Disclosing and Cooling-Off: An Analysis of Insider Trading Rules*

Jun Deng
jundeng@uibe.edu.cn
University of International Business and Economics

Huifeng Pan
panhf@uibe.edu.cn
University of International Business and Economics

Hongjun Yan
hongjun.yan.2011@gmail.com
DePaul University

Liyan Yang*
liyan.yang@rotman.utoronto.ca.
University of Toronto

March 14, 2023

*We thank Snehal Banerjee, Tobias Berg, Ing-Haw Cheng, Jérôme Dugast, Itay Goldstein, Vahid Irani, Chao Jiang, Anastasios Kagkadis, Xiaomeng Lu, Chang Ma, Liang Ma, Roberto Pinto, Francesco Sangiorgi, Sergey Tsyplakov, Zacharias Sautner, Kevin Colby Smith, Grigory Volkov, Yafei Zhang, and seminar participants at Alliance Manchester Business School & Lancaster University Management School, Darla Moore School of Business at University of South Carolina, Fanhai International School of Finance at Fudan University, and Frankfurt School of Finance Management for constructive comments that have significantly improved the paper. Corresponding author: Liyan Yang. Yang thanks the Social Sciences and Humanities Research Council of Canada for financial support.

Disclosing and Cooling-Off: An Analysis of Insider Trading Rules

Abstract

This paper analyzes insider-trading regulations, focusing on two recent proposals: advance disclosure and "cooling-off periods." The former requires an insider to disclose his trading plan at adoption, while the latter mandates a delay period before execution. Disclosure increases stock price efficiency but has mixed welfare implications. If the insider has large liquidity needs, in contrast to the conventional wisdom from "sunshine trading," disclosure can even reduce the welfare of all investors. A longer cooling-off period increases outside investors' welfare but decreases stock price efficiency. Its implication on the insider's welfare depends on whether the disclosure policy is already in place.

JEL Classification Numbers: G14, G18, D82.

Keywords: Insider trading, Rule 10b5-1, Sunshine trading, Disclosure, Cooling-off period.

1 Introduction

Insider trading has long been at the center of debates among academics and regulators. Motivated by fairness and market integrity, existing regulations in most countries prohibit trading on material nonpublic information (MNPI). Recognizing insiders' non-informational trading needs, regulators also set up rules to oversee those trading activities. In the U.S., for example, the Securities and Exchange Commission's (SEC) Rule 10b5-1 allows corporate insiders to make predetermined trades while following insider trading laws and avoiding insider trading accusations.

Soon after the rule's implementation, however, researchers and regulators are concerned about its abuse (e.g., Jagolinzer, 2009; Larcker et al., 2021). Recent controversies on the sales by the executives of Covid-19 vaccine developers shortly after their announcements of breakthroughs, once again, brought the concern into spotlights.[1] As a response, researchers and regulators have been exploring ways to improve Rule 10b5-1. In February 2022, for example, the SEC has released a report to discuss various measures to regulate Rule 10b5-1 plans.[2]

Two proposals stand out. The first is about the disclosure of 10b5-1 plans. Under the current rules, an insider does not need to pre-disclose his trading plans. Some researchers believe that this opacity invites opportunistic insider trading.[3] The proposal under consideration is to require insiders publicly disclose their trading plans upon adoption, modification, and cancellation.

The other proposal is a "cooling-off period," a mandatory minimum waiting period from the initiation of a 10b5-1 plan to the first trade under that plan. Currently, there is no explicit requirement for a cooling-off period. In fact, Larcker et al. (2021) find that one percent of the 10b5-1 plans in their sample begin trading on plan adoption days. Moreover, their evidence suggests that a short cooling-off period is a "red flag" associated with opportunistic behavior: trades with short cooling-off periods earn excess returns while those with long ones do not. As a response, a regulatory change under consideration is a mandatory cooling-off period.[4]

[1] See, e.g., *Pfizer CEO Joins Host of Executives at Covid-19 Vaccine Makers in Big Stock Sale*, Jared S. Hopkins and Gregory Zuckerman, *Wall Street Journal*, November 11, 2020.

[2] *Rule 10b5-1 and Insider Trading*, https://www.sec.gov/rules/proposed/2022/33-11013.pdf.

[3] For example, in an interview at *Knowledge at Wharton*, Daniel Taylor states that "[b]ad behavior flourishes when there's no sunlight. If you are adopting one of these plans, just disclose everything. Company insiders are using Rule 105b-1 as a sword to provide legal cover from some of the sketchier trades that they're conducting." "How Insider Trading Hides Behind a Barely Noticed Rule," *Knowledge at Wharton*, April 20, 2021.

[4] For example, in a letter to the Congress, Jay Clayton, the former Chairman of the SEC, recommends to make a cooling-off period mandatory (www.sec.gov/file/clayton-letter-chairman-sherman-20200914, accessed on 10/7/2022).

In this paper, we analyze these two proposals in a Kyle-type trading model (Kyle, 1985). A large *insider* has private information about a stock and also has a liquidity need. He sets up his 10b5-1 plan to trade the stock at a future time. Outside investors are price takers and consist of two types: *speculators* and *hedgers*. The former have their own private information while the latter trade the stock for hedging purposes. All investors have a constant-absolute-risk-aversion (CARA) utility function and submit market orders. A risk neutral market maker sets the stock price to its expected fundamental value.

Essentially, the disclosure policy provides the market maker and outside investors additional information: the insider's trade size. To analyze the implications of the policy, we construct the equilibria under both the disclosure and non-disclosure regimes. The policy implications are obtained by contrasting the two equilibria.

The mandatory cooling-off period policy is predicated on the intuition that by imposing a delay, it tends to reduce the insider's information advantage. Suppose, for example, the insider received encouraging news today about its development of a new drug. If the insider can trade right away, he would have substantial advantage over outside investors. If, however, there is a mandatory waiting period, by the time the insider is allowed to trade, his information advantage is likely diminished because, during the cooling-off period, some of the information might reach outside investors or the firm may have to make a public announcement about the development. Therefore, the implications of a cooling-off period are captured by the effects from reducing the insider's information advantage.

Our analysis suggests that disclosure increases stock price efficiency but has mixed welfare implications. Price efficiency increases for two reasons. First, through disclosure, the insider's trading order partially reveals his private information to the market maker. Second, the market maker also better reads outside speculators' information, since outsider investors' orders are separate from the insider's under disclosure. However, disclosure does not always improve investor welfare. In fact, we find that if the insider has a large hedging need, the disclosure policy makes all investors worse off. This result appears contradictory to the idea of "sunshine trading." Admati and Pfleiderer (1991) show that if an investor's trade is mostly informationless, the investor would benefit from sunshine trading, i.e., from disclosing his trade in advance. Hence, one might expect the insider, who has a large non-information trading need in this case, to benefit from the disclosure policy. However, our conclusion is exactly the opposite. What is behind this surprising result?

Further analysis shows that the sunshine trading intuition continues to hold in our model, albeit in terms of profit as opposed to welfare. That is, disclosure indeed increases the insider's expected trading profit but decreases his welfare. What is the intuition? It turns out that the result is due to the Hirshleifer effect (Hirshleifer, 1971). Under the disclosure regime, as noted earlier, the stock price reveals more information about the fundamental value. As noted in Hirshleifer (1971), information revelation reduces risk sharing opportunity. When the insider has a strong hedging need, the Hirshleifer effect dominates and the insider is worse off. Similarly, hedgers are worse off because the information revelation reduces their risk sharing opportunities. Moreover, speculators are worse off because their trades can no longer be mixed with the insider's hedging trades, making it less effective to exploit their private information. Therefore, in the case in which the insider has a large hedging need, disclosure actually makes all investors worse off.

Our analysis also characterizes scenarios under which the disclosure increases investors' welfare. In particular, the insider benefits from disclosure if his hedging need is modest so that the Hirshleifer effect does not dominate. Moreover, outside investors benefit from disclosure if the insider's trading order is highly informative (i.e., the insider has a large amount of private information and small hedging need).

Finally, our analysis on cooling-off periods shows that a longer cooling-off period increases outside investors' welfare but reduces the stock price efficiency. Intuitively, a longer cooling-off period implies less informative insider trade, which benefits outside investors through less adverse selection and better risk sharing. Naturally, since the insider's trade utilizes less information, the stock price is less informationally efficient.

How about the implication for the insider's welfare? Interestingly, our analysis shows that it depends on the interaction with the disclosure policy. That is, whether a longer cooling-off period benefits or harms the insider depends on whether the disclosure policy is already in place. For instance, when the insider's trade is mostly motivated by private information rather than hedging, which appears to be the concern of policy makers, the insider is worse off from a longer cooling-off period under the non-disclosure regime. If the disclosure policy in already in place, however, a longer cooling-off period increases the insider's welfare. The intuition is as follows. Under the non-disclosure regime, where all trading orders are mixed together, the insider can effectively exploit his information advantage. Since a longer cooling-off period reduces this advantage, it leads to a lower welfare. Under the disclosure regime, however, since the insider's trade is separated, his information is largely revealed. The more information the insider has (i.e., the shorter the cooling-off period), the more is revealed. Given the information possessed by speculators, this leads to a smaller information advantage and lower welfare for the insider. Therefore, a longer cooling-off period implies a higher welfare for the insider.

Related literature. Our paper is related to the extensive theoretical literature on insider trading.[5] Most closely, our paper is related to studies that explore insider trading disclosure. Huddart et al. (2001) and Mele and Sangiorgi (2021) examine post-trade disclosure, and Medran and Vives (2004) explore disclosure of the insider's private information. The 10b5-1 plan disclosure proposal under the SEC's current consideration is about pre-trade disclosure, which is related to the notion of "pre-announcement of insiders' trades" and "advance disclosure of insider trading" in Huddart et al. (2010) and Lenkey (2014). Our paper differs from and complements these two studies in important ways. First, our results on market quality and welfare differ from those of Lenkey (2014), because in his model, all outside investors are uninformed, while we differentiate between informed speculators and uninformed hedgers. The model in Huddart et al. (2010) features exogenous noise trading but no speculators and hedgers. Thus, it is not suited for a complete welfare analysis, and stays away from the questions we examine (e.g., welfare implications for different types of outside investors, the interactions between insider information and outside information in information aggregation). Second, neither study examines the cooling-off policy, which is a key proposal considered by the SEC. To the best of our knowledge, our paper is the first analyzing this proposal. We find that the implications of the cooling-off policy and the disclosure policy are closely intertwined.

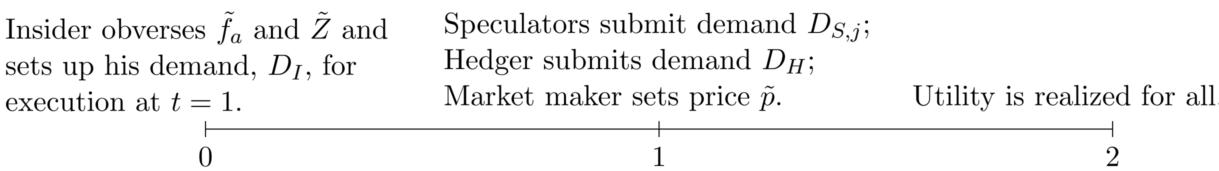
More broadly, our paper is related to the "sunshine-trading" literature. Our model shares some elements with Admati and Pfleiderer (1991), where a liquidity trader preannounce his liquidity demands to the market and such announcement is beneficial to the liquidity trader. The "sunshine trading" effect of Admati and Pfleiderer (1991) still prevails in our model although it could be dominated by the Hirshleifer effect if the insider's risk-sharing need is important.

[5] The debates on the pros and cons of insider trading go back at least to Manne (1966). A partial list of earlier studies includes Dye (1984), Glosten (1989), Manove (1989), Ausubel (1990), Fishman and Hagerty (1992), Leland (1992), and DeMarzo et al. (1998). The literature is actively growing and some recent studies include Lenkey (2014, 2017, 2019, 2021), Mele and Sangiorgi (2021), Kacperczyk and Pagnotta (2020), and Carré et al. (2022).

2 Model

We consider an economy with three dates, $t = 0, 1, 2$. There is a risky asset, a stock, which is a claim to a cash flow $\tilde{f}$ at $t = 2$, with $\tilde{f} \sim N(0, 1)$. There also exists a risk-free asset with a net interest rate of 0. The time line of events is summarized in Figure 1.

Figure 1. Timeline.



At $t = 0$, a large *insider* sets up his 10b5-1 plan to trade the stock at $t = 1$. The trading plan is a market order of D_I shares of the stock. The insider has two trading motives. The first is re-balancing (hedging), which is modeled as the insider having an endowment of $\tilde{Z}$ units the stock, where $\tilde{Z} \sim N(0, \Sigma_z)$ (with $\Sigma_z > 0$) and $\tilde{Z}$ and $\tilde{f}$ are mutually independent. The insider privately observes the realization of $\tilde{Z}$ before setting up his trading plan. This formulation is meant to capture the fact that the insider has a large position in the stock and may need to adjust the holding for liquidity needs or diversification purposes, which are not observable to outside investors.

The second motive is based on his private information about the stock's fundamental value $\tilde{f}$. Specifically, we assume that $\tilde{f}$ consists of two components $\tilde{f}_a$ and $\tilde{f}_b$:

$$\tilde{f} = \rho \tilde{f}_a + \sqrt{1 - \rho^2}\, \tilde{f}_b, \tag{1}$$

where $\rho \in [0, 1)$ is a constant and where $\tilde{f}_a \sim N(0, 1)$, $\tilde{f}_b \sim N(0, 1)$, and $\tilde{f}_a$ and $\tilde{f}_b$ are mutually independent. The insider observes the value of $\tilde{f}_a$ at $t = 0$. Hence, the parameter ρ captures the amount of the insider's private information at the time when he sets up his trading plan.

