity traders.

The rest of the paper is organized as follows. Section II describes the model. Section III solves two benchmark cases and characterizes the unique equilibrium of the main model. Section IV presents our main results. Section V discusses the scenario where the large shareholder has a direct influence over the disclosure quality. Section VI discusses dynamic disclosures. Section VII studies the implications of asymmetric information and contrasts them to the risk-sharing effects that we identify in our main model. Section VII concludes. All proofs are in Appendix A.

II. MODEL DESCRIPTION

There are two classes of traders: a large shareholder, denoted L, and a continuum of symmetric small investors, each indexed by $i \in [0, 1]$. They trade over two periods, $t \in \{1, 2\}$, and consume at $t = 3$. By definition, L has market

[5] Empirical research developed methods to disentangle trades driven by private information and routine trades. For example, Cohen et al. (2012) show that about three-quarters of insiders' trades are sales and more than half of their sales are not driven by private information but are instead due to reasons such as diversification.

power, in the sense that his trades affect the equilibrium price of the firm: the more L sells, the lower the price.[6] By contrast, small investors are price-takers and as such, they cannot affect the firm's price through their individual trades. We assume that both L and small investors have constant absolute risk aversion (CARA) preferences defined over their terminal wealth at $t = 3$. That is, their utility functions are, respectively, $u_L(w_L) = -exp(-\gamma w_L)$ and $u_i(w_i) = -exp(-\rho w_i)$, where w_L and w_i are their terminal wealths. Note that we allow L's degree of risk aversion, as captured by the parameter γ, to be different from that of small investors, ρ.

There are two investment opportunities: one risky and one riskless asset. We can interpret this firm as a large firm such that the firm's risk cannot be fully diversified or hedged against even in a large economy.[7] For small firms, the idiosyncratic risk can be priced because the "true" market portfolio may not be a tradeable asset (Merton 1973; Taylor and Verrecchia 2015) or investors may hold undiversified portfolios for exogenous reasons (Levy 1978; Merton 1987), which is consistent with ample empirical evidence (see, Huang, Liu, Rhee, and Zhang 2010).[8] The firm's stock yields stochastic terminal cash flows $\tilde{v}$ at $t = 3$, which are normally distributed with mean μ_v and precision (i.e., inverse of the variance) τ_v. The riskless asset yields a constant payoff $r_f = 1$ in the subsequent period. We normalize the price of the riskless asset to 1 (i.e., the riskless asset is the numeraire). L is initially endowed with a share x_0 of the firm and each small investor with $y_0 \equiv 1 - x_0$, his fraction of the remaining share. Throughout, we assume that L's initial endowment satisfies $x_0 > x_0^{nt} \equiv \frac{\rho}{\gamma + \rho}$, where the superscript nt on x_0^{nt} stands for "no trade." Indeed, if L's initial endowment were exactly equal to x_0^{nt}, then he would not trade in either period, because x_0^{nt} is the most efficient allocation from a risk-sharing perspective. Our assumption that $x_0 > x_0^{nt}$ is in line with the idea of dynamic risk sharing, as it is both a necessary and sufficient condition for L to be a net seller in equilibrium.[9] We let $\Delta x_t \equiv x_t - x_{t-1}$ denote L's order flow in period t. $\Delta x_t < 0$ ($\Delta x_t > 0$) means that L sells (buys) shares in that period. Similarly, we denote small investors' order flows by $\Delta y_{i,t}$.

The timeline is as follows. At $t = 1$, L and small investors engage in the first trading round: L and each small investor submit order flows Δx_1 and $\Delta y_{i,1}$, respectively. At $t = 2$, a public signal $\tilde{s}$ about the firm's terminal cash flows $\tilde{v}$ is realized (details on the signal structure below). After the signal is publicly observed, the market opens for a second trading round: L and small investors submit order flows Δx_2 and $\Delta y_{i,2}$. In each of the periods $t = 1, 2$, market clearing requires that traders' aggregate holdings are equal to the asset supply,

$$x_t + \int y_{i,t}\, \mathrm{d}i = 1. \tag{1}$$

This market-clearing condition determines the price p_t. Finally, at $t = 3$ the firm's terminal cash flows $\tilde{v}$ are realized and paid out as dividends. As in Admati et al. (1994), we assume that L's holdings $\{x_1, x_2\}$ are publicly observable.[10]

The public signal allows traders to update their beliefs before trading a second time. In other words, in the first period traders' beliefs are only determined by the prior, whereas in the second period traders form posterior beliefs conditional on the realized public signal $\tilde{s} = s$.[11] We assume that this signal takes the form $\tilde{s} = \tilde{v} + \tilde{\varepsilon}$, where $\tilde{\varepsilon}$ is a normally

[6] In the literature, there are models where L trades alongside noise traders (e.g., Kyle 1985). In such models, a higher supply by L decreases the stock price because of adverse selection. Specifically, the market maker, who observes only the total order flow of L and noise traders, interprets a higher supply as indicative of low asset value, and accordingly sets a lower price. In models without asymmetric information (such as ours and Admati et al. 1994; DeMarzo and Urošević 2006), more sales by L decrease the price because the small investors who buy the shares are risk averse and must be compensated for bearing more risk.

[7] Consistent with Diamond and Verrecchia (1991), in this context, the size of the firm is given by the total asset supply. A firm is large relative to the economy if its total supply is proportional to the risk-bearing capacity of the market; we normalize both the asset supply and the mass of small investors to unity. Formally, the model is equivalent to a limiting economy where: the total asset supply is $m > 0$; L initially owns a fraction f_0 of the total supply (i.e., $x_0 = f_0 m$); there are m small investors; each small investor has risk aversion ρ and L has risk aversion γ/m, so the per capita risk-bearing capacity is constant (as in Caskey, Hughes, and Liu 2015); and $m \to \infty$. It is not important that the risky asset supply and the number of small investors is the same; what matters is that they grow at the same rate, otherwise the per capita risk exposure in the large economy limit would be zero or infinite.

[8] When the firm is small, the large shareholders can also hedge. However, hedging is not costless. We are unaware of empirical evidence on hedging strategies of large shareholders in general, although corporate executives are found to hedge only 30 percent of their equity exposures (Edmans, Gabaix, and Jenter 2017).

[9] See the proof of Lemma 1(ii). As in Admati et al. (1994), we abstract away from how L previously acquired the large stake. Studying the subsequent game where L liquidates his stakes has implications for the *ex ante* game where they acquire the stakes. The most natural interpretation without having to specify an *ex ante* game is that there is a founder who, over time, diversifies away from his concentrated holdings.

[10] In the setting under consideration, this assumption is without loss of generality: there is a one-to-one relation between x_t and p_t, which means that investors can invert the price function to back out L's holdings. Relatedly, see footnote 14 in Admati et al. (1994).

[11] This public signal can be interpreted as capturing the information release from a periodic reporting such as an earnings release and a 10-K/Q filing. We can also interpret the first trading (i.e., sale by the large shareholder) as an IPO offering. Since the SEC imposes a 180-day lock-up period after an IPO, this public signal can be interpreted as capturing all the mandatory information releases during this lock-up period before further sales are allowed.

distributed noise with zero mean and precision τ_ε, and is independent of $\tilde{v}$.[12] Let $\mathrm{Var}[\tilde{v}|\tilde{s}]$ denote the variance of $\tilde{v}$ conditional on the public signal (with a slight abuse of notation, we condition on the random variable, as opposed to its realization, because by normality the posterior variance is the same for all realizations). The precision of the public signal, τ_ε, captures disclosure quality: when precision $\tau_\varepsilon = 0$, the public signal is completely uninformative (i.e., $\mathrm{Var}[\tilde{v}|\tilde{s}] = \mathrm{Var}[\tilde{v}]$); when $\tau_\varepsilon = \infty$, the public signal perfectly reveals $\tilde{v}$ (i.e., $\mathrm{Var}[\tilde{v}|\tilde{s}] = 0$). Generally, $\mathrm{Var}[\tilde{v}|\tilde{s}]$ is sandwiched between 0 and $\mathrm{Var}[\tilde{v}]$, and the fraction of total uncertainty that is resolved before the second period monotonically increases in τ_ε. Because our results do not hinge on any trader being privately informed, in the main model we assume away private information. Therefore, L and small investors have the same beliefs about the $\tilde{v}$ in all periods. We discuss the different implications of risk sharing versus asymmetric information in Section VII.

L's and small investors' terminal wealth are, respectively,

$$w_L = vx_2 - p_2\Delta x_2 - p_1\Delta x_1 \text{ and } w_i = vy_{i,2} - p_2\Delta y_{i,2} - p_1\Delta y_{i,1}. \tag{2}$$

We define L's *ex ante* surplus as the certainty equivalent, before the first period, of his terminal wealth, denoted $CE_{L,0} \equiv -\frac{1}{\gamma}\log \mathrm{E}[-u_L(\tilde{w}_L)]$. Similarly, we define a small investor's *ex ante* surplus as $CE_{i,0} \equiv -\frac{1}{\rho}\log \mathrm{E}[-u_i(\tilde{w}_i)]$. The *ex ante* total surplus is then the sum of L's and the aggregate small investors' surplus, denoted[13]

$$TS \equiv CE_{L,0} + \int CE_{i,0}di. \tag{3}$$

Next, Section III derives the unique sequential equilibrium of this dynamic game and studies its properties. We relegate the formal definition of traders' strategies and of the equilibrium concept to Appendix A.

III. ANALYSIS

We begin the analysis by discussing the effects of public information on traders' surplus in two relevant benchmarks. First, we consider the dynamic model without market power of L; and second, we study the dynamic trading model where L has market power but can commit *ex ante* to a trading plan. The objective of studying these benchmarks is to demonstrate that each of these two features—market power and inability to commit—are key ingredients for the results of our model, which we derive later in this section and in Section IV.

Benchmarks

No Market Power

For the purposes of this benchmark, let us assume that L lacks market power. Formally, this means that L behaves as a unit mass of small investors with risk aversion parameter γ. Because here L does not internalize his price impact, in this benchmark all traders are equal except for their risk attitude and, in equilibrium, they will bear a fraction of the total risk that is proportional to their risk tolerance. To denote equilibrium quantities in this benchmark, we use the superscript "pt" to signify "price-taker."

Remark 1: If L lacks market power, then traders' equilibrium holdings are

$$x_1^{pt} = x_2^{pt} = x_0^{nt} \equiv \frac{\rho}{\gamma + \rho} \text{ and } y_{i,t} = 1 - x_0^{nt} \text{ for all } i, t. \tag{4}$$

Traders' equilibrium *ex ante* surpluses are, respectively,

$$CE_{i,0}^{pt} = K_{\neg L}^* + \frac{\rho}{2}\mathrm{Var}[\tilde{v}](x_0 - x_0^{nt})^2 \text{ and } CE_{L,0}^{pt} = K_L^* - \frac{\gamma + 2\rho}{2}\mathrm{Var}[\tilde{v}](x^c - x_0^{nt})^2, \tag{5}$$

[12] Although we model public information as a normally distributed signal of the asset value, Suijs (2008) and Armstrong, Taylor, and Verrecchia (2016) allow for asymmetric reporting of good versus bad news under perfect competition.

[13] Alternatively, we could measure the normative implication of the disclosure policy by using the sum of utilities. Dye (1990) shows that the disclosure policy that maximizes the total surplus as defined in Equation (3) also maximizes any weighted average of the traders' utilities, regardless of the weights, if lump-sum transfers are implemented among them.

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where the constants $K^*_{\neg L}$ and K^*_L are independent of disclosure quality, τ_ε, and x^c is defined in Equation (6). Further, traders' surpluses are independent of τ_ε.

This benchmark replicates the *ex ante* irrelevance results of Christensen et al. (2010) in a version without private information and noise trading. Traders achieve efficient risk sharing in the first period and, in the second period, there is no need to trade anymore. Reaching efficient risk sharing immediately would be impossible if, instead, L had market power: the price impact of his trades would prevent him from selling as many shares as in this benchmark (see Lemma 1 below).

Commitment

Let us now revert to a version of the model where L has market power, but consider a situation where L can commit *ex ante* to a trading plan. We denote the equilibrium quantities in this benchmark with the superscript "c" to indicate "commitment."

Remark 2: If L can commit *ex ante* to a trading plan, then traders' equilibrium holdings are

$$x_1^c = x_2^c = x^c \equiv \frac{(1 + x_0)\rho}{\gamma + 2\rho} \text{ and } y_{i,t} = 1 - x^c \text{ for all } i, t. \tag{6}$$

Traders' equilibrium *ex ante* surpluses are, respectively,

$$CE^c_{i,0} \quad = K^*_{\neg L} + \frac{\rho}{2}\mathrm{Var}[\tilde{v}](x_0 - x^c)^2 \text{ and } CE^c_{L,0} = K^*_L, \tag{7}$$

where the constants $K^*_{\neg L}$ and K^*_L are independent of disclosure quality, τ_ε.[14] Further, traders' surpluses are independent of τ_ε.

Under commitment, it is optimal for L to stop selling shares after the first round of trading. The trading pattern in the equilibrium of this benchmark replicates Corollary 1(b) in Dye (2010), who studies a dynamic trading model with commitment. As will be clear later on in our analysis (see Lemma 1), the issue with lack of commitment is that L cannot refrain from trading in the second period and eventually sells too many shares, thereby driving down the price too much. On the contrary, with commitment L can maintain his position unchanged between the first and second trading periods. Disclosure quality is irrelevant for surplus because in both periods traders hold exactly the same position, and so they are indifferent between bearing risk in the first or second period.

Equilibrium Derivation

At this point, let us turn to the main model, where L has price impact and lacks commitment power. We solve the game backward, starting in the second period after the public signal is realized. Later, we solve for the equilibrium in the first period, with traders anticipating their sequentially rational behavior in the following period.