The insider derives expected utility from his date-2 wealth according to a CARA utility function:

$$U(W_I) = -e^{-\gamma W_I}, \tag{2}$$

where γ is his absolute risk aversion, and W_I is his total wealth at time $t = 2$:

$$W_I = D_I(\tilde{f} - \tilde{p}) + \tilde{Z}\tilde{f}, \tag{3}$$

where $\tilde{p}$ is the stock price that will be determined when the insider's trade is executed at $t = 1$. Thus, the insider's date-0 decision problem is:

$$\max_{D_I} \mathbb{E}\left[U(W_I)\middle|\tilde{f}_a, \tilde{Z}\right]. \tag{4}$$

We make two remarks about the insider's behavior. First, the insider's trading plan utilizes his private information $\tilde{f}_a$. Although, to be qualified for an affirmative defense against allegations of illegal insider trading, a 10b5-1 plan must be adopted at a time when the insider is not aware of material non-public information, it has been widely noted that trades under 10b5-1 plans are informed on average (see, e.g., Jagolinzer, 2009), and it is notoriously difficult for regulators and outside investors to detect insider trading.

Second, in practice, Rule 10b5-1 potentially grants an insider a selective termination option, and our analysis abstracts away this feature. Specifically, Rule 10b5-1 does not obligate an insider to execute his planned trade and thus, the insider can first establish a plan and then decides whether to implement it based on the arrival of new information in the future. In our model, there is only one round of trading and there is no new information arrival between the plan adoption time ($t = 0$) and the trading time ($t = 1$). So, the termination option is irrelevant in our model. In a more general setup with new information before the execution time, this termination-option would play a role. Note, however, that terminating a planned transaction is costly, because it could affect the defense that the plan has been "entered into in good faith and not as part of a plan or scheme to evade" insider trading laws and regulations.[6]

Outside investors are all price takers and consist of two types: *speculators* and *hedgers*. They all have the same preference as the insider. To examine information aggregation from speculators, we consider a continuum of differentially informed speculators, indexed on the interval $[0, 1]$. At $t = 1$, each speculator j possesses a private signal of the asset value, $\tilde{s}_j = \tilde{f} + \tilde{\delta}_j$, where $\tilde{\delta}_j$ is normally

[6] See, Larcker et al. (2021) for mroe discussion on this cancellable feature. Lenkey (2019) develops a model to investigate this termination-option of Rule 10b5-1 trading plan.

distributed with $\tilde{\delta}_j \sim N(0, \Sigma_\delta)$, and is independent of $\tilde{Z}$, $\tilde{f}$, and $\tilde{\delta}_l$ for $l \neq j$. At $t = 1$, speculator j trades $D_{S,j}$ shares of the stock to maximize the expected utility over his final wealth as follows:

$$\max_{D_{S,j}} \mathbb{E}\left[U(W_{S,j})\middle|F_{S,j}\right], \tag{5}$$

where $W_{S,j}$ is speculator j's wealth at time $t = 2$:

$$W_{S,j} = D_{S,j}(\tilde{f} - \tilde{p}),$$

and $F_{S,j}$ is speculator j's information set and will be described in detail in Section 2.1.

We assume that hedgers are identical and thus consider a representative hedger. The representative hedger has an endowment of $\tilde{u}$ shares of the stock, where $\tilde{u}$ is normally distributed $\tilde{u} \sim N(0, \Sigma_u)$ and is independent of $\tilde{Z}$, $\tilde{f}$, and $\tilde{\delta}_j$ for all j. At $t = 1$, the hedger privately observes the value of $\tilde{u}$ and purchases D_H shares of the stock to maximize his expected utility over his terminal wealth:

$$\max_{D_H} \mathbb{E}\left[U(W_H)\middle|F_H\right], \tag{6}$$

where W_H is the hedger's wealth at time $t = 2$:

$$W_H = D_H(\tilde{f} - \tilde{p}) + \tilde{u}\tilde{v},$$

and F_H is the hedger's information set and will be described in detail in Section 2.1.

As usual, the market marker is risk neutral and at $t = 1$, he sets the market price to his expected fundamental value:

$$\tilde{p} = \mathbb{E}\left[\tilde{f} \;\middle|F_M\right], \tag{7}$$

where F_M is the market maker's information set and will be described in detail next.

2.1 Disclosure

As noted in Larcker et al. (2021), current regulations do not require insiders to disclose their 10b5-1 plans. One major regulatory proposal under consideration by the SEC is to require insiders to publicly disclose any initiation, modification, and cancellation of their 10b5-1 plans.[7] In our setup, this policy change alters the information sets of the speculators, the hedger, and the market maker.

Specifically, the disclosure regulation affects the information sets for forming expectations in (5), (6), and (7). Under the non-disclosure regime, the insider does not need to publicly disclose his trade D_I at $t = 0$. Hence, D_I is not in the information sets of all other traders in the market:

$$F_{S,j} = \{s_j\}, \quad F_H = \{\tilde{u}\}, \quad \text{and} \quad F_M = \{\tilde{\omega}\}, \tag{8}$$

where $\tilde{\omega}$ is the total order flow

$$\tilde{\omega} = D_H + \int_0^1 D_{S,j}\, dj + D_I. \tag{9}$$

Under the proposed new regime, however, the insider is required to publicly disclose his trading plan D_I at $t = 0$. Hence, outside investors' information sets become the following:

$$F_{S,j} = \{s_j, D_I\}, \quad F_H = \{\tilde{u}, D_I\}, \quad \text{and} \quad F_M = \{\tilde{\omega}, D_I\}. \tag{10}$$

2.2 Cooling-Off Period

Currently, there is no explicit requirement for a cooling-off period, the period between the initiation of a 10b5-1 plan and the execution of the first trade. For example, Larcker et al. (2021) find that one percent of the 10b5-1 plans begin trading on the plan adoption days. Moreover, their evidence suggests that a short cooling-off period is a "red flag" associated with opportunistic use of 10b5-1 plans: trades with short cooling-off periods have excess future returns while those with long ones do not. As a response, a regulatory change under consideration is to make the cooling-off period mandatory.

Given the nature of a corporate insider's job, it is almost unavoidable that, at any given point in time, he has more information on the firm's fundamental value than most outside investors. By imposing a mandatory cooling-off period, however, it reduces the insider's information advantage. Suppose that, for example, the insider receives encouraging news today about the development of a

[7] See, for example, the press release by the SEC in 2021: *SEC Proposes Amendments Regarding Rule 10b5-1 Insider Trading Plans and Related Disclosures*, https://www.sec.gov/news/press-release/2021-256.

new drug at its firm. If the insider can trade right away, he would have substantial advantage over outside investors. However, if there is a mandatory waiting period, by the time when the insider is allowed to trade, his information advantage is likely diminished because, during the cooling-off period, some of the information might reach outside investors or the firm may have to make a public announcement about the development. Hence, the longer the cooling-off period, the smaller the insider's information advantage would tend to be at the execution time.

In our model, the cooling-off period corresponds to the period from $t = 0$ (plan adoption time) to $t = 1$ (execution time). To capture the intuition described above, we assume that the duration of this period is inversely related to the insider's information advantage. That is, this duration is directly related to parameter ρ. With a longer cooling-off period, the insider tends to possess less private information at the adoption time $t = 0$ and hence the value of ρ is smaller.

To analyze the effects of disclosure and the cooling-off period, we construct the equilibria with and without disclosure in Sections 3.1 and 3.2, respectively. Then, in Section 4, we analyze the effects of these two policies.[8]

3 Equilibrium Characterization

3.1 Equilibrium under the Non-Disclosure Regime

Under the non-disclosure regime, the information sets of speculators, the hedger, and the market maker are summarized in equation (8). We conjecture and verify the following linear demand and price functions:

$$D_I = \alpha_f \tilde{f}_a + \alpha_Z \tilde{Z}, \tag{11}$$

$$D_{S,j} = \beta_S \tilde{s}_j, \tag{12}$$

$$D_H = \phi_H \tilde{u}, \tag{13}$$

$$\tilde{p} = \lambda_\omega \tilde{\omega}. \tag{14}$$

[8]We implicitly assume that the insider does not trade outside 10b5-1 plans. One possible reason is that the firm has reputation concerns and requires all senior managers to trade under 10b5-1 plans. Alternatively, the insider may choose to trade only under 10b5-1 plans if the benefits outweigh costs. An interesting question is whether the insider or the firm would adjust behaviors after the policy changes are implemented. For example, if the insider decides that the new policies make trading under 10b5-1 plans too costly, he may decide to trade outside the plans. We leave this extension to future research.

That is, the equilibrium is determined by five parameters $\{\alpha_f, \alpha_Z, \beta_S, \phi_H, \lambda_\omega\}$, which are given in the following proposition.

Proposition 1. (Equilibrium characterization: Non-disclosure regime) *In the non-disclosure economy described above, the coefficients* $\{\alpha_f, \alpha_Z, \beta_S, \phi_H, \lambda_\omega\}$ *of the linear equilibrium in* (11)–(14) *are characterized as follows:*

$$\alpha_f = \gamma^{-1}(1-n)^{-1}M^{-1}(n-m)\rho, \tag{15}$$

$$\alpha_Z = -\alpha_f \gamma(1-\rho^2)\rho^{-1} \tag{16}$$

$$\beta_S = \gamma^{-1}M^{-1}, \tag{17}$$

$$\phi_H = \frac{m\rho^2 + n(1-\rho^2)}{N-(1-n)M - m\rho^2 - n(1-\rho^2)}, \tag{18}$$

$$\lambda_\omega = \gamma(1-n)M, \tag{19}$$

where

$$M \equiv 1 + \Sigma_\delta - m\rho^2 - n(1-\rho^2), \tag{20}$$

$$N \equiv m(1-m)\rho^2 + n(1-n)(1-\rho^2) - \gamma^2(1-\rho^2)^2\Sigma_z(n-m)^2. \tag{21}$$

The two parameters $m \in (0,1)$ *and* $n \in (0,1)$ *are determined by the following equations:*

$$(n-m)\left[N + 2(1-n)M + n^2(1-\rho^2))\right] = n(1-n)M, \tag{22}$$

$$(1-n)^2\gamma^2M^2\Sigma_u(m\rho^2 + n(1-\rho^2))^2 = N\left(N-(1-n)M - m\rho^2 - n(1-\rho^2)\right)^2. \tag{23}$$

The above proposition characterizes all five parameters for the equilibrium. Its proof, reported in Appendix A, shows that $\alpha_f > 0$ and $\alpha_Z < 0$. That is, the insider's demand for the stock is higher if his private information is more positive and has less endowment to hedge. The signs of other parameters are also intuitive: $\beta_S > 0$, i.e., speculators increase their demand if their signals are higher; $\phi_H < 0$, i.e., the hedger demands less of the stock if he already has more of the stock in his endowments; and $\lambda_\omega > 0$, i.e., when the aggregate order is larger, it implies a higher fundamental value for the stock and hence the market maker raises the price.

Moreover, the proposition shows that the equilibrium is fully determined by two parameters, m and n, which are the solutions to the two polynomial equations (22) and (23). With m and n, we can fully pin down the parameters for the equilibrium $\{\alpha_f, \alpha_Z, \beta_S, \phi_H, \lambda_\omega\}$. Hence, the existence and uniqueness of the equilibrium are determined by the properties of the solutions to equations (22) and (23). The following corollary examines this issue for two special cases.

Corollary 1. *In the non-disclosure economy, its linear equilibrium has the following properties:*

(1) *If Σ_z or Σ_u is sufficiently large, there exists a unique equilibrium.*

(2) *If γ is sufficiently small, there is no equilibrium.*

Intuitively, Σ_z and Σ_u represent the hedging needs of the insider and the hedger, respectively. Due to hedging needs, they are willing to trade in the stock market, even if they expect informed counterparties and trading losses on average. If either is large enough, the hedging needs are strong enough to sustain an equilibrium. By the same logic, if the risk aversion γ is sufficiently small, there is not enough risk sharing motive to sustain an equilibrium.

3.2 Equilibrium under the Disclosure Regime

Under the disclosure regime, the information sets of speculators, the hedger, and the market maker are given by (10). We conjecture and verify the following linear demand and price functions in the equilibrium with advance disclosure:

$$D_I^* = \alpha_f^* \tilde{f}_a + \alpha_Z^* \tilde{Z}, \tag{24}$$

$$D_{S,j}^* = \beta_S^* \tilde{s}_j + \beta_I^* D_I^*, \tag{25}$$

$$D_H^* = \phi_H^* \tilde{u} + \phi_I^* D_I^*, \tag{26}$$

$$\tilde{p}^* = \lambda_O^* \left[\beta_S^* \tilde{f} + \phi_H^* \tilde{u} \right] + \lambda_I^* D_I^*. \tag{27}$$

That is, the equilibrium is determined by eight parameters $\{\alpha_f^*, \alpha_Z^*, \beta_S^*, \beta_I^*, \phi_H^*, \phi_I^*, \lambda_O^*, \lambda_I^*\}$. We use superscript "$*$" to denote these parameters for the disclosure equilibrium to distinguish from those for the non-disclosure equilibrium. Relative to the non-disclosure equilibrium, which is determined by five parameters, there are three additional parameters for the disclosure equilibrium, because the speculators' and the hedger's demand functions and the price function depend on the insider's trade size D_I^*.

Since the market maker can observe the order from the insider and the total order from outside investors separately, he sets the stock price according to both. To see this separation, we can rewrite equation (27) as follows:

$$\tilde{p}^* = \lambda_O^* \left(D_H^* + \int_0^1 D_{S,j}^* dj \right) + \Big(\lambda_I^* - \lambda_O^* (\beta_I^* + \phi_I^*) \Big) D_I^*. \tag{28}$$

That is, λ_O^* is the stock price sensitivity to the total order flows from the outside investors and $\Big(\lambda_I^* - \lambda_O^*(\beta_I^* + \phi_I^*)\Big)$ is the sensitivity to the insider's order. We prefer to write the price function in the form of equation (27) because λ_I^* captures the overall price impact of the insider's order. The direct effect is that the market maker adjusts the stock price to the insider's order D_I^*. Indirectly, the insider's order D_I^* affects the order flows from the speculators and the hedger ($D_{S,j}^*$ and D_H^*), which then affect the stock price as highlighted in equation (28).

The following proposition characterizes the equilibrium under the disclosure regime.

Proposition 2. (Equilibrium characterization: Disclosure regime) *In the economy with disclosure, the coefficients* $\{\alpha_f^*, \alpha_Z^*, \beta_S^*, \beta_I^*, \phi_H^*, \phi_I^*, \lambda_O^*, \lambda_I^*\}$ *of the linear equilibrium* (24)–(27) *are characterized as follows:*

$$\alpha_f^* = \gamma^{-1}(k_1 - \rho^2 k n^*)^{-1} \left(k - \rho^2\right) \rho, \tag{29}$$

$$\alpha_Z^* = -\alpha_f^* \gamma (1 - \rho^2) \rho^{-1}, \tag{30}$$

$$\beta_S^* = (1 - n^*)(\lambda_O^*)^{-1}, \tag{31}$$

$$\beta_I^* = -\beta_S^* \gamma \cdot (k_1 - \rho^2 k n^*)(1 + \rho^{-2} k)^{-1} \left(k - \rho^2\right)^{-1}, \tag{32}$$

$$\phi_H^* = -(n^*)^{-1} \left[1 - n_0^* \Sigma_u^{-1/2} \gamma^{-1} k_1^{-1/2} (\rho^2 + k)^{\frac{1}{2}} \right], \tag{33}$$

$$\phi_I^* = 0, \tag{34}$$

$$\lambda_O^* = (n^*)^2 \cdot \left[\Sigma_u^{1/2} (n_0^*)^{-1} k_1^{-\frac{1}{2}} (\rho^2 + k)^{\frac{1}{2}} - \gamma^{-1} (\rho^2 + k) k_1^{-1} \right]^{-1}, \tag{35}$$

$$\lambda_I^* = \gamma n^* (k_1 - \rho^2 k n^*)(1 + \rho^{-2} k)^{-1} \left(k - \rho^2\right)^{-1}, \tag{36}$$

where

$$k = \gamma^2(1-\rho^2)^2\Sigma_z, \quad k_1 = k + \rho^2(1-\rho^2), \textit{ and } \quad k_2 = k_1(1+\Sigma_\delta) + \rho^4\Sigma_\delta. \tag{37}$$

The constant n^* *is given by* $n^* = (1+(n_0^*)^2)^{-1}$, *where* n_0^* *is the positive root of the following quartic equation:*

$$x^4 - \gamma\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2+k)^{-\frac{1}{2}} \cdot x^3 + (\rho^2+k)\Sigma_\delta k_2^{-1} \cdot x^2 - \gamma\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}}\Sigma_\delta k_2^{-1} \cdot x + k_1 k_2^{-1} = 0. \tag{38}$$

The above proposition characterizes all eight parameters for the equilibrium. For those four that have clear counterparts in the equilibrium without disclosure, $\{\alpha_f^*, \alpha_Z^*, \beta_S^*, \phi_H^*\}$, their signs are the same as those of their counterparts. The other four parameters reveal new intuitions for the economy with disclosure. Appendix A shows that both λ_O^* and λ_I^* are positive. That is, the stock price is increasing in both the insider's order D_I^* and the total order from outside investors, which is natural since a larger order increases the market maker's expected fundamental value.

Interestingly, equations (32) and (34) show that $\beta_I^* < 0$ and $\phi_I^* = 0$. That is, a speculator's demand is decreasing in the insider's order D_I^* and the hedger's demand is independent of it. The intuition is as follows. Suppose the insider discloses a higher demand D_I^*. On the one hand, this increases the hedger's expected fundamental value and hence his demand (expectation effect). On the other hand, this also increases the market maker's expectation and hence, as shown in equation (27), the stock price (price effect). Note that, relative to the market maker, the hedger does not have additional information on the fundamental value. Hence, those two effects cancel out each other, thereby making the hedger's demand independent of D_I^*. The intuition for a speculator's demand is similar. Since a speculator has private information on the fundamental value, his expectation responds less to the information in D_I^*, leading to a smaller expectation effect. Hence, the price effect dominates and a higher D_I^* leads to a lower demand from speculators.

The above proposition also shows that the entire equilibrium is fully determined once we obtain the value of parameter n^*. Hence, the existence and uniqueness of the equilibrium is determined by the properties of equation (38), as summarized in the following corollary.

Corollary 2. *In the economy with disclosure, its linear equilibrium has the following properties:*

(1) *If* $\Sigma_z > \gamma^{-2}\rho^2(1-\rho^2)^{-2}$ *and* $\Sigma_u > 4\gamma^{-2}\Sigma_\delta^{-1}$*, there exists a unique equilibrium.*

(2) *If* $\Sigma_z \leq \gamma^{-2}\rho^2(1-\rho^2)^{-2}$ *or* $\Sigma_u \leq \hat{\Sigma}_u$*, there is no equilibrium, where*

$$\hat{\Sigma}_u \equiv \frac{\sqrt{(1-k_1k_2^{-1})^2 + 16kk_2^{-1}} + k_1k_2^{-1} - 1}{2\gamma^2 k_1(\rho^2+k)^{-1}}.$$

The first result shows that if both the insider and the hedger have sufficiently large hedging needs, it would sustain a unique equilibrium. The second result offers one example, whereby either the insider or the hedger's need is small enough, a market equilibrium fails to exist.

4 Policy Assessment

With the non-disclosure and disclosure equilibria given by Propositions 1 and 2, we can now evaluate the two policy proposals: mandatory disclosure and cooling-off periods. Specifically, we examine the implications of these two policies on the efficiency and liquidity of the market, as well as investor welfare. In order to conduct these assessments, we first construct our measures of market efficiency, market liquidity, and investor welfare for the economies with and without disclosure.

4.1 Measures

Market efficiency (price informativeness). In our model, the informational efficiency of the stock market is captured by price informativeness, which is defined as follows:

$$EFF \equiv \left(Var(\tilde{f}|\tilde{p})\right)^{-1}, \tag{39}$$

$$EFF^* \equiv \left(Var(\tilde{f}|\tilde{p}^*)\right)^{-1}, \tag{40}$$

where EFF and EFF^* are price informativeness in the economies with and without disclosure, respectively. Using Propositions 1 and 2, we obtain the following corollary.

Corollary 3. *The price informativeness under the two regimes is given by*

$$EFF = (\rho^2 m + (1-\rho^2)n)^{-1}, \tag{41}$$

$$EFF^* = (n^*)^{-1}k_1^{-1}(\rho^2+k). \tag{42}$$

Market liquidity. In the economy without disclosure, the stock market illiquidity (Kyle's lambda) can be measured by λ_ω, which is given by (19). In the economy with disclosure, the stock market illiquidity is captured by two measures, λ_O^* and λ_I^*, which are given by 35 and 36, respectively. The former is the stock price sensitivity to the total order flow from outside investors, while the latter is the price sensitivity to the insider's order flow.

Investor welfare. Since the market maker always breaks even in equilibrium, we focus on the welfare of the three types of investors. Specifically, we use CE_I, CE_H, and $CE_{S,j}$ to denote the certainty equivalents for the insider, the hedger, and speculator j, respectively, in the non-disclosure equilibrium. That is, we have

$$U(CE_I) = \mathbb{E}\left[U(W_I)|\tilde{Z}, \tilde{f}_a\right], \tag{43}$$

$$U(CE_H) = \mathbb{E}\left[U(W_H)|\tilde{u}\right], \tag{44}$$

$$U(CE_{S,j}) = \mathbb{E}\left[U(W_{S,j})|\tilde{s}_j\right]. \tag{45}$$

Similarly, we use CE_I^*, CE_H^*, and $CE_{S,j}^*$ to denote the certainty equivalents for the insider, the hedger, and speculator j, respectively, in the disclosure equilibrium:

$$U(CE_I^*) = \mathbb{E}\left[U(W_I^*)|\tilde{Z}, \tilde{f}_a\right], \tag{46}$$

$$U(CE_H^*) = \mathbb{E}\left[U(W_H^*)|\tilde{u}, D_I^*\right], \tag{47}$$

$$U(CE_{S,j}^*) = \mathbb{E}\left[U(W_{S,j}^*)|\tilde{s}_j, D_I^*\right]. \tag{48}$$

Note that an investor's certainty equivalent is a function of its signals. For example, CE_I is a function of the insider's signals: $\tilde{Z}$ and $\tilde{f}_a$. To evaluate an investor's welfare, following Morris and Shin (2002) and Van Nieuwerburgh and Veldkamp (2010), we compute the ex ante expectations of those certainty equivalents in the following corollary.

Corollary 4. *The ex ante expectations of the certainty equivalents in the two economies are*

$$\mathbb{E}[CE_I] = -\frac{1}{2}\gamma(1-\rho^2)(1+\alpha_Z n)\cdot\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\cdot\alpha_Z n, \tag{49}$$

$$\mathbb{E}[CE_I^*] = -\frac{1}{2}\gamma(1-\rho^2)(1+\alpha_Z^* n^*)\cdot\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\cdot\alpha_Z^* n^*, \tag{50}$$

$$\mathbb{E}[CE_{S,j}] = \frac{1}{2}(m\rho^2 + n(1-\rho^2))\beta_S, \tag{51}$$

$$\mathbb{E}[CE_{S,j}^*] = \frac{1}{2}k_1(\rho^2+k)^{-1}n^*\beta_S^*, \tag{52}$$

$$\mathbb{E}[CE_H] = \frac{1}{2}\gamma\left[-1-\phi_H(m\rho^2+n(1-\rho^2)+\gamma^{-1}\lambda_\omega\phi_H)\right]\Sigma_u, \tag{53}$$

$$\mathbb{E}[CE_H^*] = \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2k_1(\rho^2+k)^{-1}-1\right]\Sigma_u. \tag{54}$$

With the above measures of market efficiency, market liquidity, and investor welfare, we can analyze the implications from the two policy proposals: mandatory disclosure and cooling-off periods. For example, to evaluate the effect of mandatory disclosure on the hedger's welfare, we can compare $\mathbb{E}[CE_H]$ and $\mathbb{E}[CE_H^*]$. In evaluating the implication of a cooling-off period, we explore the intuition that a longer cooling-off period leads to less information advantage for the insider. Accordingly, we assume that ρ is decreasing in the length of the cooling-off period and it is the only variable that the cooling-off period length affects.[9] Hence, to evaluate the implications of a longer cooling-off period, we can simply examine the effect of decreasing ρ on the two equilibria. Finally, since all speculators are ex ante identical, as shown in equations (51) and (52), we can remove the subscript "j" and use $\mathbb{E}[CE_S]$ and $\mathbb{E}[CE_S^*]$ to denote the ex ante expected certainty equivalents of a speculator in the economy without and with disclosure, respectively.

Finally, it is useful to define notations for the expected trading profits for each type of investors. Let π_I, π_S, and π_H be the expected trading profits of the insider, speculators, and the hedger, respectively, in the non-disclosure economy and π_I^*, π_S^*, and π_H^* be their counterparts in the disclosure economy.

In the following, to illustrate the intuition behind our results, we will first focus on two special cases in which we can obtain results analytically: (1) Section 4.2 examines the case in which the

[9] In principle, one can imagine that the cooling-off period can also affect the insider's hedging activity. With a long cooling-off period, the insider has limited information about his hedging demand when he commits his trading plan. It is straightforward to introduce this additional cost to our model. We focus on the effect on the insider's private information for clarity.

insider has a significant hedging need (i.e., Σ_z is sufficiently large); (2) Section 4.3 examines the case in which the hedger has a significant hedging need (i.e., Σ_u is sufficiently large). We then analyze the more general case numerically in Section 4.4.

4.2 Case I: The Insider Has a Large Hedging Need

Disclosure. The following proposition reports the implications of the disclosure policy when the insider's hedging need Σ_z is large.