Equilibrium in the Second Period

Take any first-period history (on or off the equilibrium path), $\{x_1, p_1, y_{i,1}\}$. Given this history, in the second period small investor i conditions on the realized public signal $\tilde{s} = s$ and, taking the price p_2 as given, chooses $y_{i,2}$ to maximize the certainty equivalent of the expected utility from his terminal wealth:

$$\max_{y_{i,2}} \mathrm{E}[\tilde{v}|s]y_{i,2} - p_2\Delta y_{i,2} - p_1\Delta y_{i,1} - \frac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]y_{i,2}^2 \tag{8}$$

The first-order condition of a small investor's problem gives the optimal second-period holdings $y^*_{i,2}$ and, aggregating over all small investors, we obtain the aggregate second-period holdings,

$$\int y^*_{i,2}\mathrm{d}i = \frac{\mathrm{E}[\tilde{v}|s] - p_2}{\rho\mathrm{Var}[\tilde{v}|\tilde{s}]}. \tag{9}$$

Plugging Equation (9) into the market-clearing Condition (1) gives the price function

[14] $K^*_{\neg L}$ and K^*_L are the same constants as in Remark 1.

$$p_2(s,x_2) = \mathrm{E}[\tilde{v}|s] - \rho \mathrm{Var}[\tilde{v}|\tilde{s}](1-x_2). \tag{10}$$

Expression (10) states that the asset price is given by its expected payoff, conditional on the information available, less a risk premium. The risk premium is proportional to the asset quantity that the small investors hold and to the posterior variance, which represents the risk per unit of asset. When small investors hold more shares, or when each share is more risky, the risk premium must be higher for the market to clear, otherwise small investors would not be willing to hold that much stock.[15] L thus acts as a monopolist who faces a downward sloping price function: the more shares L sells (i.e., the higher $1-x_2$), the lower must the price $p_2(s,x_2)$ be for small investors to be willing to absorb L's supply. Thus, L chooses his second-period holdings x_2 not only based on risk-sharing motives, but also internalizing his negative impact on the price per share as he sells more. Specifically, taking as given the previous history $\{x_1, p_1\}$ and the realized public signal $\tilde{s}=s$, L's optimization problem at $t=2$ is

$$\max_{x_2} \mathrm{E}[\tilde{v}|s]x_2 - p_2(s,x_2)\Delta x_2 - p_1 \Delta x_1 - \frac{\gamma}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]x_2^2, \tag{11}$$

where $p_2(s,x_2)$ is the price function from Equation (10). Taking the first-order condition with respect to x_2 yields that L's optimal second-period holdings, $x_2^*(x_1)$, satisfy

$$\underbrace{\mathrm{E}[\tilde{v}|s] - p_2\left(s, x_2^*(x_1)\right) - \gamma \mathrm{Var}[\tilde{v}|\tilde{s}]x_2^*(x_1)}_{\text{return-risk trade-off}} + \underbrace{\frac{\partial p_2\left(s, x_2^*(x_1)\right)}{\partial x_2}(x_1 - x_2^*(x_1))}_{\text{price impact}} = 0. \tag{12}$$

Equation (12) reveals the tradeoffs that lead to the optimal $x_2^*(x_1)$. The first term is the classic tradeoff in portfolio choice between return and risk: L's holdings are increasing in the expected gross return, $\mathrm{E}[\tilde{v}|s] - p_2(s, x_2^*(x_1))$, and decreasing in variance, $\mathrm{Var}[\tilde{v}|\tilde{s}]$. This first term is present irrespective of market power. Instead, the second term only appears when L has market power, and it represents the negative price impact on the shares that he sells in the period, $x_1 - x_2^*(x_1)$. All else equal, this price effect disincentivizes L from selling shares.

A significant feature of L's second-period holdings is that it is an increasing function of his pre-trade holdings, x_1. Specifically, the more shares L owns at the beginning of the second period, the less he sells over the two periods. The reason is that the negative price impact of L's sales decreases the market value of his pre-trade holdings and, if such holdings are greater, this negative effect is of larger magnitude. As a consequence, L sells less.

Having solved for the second-period price function (10) and L's holdings, we are now in a position to derive the equilibrium in the first period.

Equilibrium in the First Period

As for the second period, we first solve for the price function and then for L's optimal holdings. Taking x_1 and the price p_1 as given, and correctly conjecturing the outcome in the second-period continuation game, small investor i chooses $y_{i,1}$ to maximize the first-period certainty equivalent of his terminal wealth,[16]

$$\max_{y_{i,1}} \mathrm{E}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right]y_{i,1} - p_1 \Delta y_{i,1} - \frac{\rho}{2}\mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right]y_{i,1}^2 + \frac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]\left(1 - x_2^*(x_1)\right)^2, \tag{13}$$

which yields the optimal aggregate holdings of small investors,

$$\int y_{i,1}^* \mathrm{d}i = \frac{\mathrm{E}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right] - p_1}{\rho \mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right]}. \tag{14}$$

[15] Note that, in equilibrium, the risk premium will also depend on L's risk aversion parameter, since his preferences determine the equilibrium asset supply.
[16] For the derivation of this expression, see Appendix A, section "Expressions for traders' objective functions at $t=1$."

The first-period aggregate holdings Equation (14) take the same form as the second-period aggregate holdings Equation (9), however with the notable difference that, in the second period, small investors base their trading decision on the return $\tilde{v} - p_2$, whereas in the first period the relevant return is $\tilde{p}_2 - p_1$.

Plugging Equation (14) into the market-clearing Condition (1) gives the first-period price function,

$$p_1\left(x_1, x_2^*(x_1)\right) = \mu_v - \rho \text{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right](1 - x_1) - \rho \text{Var}[\tilde{v}|\tilde{s}]\left(1 - x_2^*(x_1)\right). \tag{15}$$

This expression for the first-period price shows that, in the first period, small investors require two separate risk premia: one risk premium, $\rho \text{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right](1 - x_1)$, for bearing the risk of the return $\tilde{p}_2 - p_1$ on their first-period aggregate holdings, $1 - x_1$; and another risk premium, $\rho \text{Var}[\tilde{v}|\tilde{s}]\left(1 - x_2^*(x_1)\right)$, in anticipation of having to bear the risk of the return $\tilde{v} - p_2$ on their second-period aggregate holdings, $1 - x_2$. Given this first-period price function, L chooses x_1 to maximize the certainty equivalent at $t = 1$ of his terminal wealth,[17]

$$\begin{aligned} \max_{x_1} \text{E}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right]x_1 - p_1\left(x_1, x_2^*(x_1)\right)\Delta x_1 - \frac{\gamma}{2}\text{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1)\right)\right]x_1^2 \\ + \text{Var}[\tilde{v}|\tilde{s}]\left[\rho x_2^*(x_1) - \frac{2\rho + \gamma}{2}\left(x_2^*(x_1)\right)^2\right]. \end{aligned} \tag{16}$$

Using the envelope theorem, we find that the optimal first-period holdings of L satisfy

$$\underbrace{\text{E}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right] - p_1\left(x_1^*, x_2^*(x_1^*)\right) - \gamma \text{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right]}_{\text{return-risk trade-off}} + \underbrace{\frac{dp_1\left(x_1^*, x_2^*(x_1)\right)}{dx_1}(x_0 - x_1^*)}_{\text{total price impact}} = 0, \tag{17}$$

where

$$\underbrace{\frac{dp_1\left(x_1^*, x_2^*(x_1)\right)}{dx_1}}_{\text{total price impact}} = \underbrace{\frac{\partial p_1\left(x_1^*, x_2^*(x_1^*)\right)}{\partial x_1}}_{\text{direct impact}} + \underbrace{\frac{\partial p_1\left(x_1^*, x_2^*(x_1^*)\right)}{\partial x_2}\frac{\partial x_2^*(x_1^*)}{\partial x_1}}_{\text{indirect impact}} \tag{18}$$

is the total differential of the first-period price with respect to x_1. Equation (17) bears a resemblance with Equation (12) and has an analogous interpretation. But a major difference is that here L's holdings affect the first-period price not only directly, but also indirectly through their impact on second-period trading, as is captured by the second term in the total differential. This term is positive and reflects the fact that L sells less overall when he holds more shares in the first period; hence, the second-period risk premium is lower because small investors have to bear less risk. In the commitment case, this term would be absent, because L could choose each period's holding separately.

Lemma 1 below derives explicitly L's equilibrium holdings.

Lemma 1 (Equilibrium holdings): There exists a unique equilibrium of this dynamic game. In equilibrium, L's holdings in the first and second period are, respectively,

$$x_1^* = \frac{(\text{Var}[\tilde{v}] - \text{Var}[\tilde{v}|\tilde{s}])\rho(1 + x_0) + \text{Var}[\tilde{v}|\tilde{s}]\frac{\rho^2}{\gamma + 2\rho}x_0}{(\text{Var}[\tilde{v}] - \text{Var}[\tilde{v}|\tilde{s}])(\gamma + 2\rho) + \text{Var}[\tilde{v}|\tilde{s}]\frac{\rho^2}{\gamma + 2\rho}}, \tag{19}$$

$$x_2^*(x_1^*) = \frac{(1 + x_1^*)\rho}{\gamma + 2\rho}. \tag{20}$$

Next, Lemma 2 derives traders' *ex ante* surplus in equilibrium.

[17] Also see Appendix A, section "Expressions for traders' objective functions at $t = 1$," for the derivation.

Lemma 2 (Equilibrium surplus): In equilibrium, small investors' and L's *ex ante* surpluses and the total surplus are, respectively,

$$CE^*_{i,0} = K^*_{\neg L} + \frac{\rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x_0 - x^*_1)^2 + \mathrm{Var}[\tilde{v}|\tilde{s}](x_0 - x^*_2)^2\right],$$
$$CE^*_{L,0} = K^*_L - \frac{\gamma + 2\rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x^c - x^*_1)^2 + \mathrm{Var}[\tilde{v}|\tilde{s}](x^c - x^*_2)^2\right],$$
$$TS^* = K^* - \frac{\gamma + \rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x^*_1 - x^{nt})^2 + \mathrm{Var}[\tilde{v}|\tilde{s}](x^*_2 - x^{nt})^2\right], \quad (21)$$

where the constants $K^*_{\neg L}$, K^*_L and K^* are independent of disclosure quality, τ_ε.[18]

All these expressions for traders' surplus are convex combinations of the squared distance between L's equilibrium holdings and certain benchmark holdings. The weights of this convex combination are the amount of uncertainty that is to be resolved in a given trading period. After first-period trading, the amount of uncertainty that is resolved is $\mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]] = \mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}]$, which is the variation in traders' beliefs conditional on the public signal; after second-period trading, the amount of uncertainty that is resolved is $\mathrm{Var}[\tilde{v}|\tilde{s}]$, which is the residual uncertainty after observing the public signal. When the public signal is completely uninformative, traders cannot make any updating: $\mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]] = 0$. Because all uncertainty is resolved at the end of the second period, only second-period trading affects surplus. Conversely, traders' beliefs react the most to the public signal when it perfectly reveals the asset value: $\mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]] = \mathrm{Var}[\tilde{v}]$. Because all uncertainty is resolved at the end of the first period, only first-period trading affects surplus.

The benchmark quantities are also intuitive. Small investors benchmark L's equilibrium holdings against his initial endowment, x_0. The reason is that the equilibrium price adjusts so as to reward small investors for their risk-bearing capacity. Therefore, their compensation increases as L sells more of his initial endowment. For L, the benchmark is his holdings under commitment, x^c (see Remark 2), because the inability to commit reduces his surplus. Last, from a total surplus perspective, the benchmark is L's holdings under efficient risk sharing, x^{nt}, which would obtain after one round of trade if L had no market power (see Remark 1). Market power, whether with or without commitment, introduces a distortion in the risk-sharing allocation. Hence, the closer L's holdings are to the benchmark with no market power, the higher the total surplus.

IV. MAIN RESULTS

This section presents our core results, which concern the effects of varying disclosure quality, τ_ε, on traders' surplus. First, Proposition 1 states some useful properties of L's equilibrium holdings.

Proposition 1: In equilibrium, L's holdings have the following properties.

(i) If the disclosure quality is at an interior level (i.e., $\mathrm{Var}[\tilde{v}|\tilde{s}] \in (0, \mathrm{Var}[\tilde{v}])$), then $x_0 > x^*_1 > x^c > x^*_2(x^*_1) > x^{nt}_0$.
(ii) As disclosure quality increases, L sells more in the first period and less in the second period, but in total he sells more over the two periods (i.e., $\frac{\partial \Delta x_1}{\partial \tau_\varepsilon} < 0$, $\frac{\partial \Delta x_2}{\partial \tau_\varepsilon} > 0$, and $\frac{\partial[\Delta x_1 + \Delta x_2]}{\partial \tau_\varepsilon} < 0$).
(iii) If public disclosure is perfectly informative (i.e., $\mathrm{Var}[\tilde{v}|\tilde{s}] = 0$), then $x^*_1 = x^c$ and $x^*_2(x^*_1) = x^*_2(x^c)$.
(iv) If public disclosure is completely uninformative (i.e., $\mathrm{Var}[\tilde{v}|\tilde{s}] = \mathrm{Var}[\tilde{v}]$), then $x^*_1 = x_0$ and $x^*_2(x^*_1) = x^c$.

Part (i) of the proposition offers several insights. First, L is unable to achieve efficient risk sharing over the two periods ($x^*_2(x^*_1) > x^{nt}_0$). This is due to the fact that L internalizes the negative price impact of his sales, which impedes him from selling as many shares as he would otherwise. Second, lack of commitment makes L sell too many of his shares over the two periods ($x^c > x^*_2(x^*_1)$). The reason is that, when L enters the second period, the price of the first period has already been set and he is no longer concerned about the effect of his second-period sales on the first-period price, as instead he would be when choosing the *ex ante* optimal trading plan. Third, lack of commitment makes L sell less in the first period ($x^*_1 > x^c$). The intuition is that L anticipates that the more he sells today, the more he will deviate from the

[18] These constants are the same as in Remarks 1 and 2.

commitment benchmark tomorrow, and optimally responds by limiting his sales today. As noted in prior literature that has not considered disclosure (e.g., Kihlstrom 2000), the dynamic trading model resembles a dynamic monopoly. The monopolist—L in our case—is effectively in competition with his future self, because he cannot refrain from selling shares in the second period. As a result, the Coase conjecture applies: L cannot fully exercise his market power.

Parts (ii)–(iv) of the proposition are central for our findings about traders' surplus. As disclosure quality increases, L has greater incentives to diversify early. The logic is the following. When the public signal resolves more uncertainty, L faces a higher price risk (because the first-period return $\tilde{p}_2 - p_1$ becomes more volatile) and a lower residual risk (because the second-period return $\tilde{v} - p_2$ becomes less volatile). As a consequence, L has greater incentives to sell before the public disclosure and lower incentives after. In the extreme where disclosure is completely uninformative, no trading at all occurs until the second period. By contrast, in the extreme where disclosure is perfectly informative, L's holdings in the first period reach their lower bound, which obtains in the benchmark with commitment. Despite the fact that the first-period and second-period sales react in opposite ways to an increase in disclosure quality, L always ends up selling more over the two periods (see the discussion below the optimality condition (12)).

Next, we analyze traders' surplus in the equilibrium of the dynamic trading game.

Proposition 2: Define $\hat{\tau}_\varepsilon \equiv \frac{\rho}{\gamma + 2\rho}\tau_v$.

(i) Small investors' *ex ante* surplus has a unique maximum at the disclosure quality level $\tau_\varepsilon = \hat{\tau}_\varepsilon$; oppositely,
(ii) L's *ex ante* surplus has a unique minimum at $\tau_\varepsilon = \hat{\tau}_\varepsilon$; and
(iii) Small investors' (L's) *ex ante* surplus is minimized (maximized) when the public disclosure is either perfectly informative or completely uninformative. Further, in both these two extremes L's *ex ante* surplus is the same as in the benchmark with commitment.

Figure A1, Panel A depicts the welfare effects of disclosure quality separately for L and small investors. Proposition 2 has several parts. Let us start by commenting on the results regarding L's surplus. Note that L's surplus is bounded above by his payoff under commitment, as lack of commitment induces him to sell too many shares over the two periods. Interestingly, the problem due to lack of commitment disappears if either the public signal is perfectly informative or completely uninformative. In the former case, all uncertainty is resolved during the first period; in the latter case, during the second period. In either extreme, the model effectively reduces to a one-period trading game and L enjoys full market power.[19] *Vice versa*, any interior level of disclosure quality hurts L by rendering the model dynamic and putting him in competition with his future self.

Let us now discuss the welfare effects for small investors. Their preference over disclosure quality is exactly the reverse of L's preferences. This is intuitive, because any weakening of L's market power translates into a greater surplus for small investors. In particular, small investors' surplus is minimal when disclosure is extremely precise or imprecise, as in these extremes L enjoys the greatest market power.

The unique maximizer of small investors' surplus, $\hat{\tau}_\varepsilon$, is determined by a tradeoff between two opposing effects. To visualize these two effects, let us take the total differential of small investors' surplus with respect to $\text{Var}[\tilde{v}|\tilde{s}]$:

$$\frac{dCE^*_{i,0}}{d\text{Var}[\tilde{v}|\tilde{s}]} = \underbrace{\frac{\rho}{2}\left[\left(x_0 - x_2^*(x_1^*)\right)^2 - (x_0 - x_1^*)^2\right]}_{=\frac{\partial CE^*_{i,0}}{\partial \text{Var}[\tilde{v}|\tilde{s}]} > 0}$$
$$\underbrace{-\rho\left[(\text{Var}[\tilde{v}] - \text{Var}[\tilde{v}|\tilde{s}])(x_0 - x_1^*) + \text{Var}[\tilde{v}|\tilde{s}]\left(x_0 - x_2^*(x_1^*)\right)\frac{\partial x_2^*(x_1^*)}{\partial x_1}\right]}_{=\frac{\partial CE^*_{i,0}}{\partial x_1^*} < 0}\underbrace{\frac{\partial x_1^*}{\partial \text{Var}[\tilde{v}|\tilde{s}]}}_{>0}. \quad (22)$$

The total differential above identifies two distinct effects of decreasing disclosure quality (i.e., increasing $\text{Var}[\tilde{v}|\tilde{s}]$). The first effect, captured by the term in the first line, is positive, whereas the second effect, captured by the terms in the second line, is negative. The first term represents the marginal effect of shifting the resolution of uncertainty from the first

[19] From Proposition 1(iii), it might appear as if, under perfect disclosure, second-period trading affects surplus. However, the disclosure resolves all uncertainty and, hence, traders bear no risk on their post-trade holdings in the second period. This implies that surplus is only determined by what occurs in the first period.

to the second period, while keeping constant the holdings in each period. Because small investors are net buyers, their surplus is determined by how much compensation they receive for their risk-bearing capacity. Also, because L diversifies gradually over time, small investors hold more shares in the second than in the first period. This is precisely the reason why small investors benefit from having relatively more uncertainty resolved in the second period: in equilibrium, the total compensation to small investors is greater if they have to bear more risk when their exposure to risk is greater. This economic force can be thought of as a generalization of the Hirshleifer effect: small investors are better off if disclosure occurs after traders had more opportunities to share risk. Equivalently, too much disclosure too early destroys risk-sharing opportunities.

Besides the classic Hirshleifer effect, there is another effect of disclosure on risk sharing. The terms on the second line represent the welfare effect of changing the magnitude of L's sales, while keeping constant the allocation of total uncertainty across the two periods. Decreasing disclosure quality (i.e., increasing $\mathrm{Var}[\tilde{v}|\tilde{s}]$) delays the resolution of uncertainty and, consequently, disincentivizes L to diversify (see Proposition 1(ii)). All else equal, this has a negative impact on small investors' surplus, because by holding fewer shares in all periods they are less exposed to risk and, in equilibrium, they receive a smaller compensation for risk bearing. In a sense, this is exactly the opposite of the Hirshleifer effect, as it demonstrates that disclosure can, in fact, create risk-sharing opportunities.

In other words, disclosure destroys risk-sharing opportunities, to the extent that it shifts risk before the second opportunity to trade; but, at the same time, disclosure creates risk-sharing opportunities, by increasing trading volume. The optimal disclosure quality, from small investors' perspective, balances these two countervailing forces.

Proposition 3: The *ex ante* total surplus is uniquely maximized at the disclosure quality level $\tau_\varepsilon = \hat{\tau}_\varepsilon$ and is minimized when the public disclosure is either perfectly informative or completely uninformative.

Figure A1, Panel B plots total welfare as a function of disclosure quality. Proposition 3 states that the total surplus is maximized when the small investors' surplus is maximized. Even though Proposition 2 above tells us that changes in disclosure quality can increase the small investors' surplus only at the expense of L's surplus, from an aggregate perspective across all traders, the surplus gain of the small investors is always larger in magnitude than L's surplus loss. For intuition, we can draw a parallel between this result and the surplus comparison between perfect competition and imperfect competition in a classic product-market setting. A change from imperfect competition to perfect competition is not equally favored by all agents, because it increases the consumers' surplus while decreasing the seller's surplus. Yet, the total surplus is always higher under perfect competition, because the seller's market power generates a deadweight loss by distorting the equilibrium allocation (e.g., see Tirole 1988, 67). Analogously, in our dynamic trading model, changes in the signal precision that reduce L's surplus have the effect of reducing the deadweight loss. Thus, the total surplus increases whenever L's surplus decreases.

We conclude this section with the following corollary, which derives how the efficient level of disclosure quality varies with the model parameters.

Corollary 1: The efficient level of disclosure quality, $\hat{\tau}_\varepsilon$, which maximizes the *ex ante* total surplus, is:

(i) Increasing in small investors' aggregate risk aversion (ρ);
(ii) Decreasing in the risk aversion of L (γ); and
(iii) Decreasing in the variance of the asset value ($\mathrm{Var}[\tilde{v}]$).

Recall that the optimal precision results from a tradeoff between destroying risk sharing opportunities—by disclosing before trading rounds—and creating risk sharing opportunities–by fostering trades between L and the small investors. These three parameters affect the relative magnitudes of these effects, thereby determining the value of the optimal precision. The mechanism is the following. There are more trades when the small investors are less risk averse (because they are more willing to take risk), or when L is more risk averse (because he has a greater need to diversify), or when there is more uncertainty about the asset value (because in the economy there is more risk to share). In all of these scenarios, the benefit of increasing precision to create additional risk sharing opportunities is relatively weaker than its cost, because the parameters are such that L naturally sells more. Hence, the optimal level of precision in these scenarios is lower.

V. INCENTIVE-COMPATIBLE DISCLOSURE

So far, the disclosure issue has been formulated as an optimization problem of a social planner. However, a regulator cannot set an upper bound for the disclosure quality in the institutional environment of most capital markets. In the U.S., for example, a firm can disclose as much as it sees fit as long as it satisfies certain technical requirements such as credibility and Regulation FD (which are beyond the scope of the study here). Hence, it is natural to assume that the

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regulator can set a lower bound $\underline{\tau}_\varepsilon$ for the disclosure quality. Moreover, although a large shareholder can exert direct influence over a firm's disclosure policy, the inability to perfectly foresee the future precludes disclosures that would perfectly reveal the future asset value. For parsimony, we then assume that there is an exogenous upper bound $\overline{\tau}_\varepsilon$ that L's choice of disclosure quality τ_ε is subject to. Given the highest degree of foresight $\overline{\tau}_\varepsilon$, the mathematical problem of the regulator becomes the following constrained optimization problem:

$$\max_{\underline{\tau}_\varepsilon, \tau_\varepsilon} TS^* \text{ s.t. } \tau_\varepsilon \in \arg \max_{\tau_\varepsilon \in [\underline{\tau}_\varepsilon, \overline{\tau}_\varepsilon]} CE^*_{L,0}, \tag{23}$$

where TS^* and $CE^*_{L,0}$ are given in Lemma 2 and are both functions of disclosure quality τ_ε. In other words, the regulator optimally chooses the lower bound for disclosure, $\underline{\tau}_\varepsilon$, taking into account that the actual disclosure level that will prevail in the economy, τ_ε, must satisfy L's incentive compatibility constraint. We define the solution to the above problem as $\{\underline{\tau}^*_\varepsilon, \tau^*_\varepsilon\}$.

Proposition 4: The optimal minimum level of disclosure quality $\underline{\tau}^*_\varepsilon$ and equilibrium disclosure quality τ^*_ε depend on the highest degree of foresight $\overline{\tau}_\varepsilon$:

(i) If $\overline{\tau}_\varepsilon \leq \hat{\tau}_\varepsilon$, where $\hat{\tau}_\varepsilon$ is the disclosure quality that maximizes total surplus, the regulator optimally requires the firm to disclose according to its highest degree of foresight; that is $\tau^*_\varepsilon = \underline{\tau}^*_\varepsilon = \overline{\tau}_\varepsilon$;

(ii) If $\overline{\tau}_\varepsilon > \hat{\tau}_\varepsilon$, the regulator optimally and indifferently chooses any $\underline{\tau}^*_\varepsilon \in [\overline{\tau}'_\varepsilon, \overline{\tau}_\varepsilon]$, where $\overline{\tau}'_\varepsilon < \hat{\tau}_\varepsilon$ is defined such that $CE^*_{L,0}|_{\tau_\varepsilon=\overline{\tau}'_\varepsilon} = CE^*_{L,0}|_{\tau_\varepsilon=\overline{\tau}_\varepsilon}$, and the firm voluntarily discloses according to its highest degree of foresight, that is, $\tau^*_\varepsilon = \overline{\tau}_\varepsilon$.[20]

When the firm can only foresee a relatively limited amount of information (namely, $\overline{\tau}_\varepsilon \leq \hat{\tau}_\varepsilon$) it is infeasible for the regulator to enforce disclosure quality at the social optimum level. Hence, the regulator requires the firm to disclose as much as it knows. In this case, the regulation is strictly binding because L would be better off disclosing less. When the firm can potentially know more than what is desirable for the social optimum ($\overline{\tau}_\varepsilon > \hat{\tau}_\varepsilon$), it is infeasible for the regulator to enforce the socially optimal level of disclosure because it cannot prevent the firm from disclosing more, which L strictly prefers. However, the regulator can still affect total surplus by imposing a lower bound $\underline{\tau}^*_\varepsilon \in [\overline{\tau}'_\varepsilon, \overline{\tau}_\varepsilon]$ on disclosure quality. The disclosure level $\overline{\tau}'_\varepsilon$ is the value that makes L exactly indifferent between the minimum required disclosure level and the maximum feasible level. Because L's surplus is U-shaped in disclosure quality, if the regulator mandated less than $\overline{\tau}'_\varepsilon$, L would have a strict preference for the minimum level. In other words, the regulator optimally allows the firm to disclose more than the social optimum to prevent it from disclosing too little.

The prediction that the firm overdiscloses when disclosure is credible is consistent with many voluntary disclosure models, even though here the mechanism involves risk sharing rather than adverse selection.[21] To put the result of Proposition 4 into context, it is instructive to contrast it to the implications of the Hirshleifer effect. If trading were not allowed before the disclosure, the only effect of the disclosure would be to destroy risk sharing, and the solution to the program Equation (23) would feature the regulator not mandating any disclosure and L choosing not to disclose anything. Put differently, all the insights gained in the main model about disclosure creating risk-sharing opportunities when trading is dynamic carry over to this setting in which disclosure quality is directly chosen by the large shareholder.

VI. DYNAMIC DISCLOSURE

To illustrate the central tradeoff, we assumed that disclosure only occurs once between two trading opportunities. There are two issues with this setting that we need to address to illustrate that its takeaways are without loss of generality with respect to the timing and number of trading opportunities and disclosures. First, would the traders prefer any disclosure before the first trading round? And second, what would the optimal resolution of uncertainty over time be if the traders had more than two trading opportunities? To answer these questions, we extend our model to incorporate two rounds of disclosures nested in three rounds of trades. L's holdings after each trading opportunities are $\{x_1, x_2, x_3\}$, and small investor i's holdings are $\{y_{i,1}, y_{i,2}, y_{i,3}\}$. The first public signal $\tilde{s}_1 = \tilde{v} + \tilde{\varepsilon}_1$, with precision τ_{ε_1}, is disclosed after the first trading opportunity but before the second trading opportunity when $\tilde{p}_2$ is formed. The second public signal $\tilde{s}_2 = \tilde{v} + \tilde{\varepsilon}_2$, with precision τ_{ε_2}, is disclosed after the second trading opportunity but before the third trading opportunity when $\tilde{p}_3$ is formed.

[20] When $\underline{\tau}^*_\varepsilon = \overline{\tau}'_\varepsilon$, L is indifferent between $\tau^*_\varepsilon = \overline{\tau}'_\varepsilon$ and $\tau^*_\varepsilon = \overline{\tau}_\varepsilon$.
[21] See Bertomeu, Vaysman, and Xue (2021) for a discussion.

We begin by addressing the first question by exogenously setting $x_1 = x_0$; that is, the first disclosure (i.e., s_1) occurs before any trading is possible. This extension can be applied to understand traders' preferences for pre-IPO versus post-IPO disclosures, because we can interpret $\tilde{s}_1$ ($\tilde{s}_2$) as the pre-IPO (post-IPO) disclosure.

Proposition 5: Set exogenously $x_1 = x_0$, so that the first disclosure occurs before trading.

(i) (Pre-IPO disclosure) For any level of post-IPO disclosure quality, τ_{ε_2}, all traders' surpluses are decreasing in the pre-IPO disclosure quality, τ_{ε_1}, and are maximized when the pre-IPO disclosure is completely uninformative. Additionally, L's holdings are increasing in τ_{ε_1} (i.e., $\frac{\partial x_2}{\partial \tau_{\varepsilon_1}}, \frac{\partial x_3}{\partial \tau_{\varepsilon_1}} > 0$).

(ii) (Post-IPO disclosure) For any level of pre-IPO disclosure quality, τ_{ε_1}, comparative statics of traders' surpluses and holdings with respect to post-IPO disclosure quality, τ_{ε_2}, follows from the results regarding τ_ε in the main model.

One purpose of Proposition 5(i) is to illustrate that, in this model, disclosure would optimally not occur before any trading can happen because of the Hirshleifer effect. Thus, in the setting considered in this model, there is no loss of generality in assuming that disclosure only occurs after the first trading opportunity. In other words, the reason why some level of disclosure may be desirable is precisely because trading is dynamic. However, this prediction should not be viewed as suggesting that there should not be any disclosure at all before an IPO. To focus on risk sharing, we do not model frictions such as an adverse selection problem (see, e.g., Myers and Majluf 1984; Leland and Pyle 1977), which would imply a benefit of disclosure before an offering.[22]

Proposition 5(ii) shows that, even when the pre-IPO disclosure occurs for reasons not captured by this model, all the results in the main model regarding the post-IPO disclosure still hold. The reason is that the subgame of the extended model after the first disclosure s_1 boils down to a two-period setting with one disclosure, s_2, in between the two trading rounds. The quality of post-IPO disclosure, τ_{ε_2}, corresponds to the parameter τ_ε in the main model, and the holdings $\{x_t\}_{t=2,3}$ here correspond to $\{x_t\}_{t=1,2}$ in the main model. Hence, similar to the prediction in Proposition 1(ii), L holds fewer shares when the post-IPO disclosure is more informative. The opposite holds for the quality of pre-IPO disclosure (see Proposition 5(i)). Post-IPO disclosure increases the risk-sharing benefit of trading before the information is released, which results in lower L's holdings. Instead, pre-IPO disclosure reduces the risk-sharing benefit of trading after the information is released, which results in higher L's holdings. Hence, our model predicts that founders and their affiliates sell less (more) of their shares if pre-IPO (post-IPO) disclosure quality increases.