Proposition 3. (Disclosure) *If Σ_z is sufficiently large, disclosure has the following implications:*

(1) *All investors are worse off: $\mathbb{E}[CE_I^*] < \mathbb{E}[CE_I]$, $\mathbb{E}[CE_S^*] < \mathbb{E}[CE_S]$, and $\mathbb{E}[CE_H^*] < \mathbb{E}[CE_H]$.*

(2) *It increases the insider's expected trading profit but decreases the outside investors' expected trading profits: $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$.*

(3) *It improves the informational efficiency of the stock price: $EFF^* > EFF$.*

(4) *It decreases the market liquidity for outside investors: $\lambda_O^* > \lambda_\omega$. Moreover, under the condition $|\rho| \leq 1/\sqrt{2}$, it improves the market liquidity for the insider: $\lambda_\omega > \lambda_I^*$.*

The result that a mandatory disclosure policy makes all investors worse off is surprising for two reasons. First, the disclosure partially reveals the insider's private information and hence one might expect outside investors (hedgers and speculators) to be better off. Indeed, this intuition is likely to be the motivation for the SEC's consideration of the mandatory disclosure policy. However, the proposition shows that this is not the case. Second, the result that the insider is also worse off from disclosure is, perhaps, even more surprising given the insight on "sunshine trading" from Admati and Pfleiderer (1991). Specifically, when Σ_z is large, the insider's overall trade is mostly uninformed due to his large hedging need. As demonstrated in Admati and Pfleiderer (1991), in this case, disclosing the insider's trade tends to reduce his trading cost. Hence, one might naturally expect the disclosure to improve the insider's welfare. However, the conclusion in Proposition 3 is exactly the opposite.

What is the intuition behind these surprising results? Let us first consider the case for the insider. Note that the sunshine trading intuition in Admati and Pfleiderer (1991) concerns trading profits and it continues to hold in our model. Result (2) of Proposition 3 shows that consistent with the intuition on sunshine trading, disclosure identifies the insider's trade as mostly informationless and hence increases his expected trading profit.

How does the disclosure decrease the insider's welfare despite a higher expected trading profit? It turns out that the result is due to the Hirshleifer effect (Hirshleifer, 1971). Specifically, as shown in result (3) of Proposition 3, under the disclosure regime, the stock price reveals more information about the fundamental value. The intuition is as follows. When the insider's hedging need Σ_z is large, the insider's order is primarily informationless and works as endogenous noise trading to the market maker. Under the non-disclosure regime, the order flows of outsider investors, in particular of the informed speculators, are mixed with the insider's uninformed order flow and thus, the market maker cannot infer much of the fundamental information from the total order flow. By contrast, under the disclosure regime, outsiders' order flows can no longer hide behind the insider's uninformed order flow, which in turn facilitates the market maker's inference. Thus, disclosure improve price informativeness. As pointed out by Hirshleifer (1971), revelation of information reduces risk sharing opportunities. Recall that the insider has a strong hedging need in this case. The reduced efficacy of risk sharing makes the insider worse off despite his higher expected trading profit.

Why does disclosure make outside investors worse off in result (1) of Proposition 3? A casual intuition is that disclosure partially reveals the insider's information, and hence one would expect it to benefit outside investors. However, this intuition is incomplete. As noted earlier, disclosure increases the insider's expected trading profit. This reduces the total expected trading profits for outside investors since the market maker's breaking-even pricing rule implies that the total profit of the insider and outsider investors must be zero. Indeed, result (2) shows that disclosure reduces the expected trading profits of both speculators and the hedger.

For speculators, as noted previously, disclosure reveals his information more effectively, reducing his expected trading profits. To see the intuition for the hedger, note that he has a larger price impact, which leads to a lower expected trading profit, under the disclosure regime. As discussed above, with disclosure, the market maker observes the insider's trading order and the total order from outside investors separately, and sets the stock price based on both. Hence, the insider and outside investors face different market liquidity conditions. As shown in result (4) of Proposition 3, when the insider's hedging need is large, disclosure increases outside investors' price impact (i.e.

reduces their liquidity).

Specifically, under the non-disclosure regime, outsider investors' orders are mixed with the insider's, which is mostly uniformed in this case. Hence, outsiders' trades have little price impact. Under the disclosure regime, however, outsiders' orders can no longer hide behind the insider's, and hence have a larger price impact: $\lambda_O^* > \lambda_\omega$. How about the insider? When the insider's trade is mostly informationless, as suggested by the sunshine trading intuition, disclosure reduces his price impact and improves market liquidity faced by him: $\lambda_I^* < \lambda_\omega$.[10]

Cooling-off period. What are the implications of a longer cooling-off period? Intuitively, the insider has less information about the fundamental value when the cooling-off period is longer (i.e., ρ is smaller). Its implications depend on whether the insider discloses his trading plan and are summarized in the following proposition.

Proposition 4. (Cooling-off period) *If Σ_z is sufficiently large, the effects of a longer cooling-off period are as follows:*

(1) *Under the non-disclosure regime, all investors are better off, the stock market is less efficient but more liquid. That is,*

$$\frac{\partial \mathbb{E}[CE_I]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_S]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_H]}{\partial \rho} < 0, \tag{55}$$

$$\frac{\partial EFF}{\partial \rho} > 0, \quad \frac{\partial \lambda_\omega}{\partial \rho} > 0. \tag{56}$$

(2) *Under the disclosure regime, outside investors are better off, the insider is worse off, and the price is less efficient. The insider's price impact is smaller and outsiders' price impact is larger. That is,*

$$\frac{\partial \mathbb{E}[CE_I^*]}{\partial \rho} > 0, \quad \frac{\partial \mathbb{E}[CE_S^*]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_H^*]}{\partial \rho} < 0, \tag{57}$$

$$\frac{\partial EFF^*}{\partial \rho} > 0, \quad \frac{\partial \lambda_I^*}{\partial \rho} > 0, \quad \frac{\partial \lambda_O^*}{\partial \rho} < 0. \tag{58}$$

The proposition shows that under both regimes, a longer cooling-off period implies lower stock price efficiency. This is because a longer cooling-off period implies that the insider has less private

[10] Although we obtain the inequality $\lambda_\omega > \lambda_I^*$ under the condition $|\rho| \leq 1/\sqrt{2}$. It holds generally in our numerical analysis.

information when setting up his trading plan. Hence, less information is incorporated into the stock price, leading to lower efficiency.

The proposition also shows that, under both regimes, outside investors (the hedger and speculators) benefit from a longer cooling-off period. Intuitively, a longer cooling-off period has two effects. First (information effect), it implies less private information for the insider. This is beneficial for outside investors but detrimental to the insider. Second (Hirshleifer effect), the stock price reveals less information, which improves the risk-sharing opportunities for all investors. Since outside investors benefit from both effects, the welfare implication is clear cut. A longer cooling-off period increases outside investors' welfare.

For the insider, however, these two effects work in opposite directions and the overall effect depends on the trade-off between the two. Under the non-disclosure regime, the Hirshleifer effect dominates and hence a longer cooling-off period increases the insider's welfare. In contrast, under the disclosure regime, the information effect dominates and a longer cooling-off period decreases the insider's welfare. The reason is that, under the disclosure regime, the insider's trading order is separated from the more informed orders of outside investors. Hence, the insider has a smaller price impact and can benefit from his private information more effectively.

The above intuition also sheds light on the implications for market liquidity. Under the non-disclosure regime, a longer cooling-ff period implies less private information for the insider, which leads to a smaller price impact and higher market liquidity ($\frac{\partial \lambda_\omega}{\partial \rho} > 0$). Under the disclosure regime, however, a longer cooling-off period reduces the insider's price impact ($\frac{\partial \lambda_I^*}{\partial \rho} > 0$). Since the stock price is less informative, it responds more to the total order from outside investors ($\frac{\partial \lambda_O^*}{\partial \rho} < 0$).

In the above analysis, the insider's hedging need plays a dominant role (i.e., Σ_z is sufficiently large). Hence, the insider's trade is less informed than the trades from outside investors. While this might be the case for some insiders, as suggested by the empirical evidence (e.g., Jagolinzer, 2009), the trades from many insiders are likely informed. Hence, to examine if the above implications hold more generally, we consider cases in which the insider's hedging need is not dominant (i.e., Σ_z is not overwhelmingly large). In the next subsection, we analyze the case in which the outside investors' hedging need (i.e., Σ_u) is sufficiently large. Finally, Section 4.4 considers the case in which neither the insider nor outside investors' hedging needs dominate (i.e., both Σ_z and Σ_u are moderate).

4.3 Case II: The Hedger Has a Large Hedging Need

Disclosure. The following proposition summarizes the implications of the disclosure policy when the hedger's hedging need Σ_u is large.

Proposition 5. (Disclosure) *If Σ_u is sufficiently large, disclosure has the following implications:*

(1) *All investors are worse off: $\mathbb{E}[CE_I^*] < \mathbb{E}[CE_I]$, $\mathbb{E}[CE_S^*] < \mathbb{E}[CE_S]$, and $\mathbb{E}[CE_H^*] < \mathbb{E}[CE_H]$.*

(2) *It improves the informational efficiency of the stock price: $EFF^* > EFF$.*

(3) *It improves the market liquidity for outside investors, but decreases the market liquidity for the insider: $\lambda_O^* < \lambda_\omega < \lambda_I^*$.*

The above proposition shows that, as in the case in Proposition 3, disclosure makes all investors worse off. However, the underlying intuition is different. In this case, the insider no longer has a large hedging need. Hence, disclosure reveals his private information more effectively, leading to higher informational efficiency $EFF^* > EFF$. Note that the hedger has a large liquidity need in this case. Hence both the insider and speculators can exploit their information advantage effectively under the non-disclosure regime. Under the disclosure regime, however, both are worse off since the stock price reveals a large amount of information. Similar to the intuition in Proposition 3, the information revelation reduces the risk-sharing opportunity and the hedger's welfare.

Finally, under the disclosure regime, the insider's order is no longer mixed with outside investors' total order, which is mostly informationless (in the case with a large Σ_u). Hence, the insider's trade has a larger price impact: $\lambda_I^* > \lambda_\omega$. Similarly, outside investors have a smaller price impact $\lambda_O^* < \lambda_\omega$ because the insider's order, which is relatively more informed, is set apart under the disclosure regime.

Cooling-off period. The effects of a cooling-off period are summarized in the next proposition.

Proposition 6. (Cooling-off period) *If Σ_u is sufficiently large, the effects of a longer cooling-off period are as follows:*

(1) *Under the non-disclosure regime, outside investors are better off, the insider is worse off, and*

the stock market is more liquid but the price is less efficient. That is,

$$\frac{\partial \mathbb{E}[CE_I]}{\partial \rho} > 0, \quad \frac{\partial \mathbb{E}[CE_S]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_H]}{\partial \rho} < 0, \tag{59}$$

$$\frac{\partial EFF}{\partial \rho} > 0, \quad \frac{\partial \lambda_\omega}{\partial \rho} > 0. \tag{60}$$

(2) *Under the disclosure regime, all investors better off and the price is less efficient. The insider's price impact is smaller and outsiders' price impact is larger. That is,*

$$\frac{\partial \mathbb{E}[CE_I^*]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_S^*]}{\partial \rho} < 0, \quad \frac{\partial \mathbb{E}[CE_H^*]}{\partial \rho} < 0, \tag{61}$$

$$\frac{\partial EFF^*}{\partial \rho} > 0, \quad \frac{\partial \lambda_I^*}{\partial \rho} > 0, \quad \frac{\partial \lambda_O^*}{\partial \rho} < 0. \tag{62}$$

Consistent with the implications in the previous subsection, under both regimes, if the cooling-off period is longer, outside investors are better off and the stock price is less efficient. The implications on market liquidity also remain the same as those in Proposition 4.

However, the welfare implications for the insider is different from those in the previous subsection. Specifically, under the non-disclosure regime, a longer cooling-off period reduces the insider's welfare. This is the opposite of the result in Proposition 4. However, the underlying driving forces remain the same, namely the information effect and the Hirshleifer effect. Note that outside investors have a large hedging need in this case. Under the non-disclosure regime, the insider's order is mixed with those from outside investors. Hence, the insider can effectively benefit from his private information and the information effect dominates. A longer cooling-off period reduces the insider's information advantage and hence welfare. Under the disclosure regime, however, the insider's private information is more effectively revealed, leading to a stronger Hirshleifer effect. Although a shorter cooling-off period gives the insider more information advantage, the information revelation in the market and the ensuing Hirshleifer effect are more than enough to negate the information advantage and hence reduce the insider's welfare.

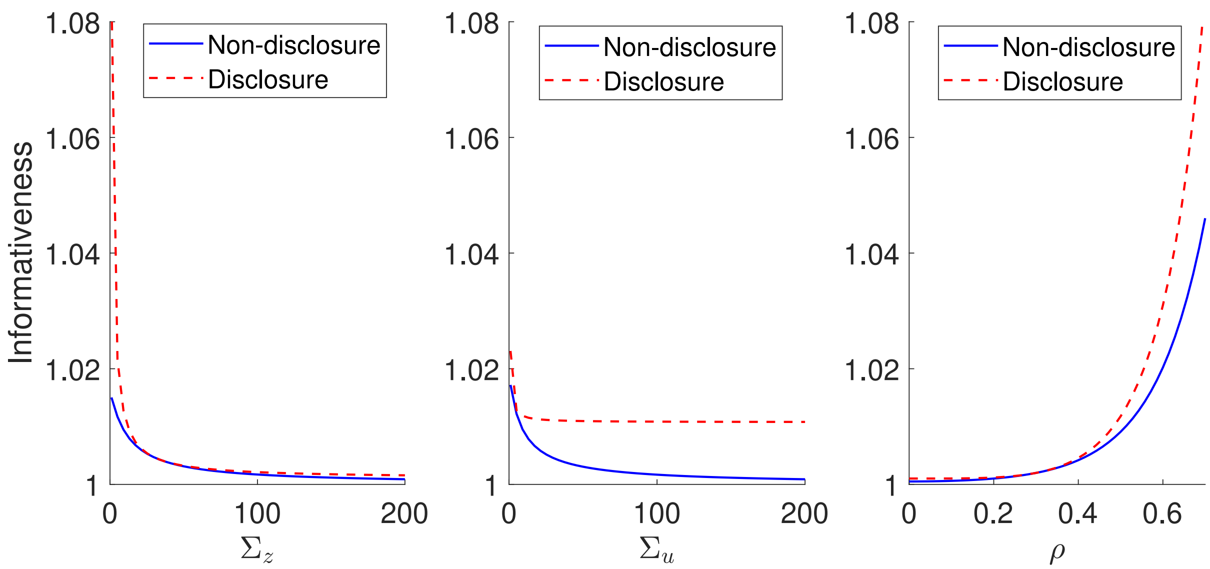
4.4 Case III: General Case

In the previous two subsections, we have considered cases in which either the insider's or the outside hedger's hedging need dominates. In this subsection, we consider cases in which both hedging needs are modest. To obtain the equilibria under the two regimes numerically, we set the following parameter values in the baseline case: $\gamma = 1, \rho = 0.5,$ and $\Sigma_z = \Sigma_u = \Sigma_\delta = 10$. We then vary one or two parameters to examine their effects.