The following result addresses the second question by allowing x_1 to be chosen endogenously. It characterizes the equilibrium holdings given that traders can trade in all three rounds and the implication of the two disclosures' quality for the traders' surpluses.

Proposition 6: In equilibrium, L's holdings are such that $x_0 > x_1^* > x_2^*(x_1^*) > x_3^*(x_2^*) > x_0^{nt}$. Define $\hat{\tau}_{\varepsilon_1} \equiv \frac{4\rho^2(\gamma+4\rho)}{(\gamma+3\rho)^2(\gamma+6\rho)}\tau_v$ and $\hat{\tau}_{\varepsilon_2} \equiv \frac{\rho}{\gamma+2\rho}(\tau_v + \hat{\tau}_{\varepsilon_1})$. The *ex ante* total surplus and small investors' (L's) *ex ante* surplus are uniquely maximized (minimized) at the disclosure quality levels $\{\hat{\tau}_{\varepsilon_1}, \hat{\tau}_{\varepsilon_2}\}$. Furthermore, $\hat{\tau}_{\varepsilon_1} < \hat{\tau}_{\varepsilon_2}$.

L sells gradually to smooth out his price impact and, because of market power, efficient risk sharing is not attained even though the extent of risk sharing improves over time. Hence, the intuition behind the tradeoff of increasing disclosure quality in the main model continues to hold here. Using backward induction, the equilibrium in the last two rounds is the same as in the main model. As a result, the efficient precision level of the second disclosure, $\hat{\tau}_{\varepsilon_2}$, has the same expression as $\hat{\tau}_\varepsilon$, except that the prior precision τ_v is now substituted with the precision conditional on the first disclosure, $\tau_v + \tau_{\varepsilon_1}$. As in the main model, this level of disclosure quality trades off the effect of increasing trading volume and the Hirshleifer effect. The same tradeoff is present for the first disclosure when trading is allowed before this disclosure. Hence, we also obtain an interior level of precision $\hat{\tau}_{\varepsilon_1}$, as opposed to nondisclosure being efficient when trading is not allowed before the first disclosure (see Proposition 5). Additionally, the efficient level of disclosure quality increases over time (i.e., $\hat{\tau}_{\varepsilon_1} < \hat{\tau}_{\varepsilon_2}$) because the Hirshleifer effect is less potent in later periods, when earlier disclosures already resolved some uncertainty and traders already had an opportunity to share risk.

[22] The desirability of unlimited disclosures before IPO is not obvious in practice. For example, the SEC implements a "quiet period" rule, which restricts communication by an issuer outside the prospectus (S-1 filing) during the IPO process. See, e.g., Bushee, Cedergren, and Michels (2020) for a discussion.

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VII. RISK SHARING VERSUS ASYMMETRIC INFORMATION

Our results on traders' surplus are derived in a setting with risk-averse traders and without asymmetric information. The purpose of this section is to compare and contrast our results with those from a model without risk-sharing consideration and with private information (e.g., Kyle 1985; Foster and Viswanathan 1993). In practice, it is plausible that both risk aversion and asymmetric information are present, but studying the limiting cases allows us to understand better the different implications of these two different frictions.[23]

In the typical Kyle (1985) model, there are three classes of risk-neutral traders: a privately informed large shareholder (L), liquidity traders, and a market maker (MM). For comparability with our main model, we maintain here the same timeline: trading takes place in two periods $t = 1, 2$ and, between the periods, a public signal $\tilde{s} = \tilde{v} + \tilde{\varepsilon}$ is released. The precisions of $\tilde{v}$ and $\tilde{\varepsilon}$ are, respectively, τ_v and τ_ε. When the public signal is uninformative, this model boils down to a two-period version of the model in Foster and Viswanathan (1993). In each trading period, L and liquidity traders submit order flows Δx_t and $\tilde{l}_t$, respectively. L privately knows the asset value $\tilde{v}$ and chooses his trades strategically. The order flows of liquidity traders are independent and identically distributed over time according to a zero-mean normal distribution with precision τ_l. In each period, the MM absorbs the total order flow, $z_t \equiv \Delta x_t + l_t$, and sets the price equal to the expectation of the asset value conditional on all information available (i.e., all current and past order flows, and the public signal once it has been released).

In this context, the appropriate notion of surplus is L's *ex ante* expected trading profits. Liquidity traders make losses, on average. Their losses correspond to L's profits. The MM breaks even because he sets the price equal to the conditional expectation.

It is natural to conjecture an equilibrium in which L's order flows take the form

$$\Delta x_1(v) = \beta_1(v - \mu_v) \text{ and } \Delta x_2(v, \Delta x_1, l_1, s) = \beta_2(v - \mathrm{E}[\tilde{v}|\tilde{z}_1 = \Delta x_1 + l_1, \tilde{s} = s]), \tag{24}$$

and price functions take the form

$$p_1(z_1) = \mu_v + \lambda_1 z_1 \text{ and } p_2(z_1, s, z_2) = \mathrm{E}[\tilde{v}|\tilde{z}_1 = z_1, \tilde{s} = s] + \lambda_2 z_2, \tag{25}$$

where $\mathrm{E}[\tilde{v}|\tilde{z}_1 = z_1, \tilde{s} = s] = p_1(z_1) + \gamma(s - p_1(z_1))$ for some coefficient γ (to be determined) and λ_t is the inverse of liquidity (i.e., the sensitivity of the period-t price to the contemporaneous order flow). In equilibrium, the following conditions are satisfied: L takes the price functions in Equation (25) as given and chooses the optimal order flows; the market maker takes the trading strategies Equation (24) as given and sets the price equal to the conditional expectations; and L's and the MM's conjectures are verified. The lemma below characterizes the equilibrium trading and pricing strategies.

Lemma 3: In equilibrium, L's order flows and price functions are such that

$$\begin{aligned} &\lambda_2 = \frac{\beta_2 \tau_l}{(\beta_1^2 + \beta_2^2)\tau_l + \tau_v + \tau_\varepsilon}, \gamma = \frac{\tau_\varepsilon}{\beta_1^2 \tau_l + \tau_v + \tau_\varepsilon}, \lambda_1 = \frac{\beta_1 \tau_l}{\beta_1^2 \tau_l + \tau_v}, \\ &\beta_2 = \frac{1}{2\lambda_2}, \beta_1 = \frac{2\lambda_2 - (1-\gamma)^2 \lambda_1}{\lambda_1(4\lambda_2 - (1-\gamma)^2 \lambda_1)}. \end{aligned} \tag{26}$$

and these coefficients satisfy the second-order conditions for L's optimization problems at $t = 1$ and $t = 2$, respectively,

$$-2\lambda_2 < 0 \text{ and } \frac{1}{2}\lambda_1\left(\frac{(1-\gamma)^2 \lambda_1}{\lambda_2} - 4\right) < 0. \tag{27}$$

In the following proposition, we determine how disclosure quality affects liquidity in each period and traders' surplus.

Proposition 7: In equilibrium:

(i) First-period liquidity is decreasing in disclosure quality (i.e., $\frac{d\lambda_1}{d\tau_\varepsilon} > 0$);

(ii) Second-period liquidity is increasing in disclosure quality (i.e., $\frac{d\lambda_2}{d\tau_\varepsilon} < 0$); and

(iii) L's *ex ante* expected trading profits (which equal liquidity traders' *ex ante* expected trading losses) are monotonically decreasing in disclosure quality.

[23] See Lambert, Leuz, and Verrecchia (2012) for a static asset pricing model with market power that combines risk aversion and private information.

As can be seen in Figure A2, Panel A, when the disclosure between trading periods becomes more precise, the market becomes less liquid in the first period and more liquid in the second period. Second-period liquidity improves because the MM has access to better information and, consequently, his pricing strategy relies less on the second-period order flow. The decrease in first-period liquidity is tightly connected to the increase in second-period liquidity; in a dynamic model, L is concerned not only about the direct impact that his first-period trades have on the contemporaneous price, but also about the indirect impact that such trades have on the second-period price. As public information becomes more precise, the second-period price responds less to the first-period order flow. L responds by trading more aggressively in the first period and, in turn, the MM's first-period conditional expectation becomes more sensitive to the first-period order flow.

Figure A2, Panel B depicts the monotonic effects of disclosure quality on traders' surpluses. More public information brings equilibrium prices closer to the true asset value, thereby limiting L's ability to profit from his private information. At the same time, liquidity traders are better off, because L's trading profits are liquidity traders' losses.

Comparison with the Risk-Sharing Model

Risk sharing and asymmetric information lead to identical predictions for liquidity, but their implications for traders' surplus are distinct. Although the underlying mechanism is different, both in the Kyle-type model and in our main model first-period (second-period) liquidity decreases (increases) as disclosure quality increases. In the main model, liquidity is inversely related to the amount of uncertainty that small investors face. When uncertainty is higher, small investors require a larger premium for bearing more risk on the margin, that is, the price becomes more sensitive to L's sales. Because higher disclosure quality increases (decreases) uncertainty in the first (second) period, the results on liquidity follow.[24]

With regard to welfare, in the Kyle-type model disclosure decreases L's surplus by reducing his informational advantage.[25] In the main model, disclosure has instead nonmonotonic effects. In particular, more precise disclosure can be beneficial for L, when it alleviates his commitment problem. L is unable to refrain from selling more shares in the second period, because he no longer worries about the impact of the second-period sales on the first-period price (which has already been determined), and thus is more willing to share risk. In contrast, in the Kyle-type model, the only reason why L engages in second-period trades is to further exploit his private information at the expense of the second-period liquidity traders. In other words, absent risk-sharing considerations, there is no risk premium and, consequently, no commitment issue.

VIII. CONCLUSION

Firms start with concentrated ownership and, over time, controlling shareholders divest their stakes to diversify (Zingales 1995; Mikkelson et al. 1997; Coates 1998; Bodnaruk et al. 2008; Cohen et al. 2012; Dong et al. 2020). In this paper, we consider a tradeoff faced by large shareholders when selling more shares: the benefit of sharing risk with other investors and the cost of negatively impacting the stock price. Because of such a price impact, the extent of risk sharing under imperfect competition is always lower than if the large shareholder was a price taker. In this setting with imperfect competition, we study the effect of disclosure on risk sharing and its implications for traders' surplus.

The canonical argument is that, in a pure-exchange economy, disclosure is undesirable because it impedes risk sharing (Hirshleifer 1971). However, in our setting, we find that some disclosure improves risk sharing, because it encourages more trades by the large shareholder. As a result of this tension, traders' surpluses are nonmonotonic in disclosure quality. In particular, the small investors prefer intermediate levels of disclosure quality, whereas the large shareholder prefers either a fully informative or a fully uninformative disclosure. Nevertheless, traders' total surplus is hump-shaped in disclosure quality, as is small investors' surplus, because any utility gain of the large shareholder is more than offset by a utility loss of the small investors.

Our model formally establishes the intuition that sellers and buyers have opposite preferences over disclosure policies: sellers prefer disclosure policies that maximize the price, whereas buyers prefer policies that minimize the price. This result stands in contrast with the extant literature, in which either all traders prefer the disclosure policy associated with the lowest price (see the survey by Bertomeu and Cheynel 2016), or the disclosure policy does not affect the price at all (e.g., Christensen et al. 2010).

[24] In the main model, the sensitivity of the price to L's holdings in the first and second periods are, respectively, $\frac{\rho}{\tau_v} - \left(\frac{\gamma+\rho}{\gamma+2\rho}\right)\frac{\rho}{\tau_v+\tau_\varepsilon}$ and $\frac{\rho}{\tau_v+\tau_\varepsilon}$.

[25] See Kim and Verrecchia (1994) and Cheynel and Levine (2020) for how, under some information structures, disclosure can actually increase information asymmetry.

To better isolate the consequences of risk-sharing incentives by traders, our main analysis focuses on the symmetric-information case. Further analysis illustrates that private information does not generate nonmonotonic welfare effects of disclosure, if traders are all risk-neutral. In that case, disclosure only reduces the large shareholder's profits by reducing his information advantage at the benefit of the small investors.

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APPENDIX A

Equilibrium Definition

Before we can state the equilibrium concept, we need to define traders' strategies. A strategy for a trader prescribes, for each period t, holdings as a function of the history of that trader. L's histories are $\mathcal{H}_{L,1} = \emptyset$ at $t = 1$ and $\mathcal{H}_{L,2} = \{x_1, p_1, s\}$ at $t = 2$, because before submitting the order flow in the second period he observes the realization of the public signal, L's past trade, and the price that prevailed in the previous period. The histories of a small investor i are $\mathcal{H}_{i,1} = \{x_1, p_1\}$ at $t = 1$ and $\mathcal{H}_{i,2} = \{x_1, p_1, y_{i,1}, s, x_2, p_2\}$. Compared to L's histories, small investors' histories also contain L's contemporaneous holdings (because they are observable), the current price (because they are price-takers, whereas L sets the price by choosing his holdings), and his own past trade $y_{i,1}$. To describe the equilibrium, we also need to introduce the price functions in each period. Let $\mathcal{H}_1^p = \emptyset$ (resp., $\mathcal{H}_2^p = \{x_1, p_1, s\}$) denote the public histories in period $t = 1$ (resp., $t = 2$) before L submits his order flows. The superscript "p" in $\mathcal{H}_t^p$ stands for "public." Price functions are $p_t(x_t, \mathcal{H}_t^p)$, which for each public history at t map L's holdings into a price. Note that L's private histories coincide with public histories because L has no private information. With this notation, in this setting we define an equilibrium as follows.

Definition A.1 (Equilibrium): A sequential equilibrium of this dynamic game consists of trading strategies for small investors, $\{y_{i,t}^*(\mathcal{H}_{i,t})\}_{i\in[0,1],t\in\{1,2\}}$, price functions, $\{p_t^*(x_t, \mathcal{H}_t^p)\}_{t\in\{1,2\}}$, and trading strategies for L, $\{x_t^*(\mathcal{H}_{L,t})\}_{t\in\{1,2\}}$, such that:

(i) Taking as given all other strategies and the price functions, each small investor's holdings in each period t are optimal for all histories, i.e.,

$$y_{i,t}^*(\mathcal{H}_{i,t}) \in \arg\max_{y_{i,t}} \mathrm{E}\left[u_i(\tilde{w}_i)|\mathcal{H}_{i,t}\right] \text{ for all } i \in [0,1], t \in \{1,2\}, \mathcal{H}_{i,t}; \tag{A1}$$

(ii) Taking as given all other strategies and the price functions, L's holdings in each period t are optimal for all histories, i.e.,

$$x_t^*(\mathcal{H}_{L,t}) \in \arg\max_{x_t} \mathrm{E}\left[u_L(\tilde{w}_L)|\mathcal{H}_{L,t}\right] \text{ for all } t \in \{1,2\}, \mathcal{H}_{L,t}; \tag{A2}$$

(iii) In each period t and for all x_t and public histories, the price $p_t^*(x_t, \mathcal{H}_t^p)$ clears the market as per Equation (1).

Derivations of Section III

Expressions for Traders' Objective Functions at t = 1

Here, we compute the certainty equivalent in the first period of small investors' and L's terminal wealth. Let us first consider the case of small investors. By the law of iterated expectations, the expected utility conditional on their information set at $t = 1$ is

$$\mathrm{E}\left[u_i(\tilde{w}_i)|\mathcal{H}_{i,1}\right] = \mathrm{E}\left[\mathrm{E}\left[u_i(\tilde{w}_i)|\mathcal{H}_{i,2}\right]|\mathcal{H}_{i,1}\right], \tag{A3}$$

where

$$\mathrm{E}\left[u_i(\tilde{w}_i)|\mathcal{H}_{i,2}\right] = -\mathrm{E}\left[\exp\left(-\rho\begin{pmatrix} p_1 y_0 + \left(p_2\left(s, x_2^*(x_1)\right) - p_1\right)y_{i,1} \\ +\left(\mathrm{E}[\tilde{v}|s] - p_2\left(s, x_2^*(x_1)\right)\right)y_{i,2}^* - \dfrac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}](y_{i,2}^*)^2 \end{pmatrix}\right)\right]. \tag{A4}$$

Because small investors' holdings are symmetric, in equilibrium each small investor i holds $y_{i,2}^* = 1 - x_2^*(x_1)$. Further, Equation (10) implies $\mathrm{E}[\tilde{v}|s] - p_2\left(s, x_2^*(x_1)\right) = \rho\mathrm{Var}[\tilde{v}|\tilde{s}]\left(1 - x_2^*(x_1)\right)$. Overall, we have that

(continued on next page)

APPENDIX A (continued)

$$\Big(\mathrm{E}[\tilde{v}|s]-p_2\Big(s,x_2^*(x_1)\Big)\Big)y_{i,2}^*-\frac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}](y_{i,2}^*)^2=\frac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]\Big(1-x_2^*(x_1)\Big)^2. \tag{A5}$$

These terms are nonrandom conditional on $\mathcal{H}_{i,1}$ because $\mathrm{Var}[\tilde{v}|\tilde{s}]$ is independent of the realization s of the public signal. Hence, taking the expectation of Equation (A4) conditional on the first-period information set $\mathcal{H}_{i,1}$, and exploiting the property that $p_2\Big(\tilde{s},x_2^*(x_1)\Big)$ is normally distributed conditional on $\mathcal{H}_{i,1}$, we obtain Equation (13) in the main text.

In the case of L, we have

$$\mathrm{E}\big[u_L(\tilde{w}_L)|\mathcal{H}_{L,2}\big]=-\mathrm{E}\left[\exp\left(-\gamma\left(\begin{array}{l}p_1x_0+\Big(p_2\Big(s,x_2^*(x_1)\Big)-p_1\Big)x_1\\+\Big(\mathrm{E}[\tilde{v}|s]-p_2\Big(s,x_2^*(x_1)\Big)\Big)x_2^*(x_1)-\frac{\gamma}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]\Big(x_2^*(x_1)\Big)^2\end{array}\right)\right)\right]. \tag{A6}$$

With analogous steps as for the case of a small investor i, we can show that

$$\Big(\mathrm{E}[\tilde{v}|s]-p_2\Big(s,x_2^*(x_1)\Big)\Big)x_2^*(x_1)-\frac{\gamma}{2}\mathrm{Var}[\tilde{v}|\tilde{s}]\Big(x_2^*(x_1)\Big)^2=\mathrm{Var}[\tilde{v}|\tilde{s}]\left[\rho x_2^*(x_1)-\frac{2\rho+\gamma}{2}\Big(x_2^*(x_1)\Big)^2\right], \tag{A7}$$

which again is nonrandom conditional on $\mathcal{H}_{i,1}$. Then, Equation (16) follows from the fact that $p_2\Big(\tilde{s},x_2^*(x_1)\Big)$ is normally distributed conditional on $\mathcal{H}_{i,1}$.

Expression for Traders' Ex Ante Surplus

We compute $CE_{i,0}$ and $CE_{L,0}$ taking $(x_1,x_2,y_{i,1},y_{i,2})$ as exogenous. The terminal wealth of trader i equals

$$\tilde{w}_i=p_1(x_1,x_2)y_0+\Big(p_2(\tilde{s},x_2)-p_1(x_1,x_2)\Big)y_{i,1}+\Big(\tilde{v}-p_2(\tilde{s},x_2)\Big)y_{i,2}. \tag{A8}$$

Define the following risk premia:

$$\begin{aligned}CoC_1&\equiv\mathrm{E}[p_2(\tilde{s},x_2)-p_1(x_1,x_2)],\\CoC_2&\equiv\mathrm{E}[\tilde{v}-p_2(\tilde{s},x_2)],\\CoC&\equiv CoC_1+CoC_2.\end{aligned} \tag{A9}$$

CoC_t is the cost of capital associated with the short-window return from t to $t+1$ and CoC is associated with the long-window return from $t=1$ to $t=3$. *Ex ante*, $\tilde{w}_i$ is normally distributed with mean

$$\begin{aligned}\mathrm{E}[\tilde{w}_i]&=p_1(x_1,x_2)y_0+\Big(\mathrm{E}[p_2(\tilde{s},x_2)]-p_1(x_1,x_2)\Big)y_{i,1}+\Big(\mathrm{E}[\tilde{v}]-\mathrm{E}[p_2(\tilde{s},x_2)]\Big)y_{i,2}\\&=(\mu_v-CoC)y_0+CoC_1y_{i,1}+CoC_2y_{i,2}\end{aligned} \tag{A10}$$

and variance

$$\begin{aligned}\mathrm{Var}[\tilde{w}_i]&=\mathrm{Var}[p_2(\tilde{s},x_2)]y_{i,1}^2+\mathrm{Var}[\tilde{v}-p_2(\tilde{s},x_2)]y_{i,2}^2+2\mathrm{Cov}\Big[p_2(\tilde{s},x_2)\Big(\tilde{v}-p_2(\tilde{s},x_2)\Big)\Big]y_{i,1}y_{i,2}\\&=\mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]]y_{i,1}^2+\mathrm{Var}[\tilde{v}-\mathrm{E}[\tilde{v}|\tilde{s}]]y_{i,2}^2+2\mathrm{Cov}\big[\mathrm{E}[\tilde{v}|\tilde{s}](\tilde{v}-\mathrm{E}[\tilde{v}|\tilde{s}])\big]y_{i,1}y_{i,2}\\&=(\mathrm{Var}[\tilde{v}]-\mathrm{Var}[\tilde{v}|\tilde{s}])y_{i,1}^2+\mathrm{Var}[\tilde{v}|\tilde{s}]y_{i,2}^2,\end{aligned} \tag{A11}$$

where the third line uses the law of total variance (i.e., $\mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]]=\mathrm{Var}[\tilde{v}]-\mathrm{Var}[\tilde{v}|\tilde{s}]$ and $\mathrm{Var}[\tilde{v}-\mathrm{E}[\tilde{v}|\tilde{s}]]=\mathrm{Var}[\tilde{v}|\tilde{s}]$) and the fact that estimation errors are orthogonal to the estimate (i.e., $\mathrm{Cov}\big[\mathrm{E}[\tilde{v}|\tilde{s}](\tilde{v}-\mathrm{E}[\tilde{v}|\tilde{s}])\big]=0$). Thus, i's *ex ante* certainty equivalent is

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$$\begin{aligned} CE_{i,0} &= \mathrm{E}[\tilde{w}_i] - \frac{\rho}{2}\mathrm{Var}[\tilde{w}_i] \\ &= (\mu_v - CoC)y_0 + CoC_1 y_{i,1} + CoC_2 y_{i,2} - \frac{\rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])y_{i,1}^2 + \mathrm{Var}[\tilde{v}|\tilde{s}]y_{i,2}^2\right]. \end{aligned} \tag{A12}$$

Similarly, L's *ex ante* surplus is given by

$$\begin{aligned} CE_{L,0} &= \mathrm{E}[\tilde{w}_L] - \frac{\gamma}{2}\mathrm{Var}[\tilde{w}_L] \\ &= (\mu_v - CoC)x_0 + CoC_1 x_1 + CoC_2 x_2 - \frac{\gamma}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])x_1^2 + \mathrm{Var}[\tilde{v}|\tilde{s}]x_2^2\right]. \end{aligned} \tag{A13}$$

Using market clearing, we can further simplify the surplus expressions in the dynamic trading game. Observe that the expressions that we derive next only require market clearing and, therefore, they apply regardless of whether L has market power or commitment. What distinguishes the settings with and without market power or commitment is only the particular equilibrium values of x_t, which are different depending on the setting under consideration. We begin by simplifying $C\mathrm{E}_{i,0}$. We can rewrite Equation (A12) as follows:

$$\begin{aligned} CE_{i,0} &= \mu_v y_0 - \frac{\rho}{2}\mathrm{Var}[\tilde{v}]y_0^2 + CoC_1(y_{i,1} - y_0) + CoC_2(y_{i,2} - y_0) \\ &\quad - \frac{\rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(y_{i,1}^2 - y_0^2) + \mathrm{Var}[\tilde{v}|\tilde{s}](y_{i,2}^2 - y_0^2)\right] \\ &= \underbrace{\mu_v y_0 - \frac{\rho}{2}\mathrm{Var}[\tilde{v}](1 - x_0)^2}_{\equiv K^*_{\neg L}} + \frac{\rho}{2}(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x_0 - x_1)^2 + \frac{\rho}{2}\mathrm{Var}[\tilde{v}|\tilde{s}](x_0 - x_2)^2. \end{aligned} \tag{A14}$$

To obtain this expression, in the first line we have added and subtracted $\frac{\rho}{2}\mathrm{Var}[\tilde{v}]y_0^2$, and in the second line we have used the market-clearing condition $y_{i,t} = 1 - x_t$. Similarly, we can rewrite L's surplus as

$$\begin{aligned} CE_{L,0} &= \mu_v x_0 + \rho\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(1 - x_1) + \mathrm{Var}[\tilde{v}|\tilde{s}](1 - x_2)\right](1 - x_0) \\ &\quad - (\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])\left[\rho(1 - x_1)^2 + \frac{\gamma}{2}x_1^2\right] - \mathrm{Var}[\tilde{v}|\tilde{s}]\left[\rho(1 - x_2)^2 + \frac{\gamma}{2}x_2^2\right] \\ &= \underbrace{\mu_v x_0 - \left[\frac{\gamma}{2} - \frac{\gamma + 2\rho}{2}(1 - x^c)^2\right]\mathrm{Var}[\tilde{v}]}_{\equiv K^*_L} - \frac{\gamma + 2\rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x_1 - x^c)^2 + \mathrm{Var}[\tilde{v}|\tilde{s}](x_2 - x^c)^2\right], \end{aligned} \tag{A15}$$

where in the first line we have added and subtracted CoC, and the second line follows from rearranging the expression.

Next, we compute TS adding up Equation (A13) and the aggregate Equation (A12) to obtain

$$\begin{aligned} TS &= \mu_v - (\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])\left[\frac{\rho}{2}y_1^2 + \frac{\gamma}{2}x_1^2\right] - \mathrm{Var}[\tilde{v}|\tilde{s}]\left[\frac{\rho}{2}y_2^2 + \frac{\gamma}{2}x_2^2\right] \\ &= \mu_v - (\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])\left[\frac{\rho}{2}(1 - x_1)^2 + \frac{\gamma}{2}x_1^2\right] - \mathrm{Var}[\tilde{v}|\tilde{s}]\left[\frac{\rho}{2}(1 - x_2)^2 + \frac{\gamma}{2}x_2^2\right] \\ &= \underbrace{\mu_v - \left[\frac{\rho}{2} - \frac{\gamma + \rho}{2}(x^{nt})^2\right]\mathrm{Var}[\tilde{v}]}_{\equiv K^*} - \frac{\gamma + \rho}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])(x_1 - x^{nt})^2 + \mathrm{Var}[\tilde{v}|\tilde{s}](x_2 - x^{nt})^2\right], \end{aligned} \tag{A16}$$

where the second line follows from market clearing ($y_t = 1 - x_t$) and the third line from rearranging the expression.

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APPENDIX A (continued)

Proofs of Section III

Proof of Remark 1

L's second-period holdings can be obtained by exogenously setting $\frac{\partial p_2}{\partial x_2} = 0$ in Equation (A24). The second-period market clearing condition is, therefore,

$$\underbrace{\frac{\mathrm{E}[\tilde{v}|s] - p_2}{\gamma \mathrm{Var}[\tilde{v}|\tilde{s}]}}_{x_2} + \underbrace{\frac{\mathrm{E}[\tilde{v}|s] - p_2}{\rho \mathrm{Var}[\tilde{v}|\tilde{s}]}}_{\int y_{i,2} \mathrm{d}i} = 1, \tag{A17}$$

whence the second-period market-clearing price

$$p_2^{pt}(s) = \mathrm{E}[\tilde{v}|s] - \frac{\rho\gamma}{\rho + \gamma} \mathrm{Var}[\tilde{v}|\tilde{s}], \tag{A18}$$

and holdings $x_2^{pt} = x_0^{nt}$ and $y_{i,2}^{pt} = 1 - x_0^{nt}$ for all i. We obtain L's first-period holdings by setting exogenously $\frac{dp_1}{dx_1} = 0$ in Equation (A25). First-period market clearing is

$$\underbrace{\frac{\mathrm{E}[p_2(\tilde{s})] - p_1}{\gamma \mathrm{Var}[p_2(\tilde{s})]}}_{x_1} + \underbrace{\frac{\mathrm{E}[p_2(\tilde{s})] - p_1}{\rho \mathrm{Var}[p_2(\tilde{s})]}}_{\int y_{i,1} \mathrm{d}i} = 1, \tag{A19}$$

whence the first-period market-clearing price

$$p_1^{pt} = \mu_v - \frac{\rho\gamma}{\rho + \gamma} \mathrm{Var}[\tilde{v}], \tag{A20}$$

where we have used $\mathrm{E}\left[p_2^{pt}(\tilde{s})\right] = \mu_v - \frac{\rho\gamma}{\rho+\gamma}\mathrm{Var}[\tilde{v}|\tilde{s}]$ and $\mathrm{Var}\left[p_2^{pt}(\tilde{s})\right] = \mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]] = \mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}]$. Plugging the market-clearing p_1^{pt} into the first-period holdings yields $x_1^{pt} = x_0^{nt}$ and $y_{i,1}^{pt} = 1 - x_0^{nt}$ for all i.