Our numerical analysis delivers two main messages. First, for the results that hold in both Cases I and II, they continue to hold in the current case. Second, when Cases I and II have opposite results, our numerical analysis provides a bridge connecting them. Specifically, our numerical results are consistent with those in Case I (Case II) if the insider's hedging need, Σ_z, is large (small) relative to the hedging need of the hedger, Σ_u.

Disclosure. To examine the effect of disclosure on stock price efficiency, we plot the informativeness measure under both regimes in Figure 2. Cases I and II show that if Σ_z or Σ_u is sufficiently large, the stock price informativeness is higher under the disclosure regime (Propositions 3 and 5). Figure 2 suggests that this result holds generally. The three panels plot informativeness against Σ_z, Σ_u, and ρ, respectively. They all show that the stock price informativeness under the disclosure regime is always higher than that under the non-disclosure regime.

Figure 2. Stock price informativeness.



This figure plots the price informativeness against the insider's private information precision ρ, his hedge variance Σ_z, and the hedger's variance Σ_u. The blue and red lines are for the non-disclosure and disclosure regimes, respectively. Parameter values: $\gamma = 1, \rho = 0.5, \Sigma_z = 10, \Sigma_u = 10$, and $\Sigma_\delta = 10$.

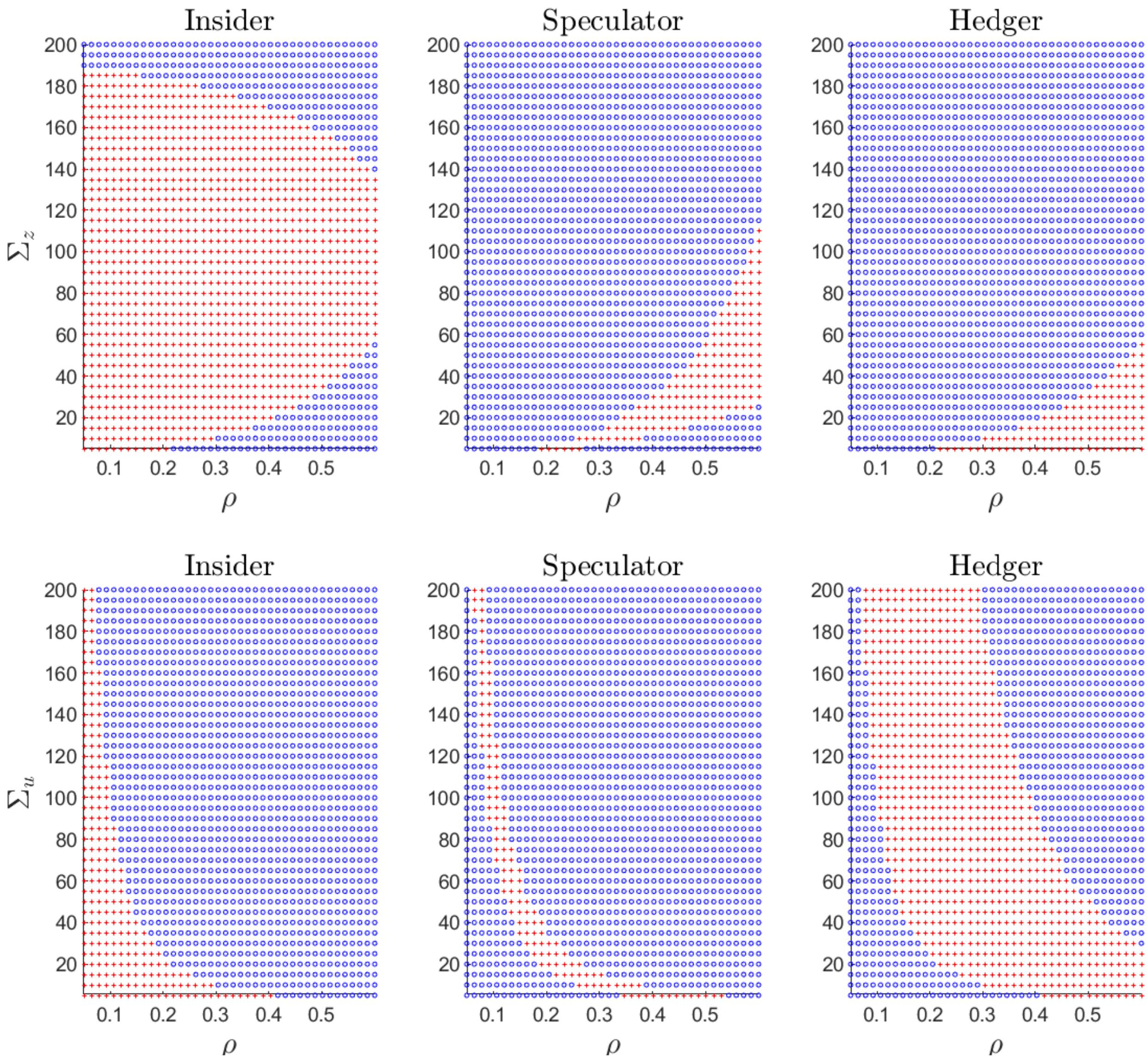
Figure 3 examines welfare implications. In each panel, we compare the welfare for a particular type of investor and use blue circles "∘" (red cross "+", respectively) to indicate the region where the investor's welfare is higher under the non-disclosure regime (under the disclosure regime, respectively).

The three panels in the top row examine welfare implications by varying the insider's information advantage, ρ, and hedging need, Σ_z. Proposition 3 shows that disclosure makes all investors worse off if Σ_z is sufficiently large. Consistent with this result, all three panels in the top row of Figure 3 are marked by blue circles (i.e., all three types of investors are worse off under the disclosure regime) for large values of Σ_z. If we reduce the value of Σ_z, welfare implications become mixed. For example, the left panel shows that the insider is better off (marked by the region with red cross +) under the disclosure regime, when his hedging need (i.e., Σ_z) is more modest, especially if he has less private information (i.e., smaller ρ). Intuitively, if the insider has little private information (i.e., ρ is small), he benefits from disclosure, as suggested by the intuition for sunshine trading. Note that, unlike in Proposition 3, the insider's hedging need (Σ_z) is modest in this case. Hence, the Hirshleifer effect is weaker and is dominated by the information effect. Interestingly, as shown by the lower right corner of the plot, if the insider has a large amount of private information but little hedging need, the effect from information revelation dominates and hence the disclosure reduces the insider's welfare. Moreover, if the price reveals a large amount of information from the insider, it reduces speculators' information advantage and the hedger's information disadvantage. Indeed, for the regions with large ρ and small Σ_z, the middle and right panels show that disclosure reduces speculators welfare but increases the hedger's welfare.

The three panels in the lower row of Figure 3 examine the welfare implications by varying the insider's information advantage, ρ, and the hedger's hedging need, Σ_u. Proposition 5 shows that disclosure makes all investors worse off if Σ_u is sufficiently large. Consistent with this result, the three panels show that all three types of investors are worse off under the disclosure regime for large values of Σ_u. If we reduce its value, welfare implications become mixed.

Cooling-off period. Propositions 4 and 6 show that, under the condition that either Σ_z or Σ_u is sufficiently large, a longer cooling-off period leads to lower stock price efficiency under both the disclosure and non-disclosure regimes. Consistent with these analytical results, the right panel of Figure 2 suggests that those conclusions also hold generally. It shows that under both regimes,

Figure 3. Disclosure and investor welfare.



This figure plots welfare comparisons under disclosure and non-disclosure regimes against the insider's information precision ρ, hedging needs Σ_z and Σ_u. The plots in the left, middle, and right columns are for the insider, a representative speculator, and the hedger, respectively. Blue circles "$\circ$" mark the region where the investor is worse off from disclosure, while red crosses "+" mark the region where the investor is better off. Parameter values: $\gamma = 1, \rho = 0.5, \Sigma_z = 10, \Sigma_u = 10$, and $\Sigma_\delta = 10$.

the stock price informativeness increases in ρ (i.e., decreases in the cooling-off period length).

How about the welfare implications? For outside investors, implications are the same in Cases I and II: a longer cooling-off period improves their welfare (Propositions 4 and 6). The numerical results in Figure 4 suggest that those results hold more generally. For example, the three panels in the middle column plot speculators' welfare against ρ. From top to bottom, the three panels are for the case with a large Σ_z, the case with a small Σ_z, and the case with a large Σ_u, respectively. They all show that speculators' welfare decreases with ρ under both the disclosure and non-disclosure regimes. That is, a longer cooling-off period (a smaller ρ) increases a speculator's welfare. The three panels in the right column show similar results for the hedger.

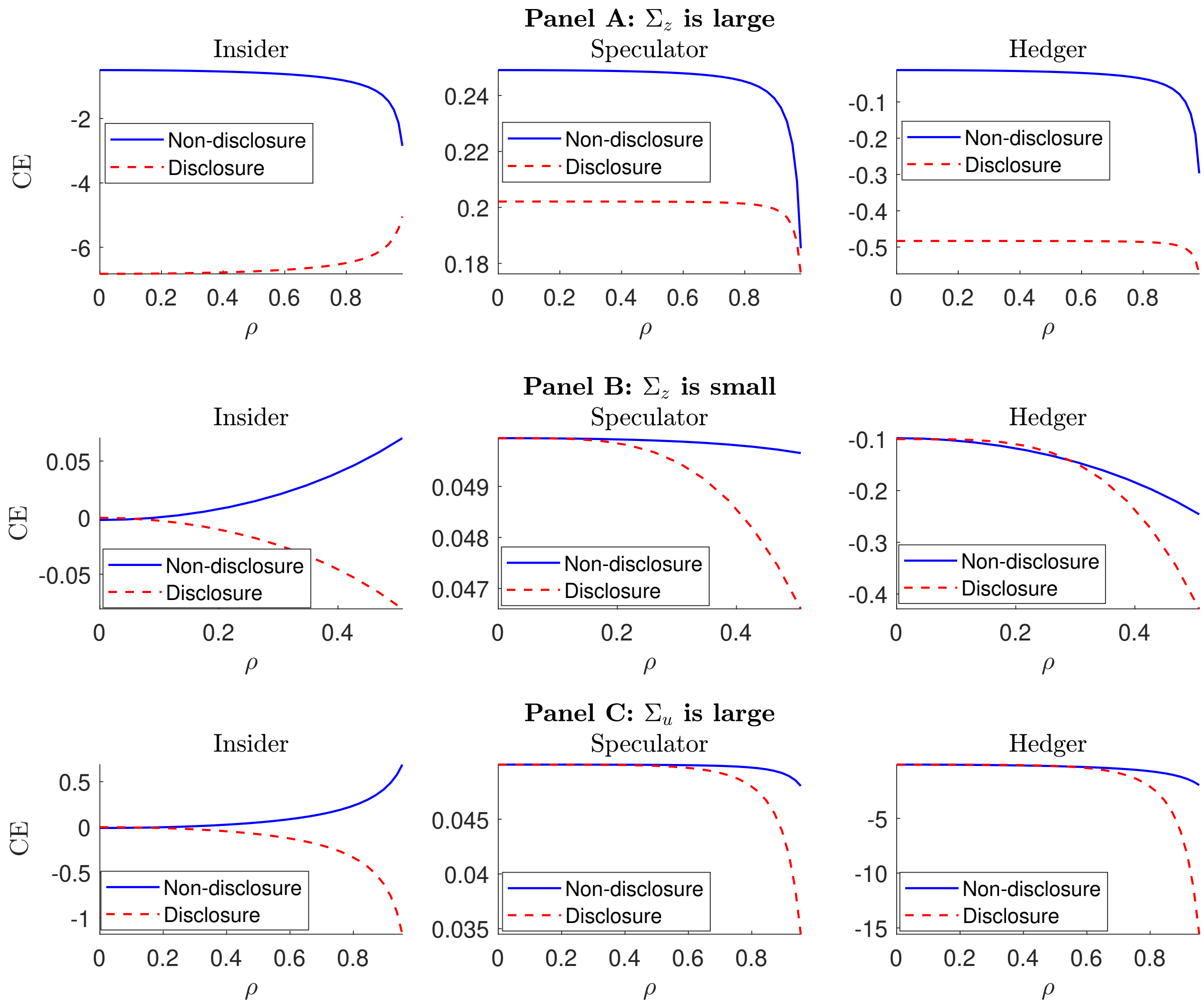
For the insider, the welfare implications in Cases I and II are the opposite of each other (Propositions 4 and 6). Our numerical results in the left column of Figure 4 reconcile those opposite results. The plot at the top is for the case with a large Σ_z, and it suggests that a longer cooling-off period increases the insider's welfare under the non-disclosure regime but decreases it under the disclosure regime. These results are consistent with Proposition 4, where Σ_z is overwhelmingly large. The intuition is also similar. The insider has a large hedging need in these cases and hence his trading order is highly uninformed relative to the trading orders from outside investors. When this condition changes, the above implications are reversed.