To compute traders' surplus, substitute $x_t = x_0^{nt}$ into Equation (A14) and Equation (A15). The fact that their surplus is independent of τ_ε follows from inspection. ■

Proof of Remark 2

Following derivations similar to the no-commitment case (see Section III), the second-period and first-period price functions are, respectively, $p_2(s, x_2) = \mathrm{E}[\tilde{v}|s] - \rho \mathrm{Var}[\tilde{v}|\tilde{s}](1 - x_2)$ and $p_1(x_1, x_2) = \mu_v - \rho \mathrm{Var}[p_2(\tilde{s}, x_2)](1 - x_1)$ $-\rho \mathrm{Var}[\tilde{v}|\tilde{s}](1 - x_2)$. The only difference between the commitment and the no-commitment case is that in the first-period price function we write x_2 in place of $x_2^*(x_1)$, because in the commitment case L maximizes separately over x_1 and x_2. Hence, in the commitment case x_2 does not have to be sequentially rational. The expression (B.11) for L's *ex ante* surplus can be rewritten as

$$\begin{aligned} CE_{L,0} &= \mu_v x_2 + \mathrm{E}[p_2(\tilde{s}, x_2)](x_1 - x_2) + p_1(x_1, x_2)(x_0 - x_1) \\ &\quad - \frac{\gamma}{2}\left[(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])x_1^2 + \mathrm{Var}[\tilde{v}|\tilde{s}]x_2^2\right]. \end{aligned} \tag{A21}$$

The first-order condition with respect to x_1 is

$$\frac{\partial CE_{L,0}}{\partial x_1} = \mathrm{E}[p_2(\tilde{s}, x_2)] - p_1(x_1, x_2) + \frac{\partial p_1(x_1, x_2)}{\partial x_1}(x_0 - x_1) - \gamma(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])x_1 = 0. \tag{A22}$$

Using $\mathrm{E}[p_2(\tilde{s}, x_2)] - p_1(x_1, x_2) = \rho \mathrm{Var}[p_2(\tilde{s}, x_2)](1 - x_1)$ and $\frac{\partial p_1(x_1, x_2)}{\partial x_1} = \rho \mathrm{Var}[p_2(\tilde{s}, x_2)] = \rho(\mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}])$, this first-order condition gives $x_1^c = x^c$. The first-order condition with respect to x_2 is

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$$\frac{\partial CE_{L,0}}{\partial x_2} = \mu_v - \mathrm{E}[p_2(\tilde{s}, x_2)] + \frac{\partial \mathrm{E}[p_2(\tilde{s}, x_2)]}{\partial x_2}(x_1 - x_2) + \frac{\partial p_1(x_1, x_2)}{\partial x_2}(x_0 - x_1) - \gamma \mathrm{Var}[\tilde{v}|\tilde{s}]x_2 = 0. \tag{A23}$$

Using $\mu_v - \mathrm{E}[p_2(\tilde{s}, x_2)] = \rho \mathrm{Var}[\tilde{v}|\tilde{s}](1 - x_2)$ and $\frac{\partial \mathrm{E}[p_2(\tilde{s}, x_2)]}{\partial x_2} = \frac{\partial p_1(x_1, x_2)}{\partial x_2} = \rho \mathrm{Var}[\tilde{v}|\tilde{s}]$ gives that also $x_2^c = x^c$.

To compute traders' surplus, substitute $x_t = x^c$ into Equation (A14) and Equation (A15). The fact that traders' surplus is independent of τ_ε follows from inspection. ■

Proof of Lemma 1

From Equation (12) and Equation (17) we obtain, respectively,

$$x_2^*(x_1) = \frac{\frac{\partial p_2\left(s, x_2^*(x_1)\right)}{\partial x_2} x_1 + \mathrm{E}[\tilde{v}|s] - p_2\left(s, x_2^*(x_1)\right)}{\frac{\partial p_2\left(s, x_2^*(x_1)\right)}{\partial x_2} + \gamma \mathrm{Var}[\tilde{v}|\tilde{s}]}. \tag{A24}$$

and

$$x_1^* = \frac{\frac{dp_1\left(x_1^*, x_2^*(x_1)\right)}{dx_1} x_0 + \mathrm{E}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right] - p_1\left(x_1^*, x_2^*(x_1^*)\right)}{\frac{dp_1\left(x_1^*, x_2^*(x_1)\right)}{dx_1} + \gamma \mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right]}, \tag{A25}$$

To obtain the closed form for $x_2^*(x_1)$, solve Equation (A24) explicitly for it, which yields Equation (20). Similarly, solve for x_1^* from Equation (A25), which yields

$$x_1^* = \frac{\mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right]\rho(1 + x_0) + \mathrm{Var}[\tilde{v}|\tilde{s}]\frac{\rho^2}{\gamma + 2\rho}x_0}{\mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right](\gamma + 2\rho) + \mathrm{Var}[\tilde{v}|\tilde{s}]\frac{\rho^2}{\gamma + 2\rho}}. \tag{A26}$$

Expression (19) then follows from substituting the variance of the second-period price

$$\mathrm{Var}\left[p_2\left(\tilde{s}, x_2^*(x_1^*)\right)\right] = \mathrm{Var}[\mathrm{E}[\tilde{v}|\tilde{s}]] = \mathrm{Var}[\tilde{v}] - \mathrm{Var}[\tilde{v}|\tilde{s}], \tag{A27}$$

where the first equality follows from Equation (10) and the second from the law of total variance. ■

Proof of Lemma 2

Substitute $x_t = x_t^*$ into Equation (A14), Equation (A15), and Equation (A16). ■

Proofs of Section IV

Proof of Proposition 1

Proof of Part (i). To show the inequalities, observe that:

- $x_0 > x_1^* \iff x_0 > x_0^{nt}$ (which holds by assumption),

- $x_1^* > x^c \iff x_0 > x^c \iff x_0 > x_0^{nt}$,

- $x^c > x_2^*(x_1^*) \iff x_0 > x_1^*$ (which holds true, see above),

- $x_2^*(x_1^*) > x_0^{nt} \iff x_1^* > x_0^{nt} \iff x_0 > x_0^{nt}$.

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APPENDIX A (continued)

Proof of Part (ii). The derivative of x_1^* with respect to $\mathrm{Var}[\tilde{v}|\tilde{s}]$ is

$$\frac{\partial x_1^*}{\partial \mathrm{Var}[\tilde{v}|\tilde{s}]} \propto \mathrm{Var}[\tilde{v}]\left[(\gamma+2\rho)\left(\frac{\rho^2}{\gamma+2\rho}x_0-\rho(1+x_0)\right)-\rho(1+x_0)\left(\frac{\rho^2}{\gamma+2\rho}-(\gamma+2\rho)\right)\right]$$
$$= \mathrm{Var}[\tilde{v}]\frac{(\gamma+\rho)\rho^2}{\gamma+2\rho}\left(x_0-\frac{\rho}{\gamma+\rho}\right)>0. \tag{A28}$$

Hence, the first-period sales, $x_0 - x_1^*$, are decreasing in $\mathrm{Var}[\tilde{v}|\tilde{s}]$ (equivalently, increasing in disclosure quality).

The derivative of $x_2^*(x_1^*)$ with respect to $\mathrm{Var}[\tilde{v}|\tilde{s}]$ is

$$\frac{dx_2^*(x_1^*)}{d\mathrm{Var}[\tilde{v}|\tilde{s}]}=\frac{\partial x_2^*(x_1^*)}{\partial x_1^*}\frac{\partial x_1^*}{\partial \mathrm{Var}[\tilde{v}|\tilde{s}]}=\frac{\rho}{\gamma+2\rho}\underbrace{\frac{\partial x_1^*}{\partial \mathrm{Var}[\tilde{v}|\tilde{s}]}}_{>0 \text{ as shown above}}>0. \tag{A29}$$

Hence, the total sales over the two periods, $x_0 - x_2^*(x_1^*)$, are decreasing in $\mathrm{Var}[\tilde{v}|\tilde{s}]$ (equivalently, increasing in disclosure quality).

Lastly, combining the previous derivatives, we find that

$$\frac{\partial x_1^*}{\partial \mathrm{Var}[\tilde{v}|\tilde{s}]}-\frac{dx_2^*(x_1^*)}{d\mathrm{Var}[\tilde{v}|\tilde{s}]}=\frac{\gamma+\rho}{\gamma+2\rho}\underbrace{\frac{\partial x_1^*}{\partial \mathrm{Var}[\tilde{v}|\tilde{s}]}}_{>0 \text{ as shown above}}>0. \tag{A30}$$

That is, second-period sales, $x_1^* - x_2^*(x_1^*)$, are increasing in $\mathrm{Var}[\tilde{v}|\tilde{s}]$ (equivalently, decreasing in disclosure quality).

Proof of Parts (iii) and (iv). By inspection. ■

Proof of Proposition 2

Substituting $\mathrm{Var}[\tilde{v}|\tilde{s}]=(\tau_v+\tau_\varepsilon)^{-1}$ into Equation (A14) and Equation (A15) gives, respectively,

$$CE_{i,0}^* = K_{\neg L}^* + \frac{\rho[\rho-(\gamma+\rho)x_0]^2\left[\tau_v^2\rho^2+\tau_\varepsilon^2(\gamma+2\rho)^2+\tau_\varepsilon\tau_v(\gamma+2\rho)(\gamma+4\rho)\right]}{2\tau_v(\tau_v+\tau_\varepsilon)(\gamma+2\rho)^2\left[\tau_v\rho^2+\tau_\varepsilon(\gamma+2\rho)^2\right]}, \tag{A31}$$

$$CE_{L,0}^* = K_L^* - \frac{\tau_\varepsilon\rho^2[\rho-(\gamma+\rho)x_0]^2}{2(\tau_v+\tau_\varepsilon)(\gamma+2\rho)\left[\tau_v\rho^2+\tau_\varepsilon(\gamma+2\rho)^2\right]}. \tag{A32}$$

Proof of Part (i). The derivative of Equation (A31) with respect to τ_ε is

$$\frac{\partial CE_{i,0}^*}{\partial \tau_\varepsilon}=\underbrace{\frac{\rho^2(2\gamma+3\rho)(\gamma+\rho)^2(x_0-x_0^{nt})^2}{2(\tau_v+\tau_\varepsilon)^2(\gamma+2\rho)^2\left[\tau_v\rho^2+\tau_\varepsilon(\gamma+2\rho)^2\right]^2}}_{>0}\left[\tau_v^2\rho^2-\tau_\varepsilon^2(\gamma+2\rho)^2\right]. \tag{A33}$$

This derivative is positive for $\tau_\varepsilon < \hat{\tau}_\varepsilon$ and negative for $\tau_\varepsilon > \hat{\tau}_\varepsilon$. Therefore, Equation (A31) is uniquely maximized at $\tau_\varepsilon = \hat{\tau}_\varepsilon$.

Proof of Part (ii). The derivative of Equation (A32) with respect to τ_ε is

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$$\frac{\partial CE^*_{L,0}}{\partial \tau_\varepsilon} = \underbrace{\frac{\rho^2(\gamma + \rho)^2(x_0 - x_0^{nt})^2}{2(\tau_v + \tau_\varepsilon)^2(\gamma + 2\rho)\left[\tau_v\rho^2 + \tau_\varepsilon(\gamma + 2\rho)^2\right]^2}}_{>0}\left[-\tau_v^2\rho^2 + \tau_\varepsilon^2(\gamma + 2\rho)^2\right]. \tag{A34}$$

This derivative is negative for $\tau_\varepsilon < \hat{\tau}_\varepsilon$ and positive for $\tau_\varepsilon > \hat{\tau}_\varepsilon$. Therefore, Equation (A32) is uniquely minimized at $\tau_\varepsilon = \hat{\tau}_\varepsilon$.

Proof of Part (iii). Evaluate Equation (A14) and Equation (A15), respectively, at $\text{Var}[\tilde{v}|\tilde{s}] \in \{0, \text{Var}[\tilde{v}]\}$:

$$\begin{aligned} CE^*_{i,0}|_{\text{Var}[\tilde{v}|\tilde{s}]=0} &= CE^*_{i,0}|_{\text{Var}[\tilde{v}|\tilde{s}]=\text{Var}[\tilde{v}]} = K^*_{\neg L} + \frac{\rho}{2}\text{Var}[\tilde{v}](x_0 - x^c)^2, \\ CE^*_{L,0}|_{\text{Var}[\tilde{v}|\tilde{s}]=0} &= CE^*_{L,0}|_{\text{Var}[\tilde{v}|\tilde{s}]=\text{Var}[\tilde{v}]} = K^*_L, \end{aligned} \tag{A35}$$

where we have used Proposition 1(iii) and (iv) for the equilibrium holdings. Hence, Equation (A31) is minimized at either extreme and Equation (A32) is maximized at either extreme. ■

Proof of Proposition 3

Substituting $\text{Var}[\tilde{v}|\tilde{s}] = (\tau_v + \tau_\varepsilon)^{-1}$ into Equation (A16) gives

$$TS^* = K^* - \frac{\rho^2[\rho - (\gamma + \rho)x_0]^2[\tau_v\rho + \tau_\varepsilon(\gamma + 2\rho)]^2}{2\tau_v(\tau_v + \tau_\varepsilon)(\gamma + \rho)(\gamma + 2\rho)^2\left[\tau_v\rho^2 + \tau_\varepsilon(\gamma + 2\rho)^2\right]}. \tag{A36}$$

The derivative of Equation (A36) with respect to τ_ε is

$$\frac{\partial TS^*}{\partial \tau_\varepsilon} = \underbrace{\frac{\rho^2(\gamma + \rho)^3(x_0 - x^{nt})^2[\tau_v\rho + \tau_\varepsilon(\gamma + 2\rho)]}{2(\tau_v + \tau_\varepsilon)^2(\gamma + 2\rho)^2\left[\tau_v\rho^2 + \tau_\varepsilon(\gamma + 2\rho)^2\right]^2}}_{>0}[\tau_v\rho - \tau_\varepsilon(\gamma + 2\rho)]. \tag{A37}$$

This derivative is positive for $\tau_\varepsilon < \hat{\tau}_\varepsilon$ and negative for $\tau_\varepsilon > \hat{\tau}_\varepsilon$. Therefore, Equation (A36) is uniquely maximized at $\tau_\varepsilon = \hat{\tau}_\varepsilon$.

As to the minima, evaluate Equation (A16) at $\text{Var}[\tilde{v}|\tilde{s}] \in \{0, \text{Var}[\tilde{v}]\}$:

$$TS^*|_{\text{Var}[\tilde{v}|\tilde{s}]=0} = TS^*|_{\text{Var}[\tilde{v}|\tilde{s}]=\text{Var}[\tilde{v}]} = K^* - \frac{\gamma + \rho}{2}\text{Var}[\tilde{v}](x^c - x^{nt})^2, \tag{A38}$$

where we have used Proposition 1(iii) and (iv) for the equilibrium holdings. Hence, Equation (A36) is minimized at either extreme. ■

Proof of Corollary 1

By inspection. ■

Proofs of Section V

Proof of Proposition 4

Proof of Part (i). If $\overline{\tau}_\varepsilon \leq \hat{\tau}_\varepsilon$, L's payoff is decreasing on the interval $[\underline{\tau}_\varepsilon, \overline{\tau}_\varepsilon]$, and so L optimally chooses the lowest possible precision, $\underline{\tau}_\varepsilon$. Because TS is increasing in that interval, anticipating L's response, it is then optimal for the regulator to set $\underline{\tau}_\varepsilon^* = \overline{\tau}_\varepsilon$.