There are two ways to make the insider's trading order more informed relative to the trading order from outside investors: increasing the information in the insider's order or decreasing the information in the outside investors' order. These two cases are illustrated in the middle and bottom plots in the left column, respectively. The middle plot is for the case of a small Σ_z. The implications are indeed reversed. A longer cooling-off period decreases the insider's welfare under the non-disclosure regime but increases it under the disclosure regime. Similar results are obtained in the bottom plot, which is for the case of a large Σ_u, as shown in Proposition 6.

5 Conclusion

We analyze the implications of insider-trading regulations in a standard Kyle-type model, focusing on two features that are under the SEC's consideration: advance disclosure and cooling-off periods. The former requires an insider to make a public disclosure upon the adoption, modification, and

Figure 4. Cooling-off period and investor welfare.



The figure plots an investors' welfare (ex ante expected certainty equivalent) against the insider's information precision ρ. The plots in the left, middle, and right columns are for the insider, a representative speculator, and the hedger, respectively. The blue and red lines are for the non-disclosure and disclosure regimes, respectively. Parameter values: $\Sigma_z = 100$ and $\Sigma_u = 10$ in Panel A; $\Sigma_z = 0.2$ and $\Sigma_u = 10$ in Panel B; and $\Sigma_z = 10$ and $\Sigma_u = 100$ in Panel C. Other parameter values: $\gamma = 1$ and $\Sigma_\delta = 10$ in all three panels.

cancellation of his 10b5-1 trading plans. The latter mandates a delay period from the adoption of a 10b5-1 plan to the first execution under that plan.

We find that the disclosure improves stock price efficiency but its welfare implication is mixed. In particular, if the insider has large liquidity needs, in contrast to the conventional wisdom from "sunshine trading," disclosure reduces the welfare of all investors. A longer cooling-off period increases outside investors' welfare but decreases the stock price efficiency. Its implication for the insider's welfare depends on whether the mandatory disclosure policy is already in place. For example, in the case in which the insider's trading is more informed than outsiders', a longer cooling-off period decreases the insider's welfare under the non-disclosure regime, but increases it under the disclosure regime.

References

Admati, A. R., and P. Pfleiderer. 1991. Sunshine trading and financial market equilibrium. *The Review of Financial Studies* 4:443–481.

Ausubel, L. M. 1990. Insider trading in a rational expectations economy. *The American Economic Review* pp. 1022–1041.

Carré, S., P. Collin-Dufresne, and F. Gabriel. 2022. Insider trading with penalties. *Journal of Economic Theory* 203:105461.

DeMarzo, P. M., M. J. Fishman, and K. M. Hagerty. 1998. The optimal enforcement of insider trading regulations. *Journal of Political Economy* 106:602–632.

Dye, R. A. 1984. Inside trading and incentives. *Journal of Business* pp. 295–313.

Fishman, M. J., and K. M. Hagerty. 1992. Insider trading and the efficiency of stock prices. *The RAND Journal of Economics* pp. 106–122.

Glosten, L. R. 1989. Insider trading, liquidity, and the role of the monopolist specialist. *Journal of Business* pp. 211–235.

Hirshleifer, J. 1971. The private and social value of information and the reward to inventive activity. *The American Economic Review* 69:561–574.

Huddart, S., J. S. Hughes, and C. B. Levine. 2001. Public disclosure and dissimulation of insider trades. *Econometrica* 69:665–681.

Huddart, S. J., J. S. Hughes, and M. Williams. 2010. Pre-announcement of insiders' trades. *Available at SSRN 216168* .

Jagolinzer, A. D. 2009. SEC Rule 10b5-1 and insiders' strategic trade. *Management Science* 55:224–239.

Kacperczyk, M. T., and E. Pagnotta. 2020. Becker Meets Kyle: Legal Risk and Insider Trading. *Available at SSRN 3142006* .

Kyle, A. S. 1985. Continuous auctions and insider trading. *Econometrica: Journal of the Econometric Society* pp. 1315–1335.

Larcker, D. F., B. Lynch, P. Quinn, B. Tayan, and D. J. Taylor. 2021. Gaming the system: Three "Red Flags" of potential 10b5-1 abuse. *Stanford Closer Look Series (https://www.gsb.stanford.edu/sites/default/files/publication-pdf/cgri-closer-look-88-gaming-the-system.pdf)* .

Leland, H. E. 1992. Insider trading: Should it be prohibited? *Journal of Political Economy* 100:859–887.

Lenkey, S. L. 2014. Advance disclosure of insider trading. *The Review of Financial Studies* 27:2504–2537.

Lenkey, S. L. 2017. Insider trading and the short-swing profit rule. *Journal of Economic Theory* 169:517–545.

Lenkey, S. L. 2019. Cancellable insider trading plans: an analysis of SEC rule 10b5-1. *The Review of Financial Studies* .

Lenkey, S. L. 2021. Informed trading with a short-sale prohibition. *Management Science* 67:1803–1824.

Manne, H. G. 1966. *Insider trading and the stock market.* Free Press.

Manove, M. 1989. The harm from insider trading and informed speculation. *The Quarterly Journal of Economics* 104:823–845.

Medran, L. A., and X. Vives. 2004. Regulating insider trading when investment matters. *Review of Finance* 8:199–277.

Mele, A., and F. Sangiorgi. 2021. Insider trading regulation and market quality tradeoffs .

Morris, S., and H. S. Shin. 2002. Social value of public information. *american economic review* 92:1521–1534.

Van Nieuwerburgh, S., and L. Veldkamp. 2010. Information acquisition and under-diversification. *The Review of Economic Studies* 77:779–805.

Appendix A: Proofs

Proof of Proposition 1 for non-disclosure equilibrium: For notation simplicity, we denote

$$\tilde{X} = \rho \tilde{f}_a, \quad \text{and,} \quad \alpha_X = \rho^{-1}\alpha_f.$$

Under the postulated linear equilibrium (11)-(14), the total order flow and price are given by

$$\begin{aligned}
\tilde{\omega} &= D_I + \int_0^1 D_{S,j}\mathrm{d}_j + D_H = D_I + \beta_S \tilde{f} + \phi_H \tilde{u} = (\alpha_X + \beta_S)\rho \tilde{f}_a + \beta_S \sqrt{1-\rho^2}\tilde{f}_b + \alpha_Z \tilde{Z} + \phi_H \tilde{u}, \\
\tilde{p} &= \lambda_\omega \tilde{\omega} = \lambda_\omega \left(D_I + \beta_S \tilde{f} + \phi_H \tilde{u} \right).
\end{aligned}$$

In the following, we solve the insider, speculators and the hedger's optimal demands consequentially.

The insider's optimal demand: Based on the insider's information set $\{\tilde{X}, \tilde{Z}\}$ and normality, the maximization problem (4) is equivalent to

$$\max_{D_I} \qquad \gamma \mathbb{E}\left[W_I \middle| \tilde{X}, \tilde{Z} \right] - \frac{1}{2}\gamma^2 Var(W_I | \tilde{X}, \tilde{Z}). \tag{A1}$$

Using his information $\{\tilde{X}, \tilde{Z}\}$, the insider's inference on the asset value $\tilde{f}$ is

$$\mathbb{E}\left[\tilde{f} \mid \tilde{X}, \tilde{Z} \right] = \mathbb{E}\left[\tilde{f} | \tilde{X} \right] = \tilde{X}, \quad Var(\tilde{f} \mid \tilde{X}, \tilde{Z}) = Var(\tilde{f} \mid \tilde{X}) = 1 - \rho^2.$$

Standard calculations yield

$$\begin{aligned}
&\gamma \mathbb{E}\left[W_I \middle| \tilde{X}, \tilde{Z} \right] - \frac{1}{2}\gamma^2 Var(W_I | \tilde{X}, \tilde{Z}) \\
&= -D_I^2 \Lambda_I - D_I \left\{ r_X \tilde{X} + r_Z \tilde{Z} \right\} + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} | \tilde{X} \right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f} | \tilde{X}).
\end{aligned}$$

Here, the constants Λ_I, r_X and r_Z are given by

$$\begin{aligned}
\Lambda_I &= \gamma \lambda_\omega + \frac{1}{2}\gamma^2 Var(\tilde{f} - \tilde{p} | \tilde{X}, \tilde{Z}) = \gamma \lambda_\omega + \frac{1}{2}\gamma^2 \left(\lambda_\omega^2 \phi_H^2 \Sigma_u + (1 - \lambda_\omega \beta_S)^2 (1 - \rho^2) \right), \\
r_X &= -\gamma(1 - \lambda_\omega \beta_S), \quad r_Z = \gamma^2 \cdot Cov(\tilde{f} - \tilde{p}, \tilde{f} | \tilde{X}, \tilde{Z}) = \gamma^2 \cdot (1 - \lambda_\omega \beta_S)(1 - \rho^2).
\end{aligned}$$

Then, the first-order-condition gives

$$D_I = -\frac{r_X \tilde{X} + r_Z \tilde{Z}}{2\Lambda_I} = \alpha_X \tilde{X} + \alpha_Z \tilde{Z}, \quad \frac{\alpha_X}{\alpha_Z} = \frac{r_X}{r_Z} = -\gamma^{-1}(1 - \rho^2)^{-1}, \quad \Lambda_I = -\frac{1}{2} r_Z \alpha_Z^{-1} \tag{A2}$$

where

$$\alpha_X = \frac{1 - \lambda_\omega \beta_S}{\gamma \lambda_\omega^2 \phi_H^2 \Sigma_u + 2\lambda_\omega + \gamma (1 - \lambda_\omega \beta_S)^2 (1 - \rho^2)}, \quad \alpha_Z = -\alpha_X \gamma (1 - \rho^2).$$

As a result, the optimal problem (A1) takes the form of

$$
\begin{aligned}
&\gamma\mathbb{E}\left[W_I\big|\tilde{X},\tilde{Z}\right]-\frac{1}{2}\gamma^2 Var(W_I\big|\tilde{X},\tilde{Z})=D_I^2\Lambda_I+\gamma\tilde{Z}\,\mathbb{E}\left[\tilde{f}\big|\tilde{X}\right]-\frac{1}{2}\gamma^2\tilde{Z}^2 Var(\tilde{f}\big|\tilde{X})\\
&=(\alpha_X\tilde{X}+\alpha_Z\tilde{Z})^2\Lambda_I+\gamma\tilde{Z}\,\mathbb{E}\left[\tilde{f}\big|\tilde{X}\right]-\frac{1}{2}\gamma^2\tilde{Z}^2 Var(\tilde{f}\big|\tilde{X})\\
&=-\frac{1}{2}(\alpha_X\tilde{X}+\alpha_Z\tilde{Z})^2\cdot r_Z\alpha_Z^{-1}+\gamma\tilde{Z}\,\mathbb{E}\left[\tilde{f}\big|\tilde{X}\right]-\frac{1}{2}\gamma^2\tilde{Z}^2 Var(\tilde{f}\big|\tilde{X})\\
&=-\frac{1}{2}(\tilde{X}\alpha_X/\alpha_Z+\tilde{Z})^2\cdot r_Z\alpha_Z+\gamma\tilde{Z}\,\mathbb{E}\left[\tilde{f}\big|\tilde{X}\right]-\frac{1}{2}\gamma^2\tilde{Z}^2 Var(\tilde{f}\big|\tilde{X}).
\end{aligned}
$$

The speculators' optimal demand: Similar to the insider, the maximization problem (5) of the speculator j given his information set $\tilde{s}_j$ is equivalent to

$$
\max_{D_{S,j}} \qquad \gamma D_{S,j}\mathbb{E}\left[\tilde{f}-\tilde{p}\big|\tilde{s}_j\right]-\frac{1}{2}\gamma^2 D_{S,j}^2 Var(\tilde{f}-\tilde{p}\big|\tilde{s}_j). \tag{A3}
$$

The first-order-condition gives

$$
D_{S,j}=\frac{\mathbb{E}\left[\tilde{f}-\tilde{p}\big|\tilde{s}_j\right]}{\gamma Var(\tilde{f}-\tilde{p}\big|\tilde{s}_j)}.
$$

Using the information $\tilde{s}_j$, the speculator j updates his belief of the asset value $\tilde{f}_a$, $\tilde{f}_b$ and the return $\tilde{f}-\tilde{p}$ as

$$
\begin{aligned}
\mathbb{E}[\tilde{f}_a\big|\tilde{s}_j]&=\frac{\rho}{1+\Sigma_\delta}\tilde{s}_j,\quad \mathbb{E}[\tilde{f}_b\big|\tilde{s}_j]=\frac{\sqrt{1-\rho^2}}{1+\Sigma_\delta}\tilde{s}_j,\\
\mathbb{E}[\tilde{p}\big|\tilde{s}_j]&=\lambda_\omega(\alpha_X+\beta_S)\frac{\rho^2}{1+\Sigma_\delta}\tilde{s}_j+\lambda_\omega\beta_S\frac{1-\rho^2}{1+\Sigma_\delta}\tilde{s}_j,\\
\mathbb{E}[\tilde{f}-\tilde{p}\big|\tilde{s}_j]&=\left[(1-\lambda_\omega(\alpha_X+\beta_S))\rho^2+(1-\lambda_\omega\beta_S)(1-\rho^2)\right](1+\Sigma_\delta)^{-1}\,\tilde{s}_j.
\end{aligned}
$$