Proof of Part (ii). First, we show that the regulator is indifferent in choosing any lower bound in the interval $[\overline{\tau}'_\varepsilon, \overline{\tau}_\varepsilon]$. Second, we show that choosing any $\underline{\tau}_\varepsilon < \overline{\tau}'_\varepsilon$ yields a strictly lower total surplus.

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APPENDIX A (continued)

If the regulator chooses $\underline{\tau}_\varepsilon \in (\overline{\tau}'_\varepsilon, \overline{\tau}_\varepsilon]$, L optimally chooses the highest possible precision, $\overline{\tau}_\varepsilon$, yielding a total surplus equal to $TS(\overline{\tau}_\varepsilon)$. And if the regulator chooses $\underline{\tau}_\varepsilon = \overline{\tau}'_\varepsilon$, L is indifferent between $\overline{\tau}'_\varepsilon$ and $\overline{\tau}_\varepsilon$ (because of how $\overline{\tau}'_\varepsilon$ is defined). Whether L chooses $\overline{\tau}'_\varepsilon$ or $\overline{\tau}_\varepsilon$ yields the same total surplus, $TS^*(\overline{\tau}'_\varepsilon) = TS^*(\overline{\tau}_\varepsilon)$. This claim follows because total surplus is an affine transformation of L's surplus, that is, $TS^* = a + b\, CE^*_{L,0}$ for some constants a and b (note that the $\partial CE^*_{L,0}/\partial\tau_\varepsilon$ and $\partial TS^*/\partial\tau_\varepsilon$ are given by the same function of τ_ε up to a multiplying coefficient, see Equation (A34) and Equation (A37)).

Last, if the regulator chooses $\underline{\tau}_\varepsilon < \overline{\tau}'_\varepsilon$, L will select the lowest possible precision, and $TS^*(\tau_\varepsilon) < TS^*(\overline{\tau}'_\varepsilon) = TS^*(\overline{\tau}_\varepsilon)$ for all $\tau_\varepsilon < \overline{\tau}'_\varepsilon$. ■

Proofs of Section VI

Proof of Proposition 5 and Proposition 6

We prove the holdings by backward induction. Equilibrium holdings in the third period and the second period follow directly from Lemma 1.

$$x_2^*(x_1) = \frac{(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])\rho(1 + x_1) + \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2]\frac{\rho^2}{\gamma+2\rho}x_1}{(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])(\gamma + 2\rho) + \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2]\frac{\rho^2}{\gamma+2\rho}}, \tag{A39}$$

$$x_3^*\left(x_2^*(x_1)\right) = \frac{\left(1 + x_2^*(x_1)\right)\rho}{\gamma + 2\rho}. \tag{A40}$$

In the first period, the large shareholder's problem is

$$\begin{aligned}\max_{x_1}\, & p_1x_0 + (p_2^* - p_1)x_1 + (p_3^* - p_2^*)x_2^*(x_1) + (\mu - p_3^*)x_3^*\left(x_2^*(x_1)\right) - \frac{\gamma}{2}(\mathrm{Var}[\tilde v] - \mathrm{Var}[\tilde v|\tilde s_1])x_1^2 \\ & - \frac{\gamma}{2}(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])\left(x_2^*(x_1)\right)^2 - \frac{\gamma}{2}\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2]\left(x_3^*\left(x_2^*(x_1)\right)\right)^2\end{aligned} \tag{A41}$$

Plug $x_2^*(x_1)$ and $x_3^*\left(x_2^*(x_1)\right)$ in Equation (A41) and apply the market clearing condition in the first period; that is,

$$\begin{aligned}p_1 = {} & \mu - \rho(1 - x_1)(\mathrm{Var}[\tilde v] - \mathrm{Var}[\tilde v|\tilde s_1]) - \rho\left(1 - x_2^*(x_1)\right)(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2]) \\ & - \rho\left(1 - x_3^*\left(x_2^*(x_1)\right)\right)\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2]\end{aligned} \tag{A42}$$

we can solve for the large shareholder's holding in the first period, which is given by

$$x_1^* = \frac{\begin{array}{l}[\rho\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2] + (\gamma + 2\rho)(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])]^2\dfrac{\rho^2}{\gamma + 2\rho}x_0 \\ + \left[\rho^2\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2] + (\gamma + 2\rho)^2(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])\right](\mathrm{Var}[\tilde v] - \mathrm{Var}[\tilde v|\tilde s_1])\rho(1 + x_0)\end{array}}{\begin{array}{l}[\rho\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2] + (\gamma + 2\rho)(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])]^2\dfrac{\rho^2}{\gamma + 2\rho} \\ + (\gamma + 2\rho)\left[\rho^2\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2] + (\gamma + 2\rho)^2(\mathrm{Var}[\tilde v|\tilde s_1] - \mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2])\right](\mathrm{Var}[\tilde v] - \mathrm{Var}[\tilde v|\tilde s_1])\end{array}}. \tag{A43}$$

$CE^*_{L,0}$ can be computed by substituting Equation (A43) into Equation (A41). Substituting $\mathrm{Var}[\tilde v] = \tau_v^{-1}$, $\mathrm{Var}[\tilde v|\tilde s_1] = (\tau_v + \tau_{\varepsilon_1})^{-1}$, and $\mathrm{Var}[\tilde v|\tilde s_1,\tilde s_2] = (\tau_v + \tau_{\varepsilon_1} + \tau_{\varepsilon_2})^{-1}$ into $CE^*_{L,0}$ and take derivative with respect to τ_{ε_2}, it can be shown that

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APPENDIX A (continued)

$$\frac{\partial CE^*_{L,0}}{\partial \tau_{\varepsilon_2}} \propto \left[(\gamma+2\rho)\tau_{\varepsilon_2} - \rho(\tau_v + \tau_{\varepsilon_1})\right] \tag{A44}$$

and thus $\hat{\tau}_{\varepsilon_2}(\tau_{\varepsilon_1}) = \frac{\rho(\tau_v+\tau_{\varepsilon_1})}{\gamma+2\rho}$. Using $\frac{\partial CE^*_{L,0}}{\partial \tau_{\varepsilon_2}}|_{\tau_{\varepsilon_2}=\hat{\tau}_{\varepsilon_2}(\tau_{\varepsilon_1})} = 0$, we know that $\hat{\tau}_{\varepsilon_1}$ solves

$$\frac{\partial CE^*_{L,0}\left(\tau_{\varepsilon_1}, \hat{\tau}_{\varepsilon_2}(\tau_{\varepsilon_1})\right)}{\partial \tau_{\varepsilon_1}} = \frac{\partial CE^*_{L,0}}{\partial \tau_{\varepsilon_1}}|_{\tau_{\varepsilon_2}=\hat{\tau}_{\varepsilon_2}(\tau_{\varepsilon_1})} \propto \left[\tau_{\varepsilon_1} - \frac{4\rho^2(\gamma+4\rho)\tau_v}{(\gamma+3\rho)^2(\gamma+6\rho)}\right] = 0. \tag{A45}$$

Similar derivations apply for $CE^*_{i,0}$ and TS^*. Proposition 5 can be directly proved by substituting x_0 for x_1^* above in Equation (A43). ■

Proofs of Section VII

Proof of Lemma 3

The asset value $\tilde{v}$, liquidity trades $\{\tilde{l}_t\}_{t=1,2}$, and the signal noise $\tilde{\varepsilon}$ are jointly normally distributed,

$$\begin{pmatrix} \tilde{v} \\ \tilde{\varepsilon} \\ \tilde{l}_1 \\ \tilde{l}_2 \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} \mu_v \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \frac{1}{\tau_v} & 0 & 0 & 0 \\ 0 & \frac{1}{\tau_\varepsilon} & 0 & 0 \\ 0 & 0 & \frac{1}{\tau_l} & 0 \\ 0 & 0 & 0 & \frac{1}{\tau_l} \end{pmatrix}\right). \tag{A46}$$

L's *ex post* payoff (i.e., after all uncertainty is realized) is

$$U_L(v, \Delta x_1, \Delta x_2, l_1, l_2, s) = v x_0 + [v - p_1(\Delta x_1 + l_1)]\Delta x_1 + [v - p_2(\Delta x_1 + l_1, s, \Delta x_2 + l_2)]\Delta x_2. \tag{A47}$$

Taking the prices in Equation (25) as given, we solve backward for L's equilibrium order flows in each period:

$$\begin{aligned} &\frac{\partial \mathrm{E}[U_L(v, \Delta x_1, \Delta x_2, l_1, \tilde{l}_2, s)]}{\partial \Delta x_2} = 0 \Rightarrow \Delta x_2^*(v, \Delta x_1, l_1, s) = \underbrace{\frac{1}{2\lambda_2}}_{\equiv \beta_2}(v - \mathrm{E}[\tilde{v}|\tilde{z}_1 = \Delta x_1 + l_1, \tilde{s} = s]) \\ &\frac{\partial \mathrm{E}[U_L(v, \Delta x_1, \Delta x_2^*(v, \Delta x_1, \tilde{l}_1, \tilde{s}), \tilde{l}_1, \tilde{l}_2, \tilde{s})]}{\partial \Delta x_2} = 0 \Rightarrow \Delta x_1^*(v) = \underbrace{\frac{2\lambda_2 - (1-\gamma)^2\lambda_1}{\lambda_1(4\lambda_2 - (1-\gamma)^2\lambda_1)}}_{\equiv \beta_1}(v - \mu_v). \end{aligned} \tag{A48}$$

Taking the second-order derivatives in each period gives us the second-order conditions for a maximum in Equation (27).

Next, we solve for the MM's updating. At $t = 1$, we have

$$\begin{pmatrix} \tilde{v} \\ \tilde{z}_1 \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} \mu_v \\ 0 \end{pmatrix}, \begin{pmatrix} \frac{1}{\tau_v} & \frac{\beta_1}{\tau_v} \\ \frac{\beta_1}{\tau_v} & \frac{\beta_1^2}{\tau_v} + \frac{1}{\tau_l} \end{pmatrix}\right), \tag{A49}$$

hence

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APPENDIX A (continued)

$$p_1(z_1) = \mathrm{E}[\tilde{v}|\tilde{z}_1 = z_1] = \mu_v + \frac{\beta_1 \tau_l}{\beta_1^2 \tau_l + \tau_v} z_1,$$
$$\mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1] = \frac{1}{\beta_1^2 \tau_l + \tau_v}. \tag{A50}$$

After the realization of the public signal but before $t = 2$, we have

$$\begin{pmatrix} \tilde{v} \\ \tilde{s} - p_1(z_1) \end{pmatrix} \Bigg| (\tilde{z}_1 = z_1) \sim \mathcal{N}\left(\begin{pmatrix} p_1(z_1) \\ 0 \end{pmatrix}, \begin{pmatrix} \mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1] & \mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1] \\ \mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1] & \mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1] + \frac{1}{\tau_\varepsilon} \end{pmatrix} \right), \tag{A51}$$

hence

$$\mathrm{E}[\tilde{v}|\tilde{z}_1 = z_1, \tilde{s} = s] = p_1(z_1) + \frac{\tau_\varepsilon}{\beta_1^2 \tau_l + \tau_v + \tau_\varepsilon}(s - p_1(z_1)),$$
$$\mathrm{Var}[\tilde{v}|\tilde{z}_1 = z_1, \tilde{s} = s] = \frac{1}{\beta_1^2 \tau_l + \tau_v + \tau_\varepsilon}. \tag{A52}$$

At $t = 2$, we have

$$\begin{pmatrix} \tilde{v} \\ \tilde{z}_2 \end{pmatrix} \Bigg| (\tilde{z}_1 = z_1, \tilde{s} = s) \sim \mathcal{N}\left(\begin{pmatrix} \mathrm{E}[\tilde{v}|z_1, s] \\ 0 \end{pmatrix}, \begin{pmatrix} \mathrm{Var}[\tilde{v}|z_1, s] & \beta_2 \mathrm{Var}[\tilde{v}|z_1, s] \\ \beta_2 \mathrm{Var}[\tilde{v}|z_1, s] & \beta_2^2 \mathrm{Var}[\tilde{v}|z_1, s] + \frac{1}{\tau_l} \end{pmatrix} \right), \tag{A53}$$

hence

$$p_2(z_1, s, z_2) = \mathrm{E}[\tilde{v}|z_1, s] + \frac{\beta_2 \tau_l}{(\beta_1^2 + \beta_2^2)\tau_l + \tau_v + \tau_\varepsilon} z_2. \tag{A54}$$

Equating the coefficients, we obtain the system of five equations in five unknowns in Equation (26). In the numerical examples, we retain the unique solution such that $\lambda_1, \lambda_2 > 0$ and verify that the second-order conditions are satisfied.