His inference of the return variance is

$$
\begin{aligned}
Var(\tilde{f}-\tilde{p}|\tilde{s}_j)&=Var\left((1-\lambda_\omega(\alpha_X+\beta_S))\rho\tilde{f}_a+(1-\lambda_\omega\beta_S)\sqrt{1-\rho^2}\tilde{f}_b-\lambda_\omega\left(\alpha_Z\tilde{Z}+\phi_H\tilde{u}\right)|\tilde{s}_j\right)\\
&=(1-\lambda_\omega(\alpha_X+\beta_S))^2\rho^2+(1-\lambda_\omega\beta_S)^2(1-\rho^2)\\
&-\left[(1-\lambda_\omega(\alpha_X+\beta_S))\rho^2+(1-\lambda_\omega\beta_S)(1-\rho^2)\right]^2(1+\Sigma_\delta)^{-1}\\
&+\lambda_\omega^2\left(\alpha_Z^2\Sigma_z+\phi_H^2\Sigma_u\right)\equiv\Lambda_S.
\end{aligned}
$$

Therefore, his optimal demand is

$$
\beta_S=\left[(1-\lambda_\omega(\alpha_X+\beta_S))\rho^2+(1-\lambda_\omega\beta_S)(1-\rho^2)\right](1+\Sigma_\delta)^{-1}\gamma^{-1}\Lambda_S^{-1}. \tag{A4}
$$

As a result,

$$
\gamma\mathbb{E}\left[W_S\big|\tilde{s}_j\right]-\frac{1}{2}\gamma^2 Var(W_S\big|\tilde{s}_j)=\frac{1}{2}\gamma^2\cdot Var(\tilde{f}-\tilde{p}\big|\tilde{s}_j)\cdot D_S^2=\frac{1}{2}\gamma^2\cdot Var(\tilde{f}-\tilde{p}\big|\tilde{s}_j)\cdot\beta_S^2\tilde{s}_j^2. \tag{A5}
$$

The hedger's optimal demand: The maximization problem (6) of the hedger given his information set $\tilde{u}$ is equivalent to

$$\begin{aligned}\max_{D_H} \quad & \gamma \mathbb{E}\left[W_H \middle| \tilde{u}\right] - \frac{1}{2}\gamma^2 Var(W_H|\tilde{u}) \\ & = \gamma D_H \mathbb{E}\left[\tilde{f} - \tilde{p}\middle|\tilde{u}\right] - \frac{1}{2}\gamma^2 \cdot \left\{D_H^2 \cdot Var(\tilde{f} - \tilde{p}|\tilde{u}) + \tilde{u}^2 Var(\tilde{f}|\tilde{u}) + 2D_H\tilde{u} \cdot Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u})\right\} \\ & = -\frac{1}{2}\gamma^2 Var(\tilde{f} - \tilde{p}|\tilde{u}) \cdot D_H^2 + (\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}\middle|\tilde{u}\right] - Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u}) \cdot \tilde{u})\gamma^2 \cdot D_H - \frac{1}{2}\gamma^2\tilde{u}^2.\end{aligned}$$

The first-order-condition gives

$$D_H = \frac{\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}\middle|\tilde{u}\right] - Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u}) \cdot \tilde{u}}{Var(\tilde{f} - \tilde{p}|\tilde{u})}. \tag{A6}$$

The hedger's inference on asset return $\tilde{f} - \tilde{p}$ and its variance are

$$\begin{aligned}\mathbb{E}\left[\tilde{f} - \tilde{p} \,|\, \tilde{u}\right] &= \mathbb{E}\left[\tilde{f} - \lambda_\omega\left(\alpha_X\rho\tilde{f}_a + \alpha_Z\tilde{Z} + \beta_S\tilde{f} + \phi_H\tilde{u}\right) \,|\, \tilde{u}\right] = -\lambda_\omega\phi_H\tilde{u}, \\ Var\left(\tilde{f} - \tilde{p} \,|\, \tilde{u}\right) &= Var\left((1 - \lambda_\omega(\alpha_X + \beta_S))\rho\tilde{f}_a + (1 - \lambda_\omega\beta_S)\sqrt{1-\rho^2}\tilde{f}_b - \lambda_\omega\left(\alpha_Z\tilde{Z} + \phi_H\tilde{u}\right) \,|\, \tilde{u}\right) \\ &= (1 - \lambda_\omega(\alpha_X + \beta_S))^2\rho^2 + (1 - \lambda_\omega\beta_S)^2(1-\rho^2) + \lambda_\omega^2\alpha_Z^2\Sigma_z, \\ Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u}) &= (1 - \lambda_\omega(\alpha_X + \beta_S))\rho^2 + (1 - \lambda_\omega\beta_S)(1-\rho^2).\end{aligned}$$

Then

$$\phi_H = -1 \cdot \frac{(1 - \lambda_\omega(\alpha_X + \beta_S))\rho^2 + (1 - \lambda_\omega\beta_S)(1-\rho^2) + \gamma^{-1}\lambda_\omega\phi_H}{(1 - \lambda_\omega(\alpha_X + \beta_S))^2\rho^2 + (1 - \lambda_\omega\beta_S)^2(1-\rho^2) + \lambda_\omega^2\alpha_Z^2\Sigma_z}. \tag{A7}$$

As a result,

$$\begin{aligned}\gamma\mathbb{E}\left[W_H|\tilde{u}\right] - \frac{1}{2}\gamma^2 Var(W_H|\tilde{u}) &= \frac{1}{2}\gamma^2\frac{\left(-\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}\middle|\tilde{u}\right] + Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u}) \cdot \tilde{u}\right)^2}{Var(\tilde{f} - \tilde{p}|\tilde{u})} - \frac{1}{2}\gamma^2\tilde{u}^2 \\ = \frac{1}{2}\gamma^2\left(\frac{-\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}\middle|\tilde{u}\right]}{Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u})} + \tilde{u}\right)^2 &\frac{Cov(\tilde{f} - \tilde{p}, \tilde{f}|\tilde{u})^2}{Var(\tilde{f} - \tilde{p}|\tilde{u})} - \frac{1}{2}\gamma^2\tilde{u}^2.\end{aligned}$$

The market maker sets the equilibrium price: After observing the total order flow $\tilde{\omega} = (\alpha_X + \beta_S)\rho\tilde{f}_a + \beta_S\sqrt{1-\rho^2}\tilde{f}_b + \alpha_Z\tilde{Z} + \phi_H\tilde{u}$, the risk-neutral market maker sets the price by

$$\tilde{p} = \mathbb{E}[\tilde{f}|\tilde{\omega}] = \frac{(\alpha_X + \beta_S)\rho^2 + \beta_S(1-\rho^2)}{(\alpha_X + \beta_S)^2\rho^2 + \beta_S^2(1-\rho^2) + \alpha_Z^2\Sigma_z + \phi_H^2\Sigma_u}\tilde{\omega} = \lambda_\omega\tilde{\omega}.$$

To get the equilibrium parameters $(\alpha_X, \alpha_Z, \beta_S, \phi_H, \lambda_\omega)$, we need to solve the following equations.

$$\alpha_X = \frac{1 - \lambda_\omega \beta_S}{\gamma \lambda_\omega^2 \phi_H^2 \Sigma_u + 2\lambda_\omega + \gamma(1 - \lambda_\omega \beta_S)^2 (1 - \rho^2)}, \quad \alpha_Z = -\alpha_X \gamma (1 - \rho^2), \tag{A8}$$

$$\beta_S = \left[(1 - \lambda_\omega(\alpha_X + \beta_S))\rho^2 + (1 - \lambda_\omega \beta_S)(1 - \rho^2)\right] \gamma^{-1} \Lambda_S^{-1} (1 + \Sigma_\delta)^{-1}, \tag{A9}$$

$$\phi_H = -1 \cdot \frac{(1 - \lambda_\omega(\alpha_X + \beta_S))\rho^2 + (1 - \lambda_\omega \beta_S)(1 - \rho^2) + \gamma^{-1}\lambda_\omega \phi_H}{(1 - \lambda_\omega(\alpha_X + \beta_S))^2 \rho^2 + (1 - \lambda_\omega \beta_S)^2 (1 - \rho^2) + \lambda_\omega^2 \alpha_Z^2 \Sigma_z}, \tag{A10}$$

$$\lambda_\omega = \frac{(\alpha_X + \beta_S)\rho^2 + \beta_S(1 - \rho^2)}{(\alpha_X + \beta_S)^2 \rho^2 + \beta_S^2 (1 - \rho^2) + \alpha_Z^2 \Sigma_z + \phi_H^2 \Sigma_u}. \tag{A11}$$

Denote

$$m = 1 - \lambda_\omega(\alpha_X + \beta_S), \qquad n = 1 - \lambda_\omega \beta_S, \qquad k = \gamma^2 (1 - \rho^2)^2 \Sigma_z. \tag{A12}$$

From (A11), we derive

$$\begin{aligned}
&\lambda_\omega^2 (\alpha_X + \beta_S)^2 \rho^2 + \lambda_\omega^2 \beta_S^2 (1 - \rho^2) + \lambda_\omega^2 \alpha_Z^2 \Sigma_z + \lambda_\omega^2 \phi_H^2 \Sigma_u = \lambda_\omega (\alpha_X + \beta_S)\rho^2 + \lambda_\omega \beta_S (1 - \rho^2). \\
&\Longleftrightarrow \\
&(1 - m)^2 \rho^2 + (1 - n)^2 (1 - \rho^2) + \lambda_\omega^2 \alpha_Z^2 \Sigma_z + \lambda_\omega^2 \phi_H^2 \Sigma_u = (1 - m)\rho^2 + (1 - n)(1 - \rho^2). \\
&\Longleftrightarrow \\
&\lambda_\omega^2 \alpha_Z^2 \Sigma_z + \lambda_\omega^2 \phi_H^2 \Sigma_u = \lambda_\omega^2 \alpha_X^2 k + \lambda_\omega^2 \phi_H^2 \Sigma_u = (1 - m) m \rho^2 + (1 - n) n (1 - \rho^2), \\
&\Longleftrightarrow \\
&\lambda_\omega^2 \phi_H^2 \Sigma_u = m(1 - m)\rho^2 + n(1 - n)(1 - \rho^2) - k(n - m)^2 = N.
\end{aligned} \tag{A13}$$

Therefore,

$$\begin{aligned}
\Lambda_S &= m^2 \rho^2 + n^2 (1 - \rho^2) - (m\rho^2 + n(1 - \rho^2))^2 (1 + \Sigma_\delta)^{-1} + \lambda_\omega^2 \left(\alpha_Z^2 \Sigma_z + \phi_H^2 \Sigma_u\right) \\
&= m^2 \rho^2 + n^2 (1 - \rho^2) - (m\rho^2 + n(1 - \rho^2))^2 (1 + \Sigma_\delta)^{-1} + (1 - m) m \rho^2 + (1 - n) n (1 - \rho^2) \\
&= (m\rho^2 + n(1 - \rho^2)) \left[1 + \Sigma_\delta - m\rho^2 - n(1 - \rho^2)\right] (1 + \Sigma_\delta)^{-1}, \\
\beta_S &= \gamma^{-1} \left[1 + \Sigma_\delta - m\rho^2 - n(1 - \rho^2)\right]^{-1} = \gamma^{-1} M^{-1}.
\end{aligned}$$

Then,

$$\alpha_X = \frac{n}{\gamma \lambda_\omega^2 \phi_H^2 \Sigma_u + 2\lambda_\omega + \gamma n^2 (1 - \rho^2)}, \tag{A14}$$

$$\phi_H = -1 \cdot \frac{m\rho^2 + n(1 - \rho^2) + \gamma^{-1} \lambda_\omega \phi_H}{m^2 \rho^2 + n^2 (1 - \rho^2) + \lambda_\omega^2 \alpha_Z^2 \Sigma_z}. \tag{A15}$$

Since $\lambda_\omega = (1 - n)\beta_S^{-1} = (1 - n)\gamma M$, $\alpha_X = (n - m)\lambda_\omega^{-1} = (n - m)(1 - n)^{-1}\gamma^{-1} M^{-1}$, from (A14), we get

$$\begin{aligned}
(n - m)^{-1} (1 - n)\gamma M &= n^{-1} \left[\gamma \lambda_\omega^2 \phi_H^2 \Sigma_u + 2\lambda_\omega + \gamma n^2 (1 - \rho^2)\right] \\
&= n^{-1} \left[\gamma N + 2(1 - n)\gamma M + \gamma n^2 (1 - \rho^2)\right].
\end{aligned} \tag{A16}$$

From (A15), it yields

$$\phi_H = -1 \cdot \frac{m\rho^2 + n(1-\rho^2)}{m^2\rho^2 + n^2(1-\rho^2) + \lambda_\omega^2 \alpha_X^2 k + \gamma^{-1}\lambda_\omega} = -1 \cdot \frac{m\rho^2 + n(1-\rho^2)}{m^2\rho^2 + n^2(1-\rho^2) + k(n-m)^2 + \gamma^{-1}\lambda_\omega}$$
$$= \frac{m\rho^2 + n(1-\rho^2)}{N - (1-n)M - m\rho^2 - n(1-\rho^2)}.$$