L's and small liquidity traders' *ex ante* payoffs are, respectively,

$$\mathrm{E}\left[U_L(\tilde{v}, \Delta x_1^*(\tilde{v}), \Delta x_2^*(\tilde{v}, \Delta x_1^*(\tilde{v}), \tilde{l}_1, \tilde{s}), \tilde{l}_1, \tilde{l}_2, \tilde{s})\right],$$
$$\mathrm{E}\left[\tilde{v}(1 - x_0) + (\tilde{v} - p_1(\tilde{z}_1))\tilde{l}_1 + (\tilde{v} - p_2(\tilde{z}_1, \tilde{s}, \tilde{z}_2))\tilde{l}_2\right]. \quad \blacksquare \tag{A55}$$

Proof of Proposition 7

It is useful to represent the equilibrium conditions in Equation (26) in the following manner:

$$\lambda_2\left((\beta_1^2 + \beta_2^2)\tau_l + \tau_v + \tau_\varepsilon\right) - \beta_2 \tau_l = 0. \tag{A56}$$

$$\gamma(\beta_1^2 \tau_l + \tau_v + \tau_\varepsilon) - \tau_\varepsilon = 0. \tag{A57}$$

$$\lambda_1(\beta_1^2 \tau_l + \tau_v) - \beta_1 \tau_l = 0. \tag{A58}$$

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APPENDIX A (continued)

$$2\beta_2\lambda_2 - 1 = 0. \tag{A59}$$

$$\beta_1\lambda_1\left(4\lambda_2 - (1-\gamma)^2\lambda_1\right) - \left(2\lambda_2 - (1-\gamma)^2\lambda_1\right) = 0. \tag{A60}$$

Denote the left-hand side terms of this system of equations as the vector $\overrightarrow{l}$. Denote $\overrightarrow{v} \equiv (\beta_1, \beta_2, \lambda_1, \lambda_2, \gamma)$, $A \equiv d\overrightarrow{l}/d\overrightarrow{v}$ and $B \equiv d\overrightarrow{l}/d\tau_\varepsilon$. Using the implicit function theorem, it follows that $d\overrightarrow{v}/d\tau_\varepsilon = -[A]^{-1} \cdot B$. It can be shown that, given these equilibrium conditions, the first-order derivatives of price impacts λ_1 and λ_2 with respect to τ_ε are given by

$$\frac{d\lambda_1}{d\tau_\varepsilon} = -\frac{3\tau_l(4\lambda_1^2\tau_v - \tau_l)}{2\tau_l\left(2\tau_v\left(-\beta_2\tau_l + \lambda_2(3\tau_v + 2\tau_\varepsilon) + 5\lambda_1\tau_\varepsilon\right) + \beta_1\tau_l(4\tau_v - 3\tau_\varepsilon)\right)}, \tag{A61}$$

$$\frac{d\lambda_2}{d\tau_\varepsilon} = -\frac{2\lambda_2\left(2\lambda_1 + (1-\gamma)\lambda_2\right)\tau_l\tau_v}{2\tau_l\left(2\tau_v\left(-\beta_2\tau_l + \lambda_2(3\tau_v + 2\tau_\varepsilon) + 5\lambda_1\tau_\varepsilon\right) + \beta_1\tau_l(4\tau_v - 3\tau_\varepsilon)\right)}. \tag{A62}$$

Additionally, letting $\tilde{\pi} \equiv (\tilde{v} - \tilde{p}_1)\Delta\tilde{x}_1 + (\tilde{v} - \tilde{p}_2)\Delta\tilde{x}_2$ denote L's trading profits, we have[26]

$$\frac{d\mathrm{E}[\tilde{\pi}]}{d\tau_\varepsilon} \propto \frac{d\lambda_1}{d\tau_\varepsilon} + \frac{d\lambda_2}{d\tau_\varepsilon}. \tag{A63}$$

To determine the sign of these derivatives, we denote the numerators and the common denominator as follows:

$$n_1 \equiv 3\tau_l(4\lambda_1^2\tau_v - \tau_l), \tag{A64}$$

$$n_2 \equiv 2\lambda_2\left(2\lambda_1 + (1-\gamma)\lambda_2\right)\tau_l\tau_v, \tag{A65}$$

$$d \equiv 2\tau_l\left(2\tau_v\left(-\beta_2\tau_l + \lambda_2(3\tau_v + 2\tau_\varepsilon) + 5\lambda_1\tau_\varepsilon\right) + \beta_1\tau_l(4\tau_v - 3\tau_\varepsilon)\right). \tag{A66}$$

In what follows, we show $n_1 < 0, n_2 > 0, d > 0, n_1 + n_2 > 0$. Therefore $\frac{d\lambda_1}{d\tau_\varepsilon} = -\frac{n_1}{d} > 0$, $\frac{d\lambda_2}{d\tau_\varepsilon} = -\frac{n_2}{d} < 0$, $\frac{d\mathrm{E}[\tilde{\pi}]}{d\tau_\varepsilon} \propto -\frac{n_1+n_2}{d} < 0$.

Step 1: Proof of $n_1 < 0$ *and* $n_2 > 0$. Solving for τ_v from Equation (A58), we have

$$\tau_v = \frac{\beta_1\tau_l - \beta_1^2\lambda_1\tau_l}{\lambda_1}. \tag{A67}$$

Plugging Equation (A67) into Equation (A64), we have

$$n_1 = -3(1 - 2\beta_1\lambda_1)^2\tau_l^2. \tag{A68}$$

From Equation (A60) we have

$$\beta_1\lambda_1 = \frac{2\lambda_2 - (1-\gamma)^2\lambda_1}{4\lambda_2 - (1-\gamma)^2\lambda_1} < \frac{1}{2}. \tag{A69}$$

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[26] Because the MM's breaks even in expectation, L's *ex ante* expected trading profits are the same as liquidity traders' *ex ante* expected losses, that is, $\mathrm{E}[\tilde{\pi}] = -\mathrm{E}[(\tilde{v} - \tilde{p}_1)\tilde{l}_1 + (\tilde{v} - \tilde{p}_2)\tilde{l}_2] = -\frac{\lambda_1+\lambda_2}{\tau_l}$.

APPENDIX A (continued)

It then follows that

$$n_1 = -3(1-2\beta_1\lambda_1)^2\tau_l^2 < 0. \tag{A70}$$

From Equation (A65), it can be seen that $n_2 > 0$ given that $\lambda_1 > 0, \lambda_2 > 0, \tau_l > 0, \tau_v > 0$, and $0 < \gamma < 1$.

Step 2: Proof of $d > 0$. To show that $d > 0$ as in Equation (A66), since $\tau_l > 0$, we only need to show that

$$2\tau_v\Big(-\beta_2\tau_l + \lambda_2(3\tau_v + 2\tau_\varepsilon) + 5\lambda_1\tau_\varepsilon\Big) + \beta_1\tau_l(4\tau_v - 3\tau_\varepsilon) > 0. \tag{A71}$$

Solving for β_2 from Equation (A59), we have

$$\beta_2 = \frac{1}{2\lambda_2}. \tag{A72}$$

Solving for τ_ε from Equation (A57), we have

$$\tau_\varepsilon = \frac{\gamma(\beta_1^2\tau_l + \tau_v)}{1-\gamma}. \tag{A73}$$

Plugging Equation (A72), Equation (A73), and Equation (A67) into Equation (A56), and rearranging terms, we have

$$\gamma = 1 - \frac{4\beta_1\lambda_2^2}{\lambda_1}. \tag{A74}$$

Plugging Equation (A73), Equation (A74), Equation (A67), and Equation (A72) into Equation (A71), we have

$$\beta_1\lambda_1^2\lambda_2^2\Big(-10\beta_1\lambda_1^3 + \lambda_1^2(24\beta_1^3\lambda_2^3 + 24\beta_1^2\lambda_2^2 + 7) - 4\beta_1\lambda_2^2\lambda_1(8\beta_1\lambda_2 + 3) + 8\beta_1\lambda_2^3\Big)\tau_l^2 > 0. \tag{A75}$$

To show that $d > 0$ it suffices to show that Equation (A75) holds. Given that all involved parameters are positive, it suffices to show that

$$-10\beta_1\lambda_1^3 + \lambda_1^2(24\beta_1^3\lambda_2^3 + 24\beta_1^2\lambda_2^2 + 7) - 4\beta_1\lambda_2^2\lambda_1(8\beta_1\lambda_2 + 3) + 8\beta_1\lambda_2^3 > 0. \tag{A76}$$

Denote $b \equiv \beta_1\lambda_1$ and $c \equiv \beta_1\lambda_2$. Given that $\beta_1, \lambda_1, \lambda_2 > 0$, we have $b > 0$ and $c > 0$. Equation (A76) can be re-written as

$$-10b^3 + b^2(24c^3 + 24c^2 + 7) - 4bc^2(8c + 3) + 8c^3 > 0. \tag{A77}$$

Now our task is to show that Equation (A77) holds. Rewriting Equation (A74), we have

$$\gamma = 1 - \frac{4c^2}{b} \in (0, 1), \tag{A78}$$

which implies

$$b > 4c^2. \tag{A79}$$

Plugging Equation (A74) into Equation (A60), we have

$$-8\beta_1^2\lambda_2^3 - 2\beta_1\lambda_1^2 + \lambda_1(8\beta_1^3\lambda_2^3 + 1) = 0, \tag{A80}$$

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APPENDIX A (continued)

which can be equivalently written as

$$-2b^2 + b(8c^3 + 1) - 8c^3 = 0. \tag{A81}$$

Solving for b from Equation (A81), and making sure it satisfies the constraint specified in Equation (A79), we have

$$b = \frac{1}{4}(8c^3 + \sqrt{64c^6 - 48c^3 + 1} + 1). \tag{A82}$$

Plug Equation (A82) into the left-hand side term of Equation (A77), and denote it as $G(c)$. To show that $d > 0$, it suffices to show that $G(c) > 0$. From Equation (A67) we have $b < \frac{1}{2}$, which implies that $c \leq \frac{1}{2}\sqrt[3]{3 - 2\sqrt{2}} \equiv \bar{c}$.[27] One can verify that, on the interval $[0, \bar{c}]$, the only point such that $G(c) = G(\bar{c})$ is $c = \bar{c}$ itself. Additionally, $G(\bar{c}) > 0$ and $G'(\bar{c}) < 0$, which implies $G(c) > 0$ for all $c \in [0, \bar{c}]$. Hence, $d > 0$.

Step 3: Proof of $n_1 + n_2 > 0$. Adding up n_1 and n_2 given by Equation (A64) and Equation (A65), we have $n_1 + n_2 = \tau_l\Big(2\Big((1-\gamma)\lambda_2^2 + 6\lambda_1^2 + 2\lambda_2\lambda_1\Big)\tau_v - 3\tau_l\Big)$. Given that $\tau_l > 0$, it suffices to show that

$$2\Big((1-\gamma)\lambda_2^2 + 6\lambda_1^2 + 2\lambda_2\lambda_1\Big)\tau_v - 3\tau_l > 0. \tag{A83}$$

Plugging Equation (A67) and Equation (A74) into Equation (A83), we have

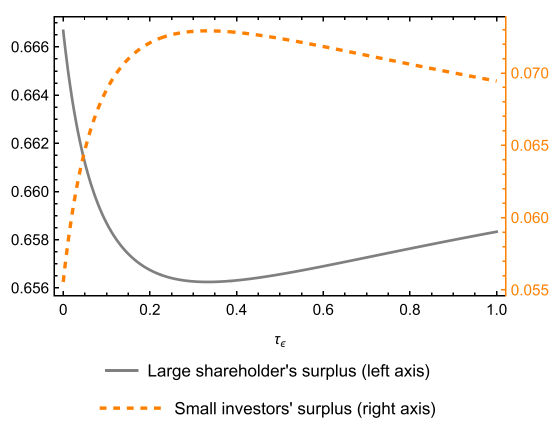
$$4\beta_1(\beta_1\lambda_1 - 1)(2\beta_1\lambda_2^4 + \lambda_1^2\lambda_2 + 3\lambda_1^3) + 3\lambda_1^2 < 0. \tag{A84}$$

Now our task is to show Equation (A84). As defined above, we plug in $b \equiv \beta_1\lambda_1$ and $c \equiv \beta_1\lambda_2$ and rewrite Equation (A84) as

$$3b^2 - 4(1-b)(3b^3 + b^2c + 2c^4) < 0. \tag{A85}$$

FIGURE A1
Effects of Disclosure Quality on Welfare

Panel A: Effects of Disclosure Quality on Traders' Surplus



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[27] Note that $64c^6 - 48c^3 + 1 \geq 0$ for $c \leq \bar{c}$, so b and $G(c)$ are well defined on $[0, \bar{c}]$.

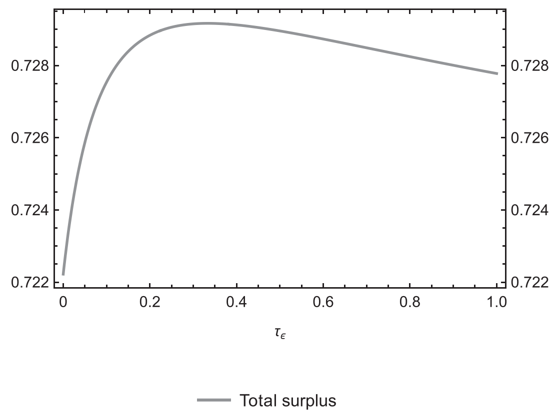
APPENDIX A (continued)

Plug Equation (A82) into the left-hand side term of Equation (A85), and denote it as $H(c)$. To show that $n_1 + n_2 > 0$, we only need to show $H(c) < 0$. One can verify that, on the interval $[0, \overline{c}]$, the only point such that $H(c) = H(0)$ is $c = 0$ itself. Additionally, $H(0) = 0$ and $H'(0) < 0$, which implies $H(c) < 0$ for all $c \in [0, \overline{c}]$. Hence, $n_1 + n_2 > 0$.

Overall, we have shown that $n_1 < 0, n_2 > 0, d > 0, n_1 + n_2 > 0$. Hence, $\frac{d\lambda_1}{d\tau_\varepsilon} = -\frac{n_1}{d} > 0$, $\frac{d\lambda_2}{d\tau_\varepsilon} = -\frac{n_2}{d} < 0$, $\frac{d\mathrm{E}[\tilde{\pi}]}{d\tau_\varepsilon} \propto -\frac{n_1 + n_2}{d} < 0$.

FIGURE A1 (continued)

Panel B: Effects of Disclosure Quality on Total Surplus

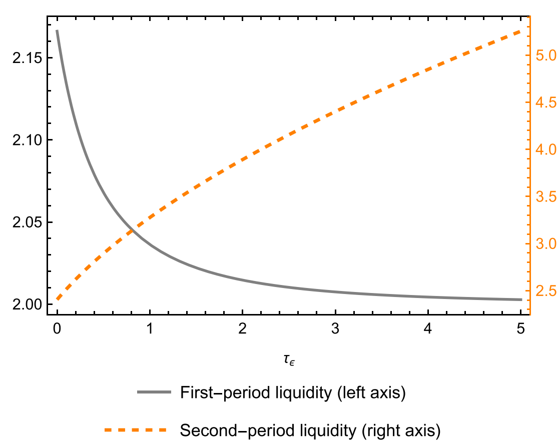


Panel A plots traders' individual surplus as a function of disclosure quality, τ_ε. Panel B plots traders' total surplus as a function of disclosure quality, τ_ε. The large shareholder's and small investors' surpluses are their respective *ex ante* certainty equivalents. See Section II for the model specification. The parameter values are: $\mu_v = \tau_v = \gamma = \rho = x_0 = 1$.
(The full-color version is available online.)

FIGURE A2

Effects of Disclosure Quality under Asymmetric Information and Risk Neutrality

Panel A: Effects of Disclosure Quality on Liquidity



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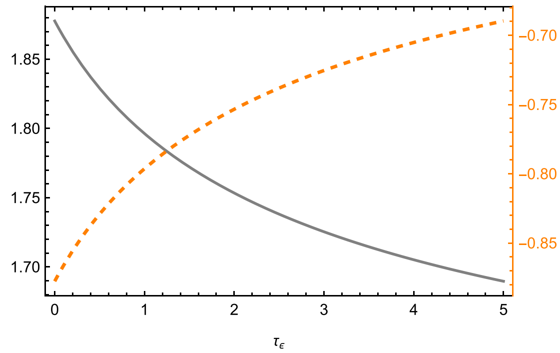
APPENDIX A (continued)

FIGURE A2 (continued)

Panel B: Effects of Disclosure Quality on Traders' Expected Payoff



Panel A plots the respective liquidity of the two periods as a function of disclosure quality, τ_ε. Panel B plots the respective *ex ante* expected payoff of the two traders as a function of disclosure quality, τ_ε. See Section VII for the model specification. The parameter values are $\mu_v = \tau_v = \tau_l = x_0 = 1$.
(The full-color version is available online.)