Plugging ϕ_H into (A13) gives

$$N = \lambda_\omega^2 \phi_H^2 \Sigma_u = \left(\frac{m\rho^2 + n(1-\rho^2)}{N - (1-n)M - m\rho^2 - n(1-\rho^2)} \right)^2 \Sigma_u (1-n)^2 \gamma^2 M^2,$$

which is equivalent to

$$(1-n)^2\gamma^2 M^2 \Sigma_u (m\rho^2 + n(1-\rho^2))^2 = N\left(N - (1-n)M - m\rho^2 - n(1-\rho^2)\right)^2. \tag{A17}$$

Once solving m and n via two equations (A16) and (A17), we could pin down remaining parameters. Notice that the second-order-condition for the insider, speculators and the hedge require that $\alpha_f > 0$ and $m, n \in [0, 1]$. □

Proof of Corollary 1: When Σ_z or Σ_u is sufficient large, we could derive explicitly the equilibrium which is given in Proposition B1 in the appendix. When the risk aversion γ is sufficiently small, the equations groups (22) and (23) do not sustain a solution. □

Proof of Proposition 2 for disclosure equilibrium. For notation simplicity, in the proof, we denote

$$\tilde{X} = \rho \tilde{f}_a, \quad \alpha_X^* = \rho^{-1}\alpha_f^*, \quad k = \gamma^2(1-\rho^2)^2\Sigma_z, \quad \text{and,} \quad n = 1 - \lambda_O^*\beta_S^*.$$

The total order flow and return are

$$\begin{aligned}
\omega^* &= (1 + \beta_I^* + \phi_I^*)D_I^* + \beta_S^*\tilde{f} + \phi_H^*\tilde{u}, \\
&= \rho\tilde{f}_a\left[\alpha_X^*(1 + \beta_I^* + \phi_I^*) + \beta_S^*\right] + \beta_S^*\sqrt{1-\rho^2}\tilde{f}_b + (1 + \beta_I^* + \phi_I^*)\alpha_Z^*\tilde{Z} + \phi_H^*\tilde{u}, \\
\tilde{f} - \tilde{p}^* &= (1 - \lambda_O^*\beta_S^*)\tilde{f} - \lambda_I^* D_I^* - \lambda_O^*\phi_H^*\tilde{u}.
\end{aligned}$$

The insider's optimal demand: Based on the insider's information set $\{\tilde{X}, \tilde{Z}\}$, the insider's inference on asset value $\tilde{f}$ is the same as non-disclosure regime.

$$\mathbb{E}\left[\tilde{f} \mid \tilde{X}, \tilde{Z}\right] = \tilde{X}, \quad Var(\tilde{f} \mid \tilde{X}, \tilde{Z}) = 1 - \rho^2.$$

In contrast, the posterior inference of the return variance and covariance change to

$$\begin{aligned}
Var(\tilde{f} - \tilde{p}^* \mid \tilde{X}, \tilde{Z}) &= (1 - \lambda_O^*\beta_S^*)^2(1-\rho^2) + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u, \\
Cov(\tilde{f} - \tilde{p}^*, \tilde{f} \mid \tilde{X}, \tilde{Z}) &= (1 - \lambda_O^*\beta_S^*)(1-\rho^2).
\end{aligned}$$

Then, after some tedious calculations, the insider's maximization problem (4) is equivalent to

$$\begin{aligned}\max_{D_I^*} \quad & \gamma \mathbb{E}\left[W_I^* \middle| \tilde{X}, \tilde{Z}\right] - \frac{1}{2}\gamma^2 Var(W_I^* | \tilde{X}, \tilde{Z}) \\ & = -(D_I^*)^2 \Lambda_I^* - D_I^* \left\{ r_X^* \tilde{X} + r_Z^* \tilde{Z} \right\} + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} \middle| \tilde{X}\right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f} | \tilde{X}).\end{aligned}$$

with the parameters,

$$\begin{aligned}&\Lambda_i^* = \gamma \lambda_I^* + \frac{1}{2}\gamma^2 \left((1-\lambda_O^*\beta_S^*)^2(1-\rho^2) + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right), \\ &r_X^* = -\gamma(1-\lambda_O^*\beta_S^*), \quad r_Z^* = \gamma^2 \cdot Cov(\tilde{f}-\tilde{p}^*, \tilde{f}|\tilde{X}, \tilde{Z}) = \gamma^2(1-\lambda_O^*\beta_S^*)(1-\rho^2).\end{aligned}$$

Then, the first-order-condition gives

$$D_I^* = -\frac{r_X^* \tilde{X} + r_Z^* \tilde{Z}}{2\Lambda_I^*} = \alpha_X^* \tilde{X} + \alpha_Z^* \tilde{Z}, \quad \text{and,} \quad \alpha_X^*/\alpha_Z^* = r_X^*/r_Z^*, \quad \Lambda_I^* = -\frac{1}{2} r_Z^* (\alpha_Z^*)^{-1}.$$

Here,

$$\begin{aligned}\alpha_X^* &= \frac{1-\lambda_O^*\beta_S^*}{2\lambda_I^* + \gamma\left((1-\lambda_O^*\beta_S^*)^2(1-\rho^2) + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right)}, \\ \alpha_Z^* &= -\alpha_X^*\gamma(1-\rho^2).\end{aligned}$$

As a result,

$$\begin{aligned}&\gamma \mathbb{E}\left[W_I^* \middle| \tilde{X}, \tilde{Z}\right] - \frac{1}{2}\gamma^2 Var(W_I^* | \tilde{X}, \tilde{Z}) \\ &= (D_I^*)^2 \Lambda_I^* + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} \middle| \tilde{X}\right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f}|\tilde{X}) \\ &= (\alpha_X^* \tilde{X} + \alpha_Z^* \tilde{Z})^2 \Lambda_I^* + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} \middle| \tilde{X}\right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f}|\tilde{X}) \\ &= -\frac{1}{2} r_Z^* (\alpha_X^* \tilde{X} + \alpha_Z^* \tilde{Z})^2 (\alpha_Z^*)^{-1} + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} \middle| \tilde{X}\right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f}|\tilde{X}) \\ &= -\frac{1}{2} r_Z^* (\tilde{X}\alpha_X^*/\alpha_Z^* + \tilde{Z})^2 \alpha_Z^* + \gamma \tilde{Z}\, \mathbb{E}\left[\tilde{f} \middle| \tilde{X}\right] - \frac{1}{2}\gamma^2 \tilde{Z}^2 Var(\tilde{f}|\tilde{X}).\end{aligned}$$

The speculators' optimal demand: Under disclosure regime, the information set of speculator j is $\{\tilde{s}_j, D_I^*\}$. Using normality, the speculator j's optimal problem is equivalent to

$$\max_{D_{S,j}} \quad \gamma D_{S,j} \mathbb{E}\left[\tilde{f} - \tilde{p}^* \middle| \tilde{s}_j, D_I^*\right] - \frac{1}{2}\gamma^2 D_{S,j}^2 Var(\tilde{f} - \tilde{p}^* | \tilde{s}_j, D_I^*).$$

The first-order-condition gives the optimal demand as

$$D_{S,j} = \frac{\mathbb{E}\left[\tilde{f} - \tilde{p}^* \middle| \tilde{s}_j, D_I^*\right]}{\gamma Var(\tilde{f} - \tilde{p}^* | \tilde{s}_j, D_I^*)}.$$

The speculator j's estimation of asset value and return are

$$\begin{aligned}
\mathbb{E}[\tilde{f}|\tilde{s}_j, D_I^*] &= a_s\tilde{s}_j + a_I D_I^*,\\
\mathbb{E}[\tilde{f}-\tilde{p}^*|\tilde{s}_j, D_I^*] &= \mathbb{E}[(1-\lambda_O^*\beta_S^*)\tilde{f} - \lambda_I^* D_I^* - \lambda_O^*\phi_H^*\tilde{u}|\tilde{s}_j, D_I^*]\\
&= -\lambda_I^* D_I^* + (1-\lambda_O^*\beta_S^*)\mathbb{E}[\tilde{f}|\tilde{s}_j, D_I^*]\\
&= -\lambda_I^* D_I^* + n^* a_s\tilde{s}_j + n^* a_I D_I^* = (n^* a_I - \lambda_I^*)\, D_I^* + n^* a_s \tilde{s}_j.
\end{aligned}$$

Here, the two constants a_s and a_I are

$$a_s = k_1 k_2^{-1}, \quad a_I = (\alpha_X^*)^{-1}\rho^2\Sigma_\delta k_2^{-1}. \tag{A18}$$

The speculator j's posterior estimation of asset price and return variances are

$$\begin{aligned}
Var(\tilde{f}|\tilde{s}_j, D_I^*) &= Var(\tilde{f}) - Var(\mathbb{E}[\tilde{f}|\tilde{s}_j, D_I^*]) = \Sigma_\delta a_s,\\
Var(\tilde{f}-\tilde{p}^*|\tilde{s}_j, D_I^*) &= Var((1-\lambda_O^*\beta_S^*)\tilde{f} - \lambda_O^*\phi_H^*\tilde{u}|\tilde{s}_j, D_I^*) = (n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u.
\end{aligned}$$

Then,

$$\beta_S^* = \frac{n^* a_s}{\gamma\left[n^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}, \quad \beta_I^* = \frac{-\lambda_I^* + n^* a_I}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}. \tag{A19}$$

As a result,

$$\begin{aligned}
\gamma\mathbb{E}\left[W_S^*|\tilde{s}_j, D_I^*\right] - \frac{1}{2}\gamma^2 Var(W_S^*|\tilde{s}_j, D_I^*) &= \frac{1}{2}\gamma^2\cdot Var(\tilde{f}-\tilde{p}^*|\tilde{s}_j, D_I^*)\cdot(D_S^*)^2\\
&= \frac{1}{2}\gamma^2\cdot Var(\tilde{f}-\tilde{p}^*|\tilde{s}_j, D_I^*)\cdot(\beta_S^*\tilde{s}_j + \beta_I^* D_I^*)^2\\
&= \frac{1}{2}\gamma^2(\beta_S^*)^2 Var(\tilde{f}-\tilde{p}^*|\tilde{s}_j, D_I^*)\cdot(\tilde{s}_j + \beta_I^* D_I^*/\beta_S^*)^2.
\end{aligned}$$

The hedger's optimal demand: Under disclosure regime, the information set of the hedger is $\{\tilde{u}, D_I^*\}$. Using normality, the hedger's optimal problem is equivalent to

$$\begin{aligned}
\max_{D_H}\quad & \gamma\mathbb{E}\left[W_H^*|\tilde{u}, D_I^*\right] - \frac{1}{2}\gamma^2 Var(W_H^*|\tilde{u}, D_I^*)\\
&= \gamma\left(D_H^*\mathbb{E}\left[\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*\right] + \tilde{u}\cdot\mathbb{E}\left[\tilde{f}|D_I^*\right]\right)\\
&- \frac{1}{2}\gamma^2\cdot\left\{(D_H^*)^2\cdot Var(\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*) + \tilde{u}^2 Var(\tilde{f}|\tilde{u}, D_I^*) + 2D_H^*\tilde{u}\cdot Cov(\tilde{f}-\tilde{p}^*, \tilde{f}|\tilde{u}, D_I^*)\right\}\\
&= -\frac{1}{2}\gamma^2 Var(\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*)\cdot(D_H^*)^2\\
&+ \left(\gamma^{-1}\mathbb{E}\left[\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*\right] - Cov(\tilde{f}-\tilde{p}^*, \tilde{f}|\tilde{u}, D_I^*)\cdot\tilde{u}\right)\gamma^2\cdot D_H^* + \gamma\tilde{u}\cdot\mathbb{E}\left[\tilde{f}|D_I^*\right] - \frac{1}{2}\gamma^2\tilde{u}^2 Var(\tilde{f}|\tilde{u}, D_I^*).
\end{aligned}$$

Then, the first-order-condition gives

$$D_H^* = \frac{\gamma^{-1}\mathbb{E}\left[\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*\right] - Cov(\tilde{f}-\tilde{p}^*, \tilde{f}|\tilde{u}, D_I^*)\cdot\tilde{u}}{Var(\tilde{f}-\tilde{p}^*|\tilde{u}, D_I^*)}.$$

The hedger's inference on asset value $\tilde{f}$ and return $\tilde{f} - \tilde{p}^*$ are

$$\begin{aligned}
\mathbb{E}\left[\tilde{f} \mid \tilde{u}, D_I^*\right] &= \mathbb{E}\left[\tilde{f}|D_I^*\right] = \frac{Cov(\tilde{f}, D_I^*)}{Var(D_I^*)} D_I^* = (\alpha_X^*)^{-1}(1+\rho^{-2}k)^{-1} D_I^*, \\
\mathbb{E}\left[\tilde{f} - \tilde{p}^* \mid \tilde{u}, D_I^*\right] &= -\lambda_I^* D_I^* + \mathbb{E}\left[(1-\lambda_O^*\beta_S^*)\tilde{f} - \lambda_O^*\phi_H^*\tilde{u} \mid \tilde{u}, D_I^*\right] \\
&= -\lambda_I^* D_I^* + n^*(\alpha_X^*)^{-1}(1+\rho^{-2}k)^{-1} D_I^* - \lambda_O^*\phi_H^*\tilde{u}, \\
Var(\tilde{f} \mid \tilde{u}, D_I^*) &= Var(\tilde{f}) - Var\left(\mathbb{E}\left[\tilde{f} \mid \tilde{u}, D_I^*\right]\right) = k_1(\rho^2+k)^{-1}, \\
Var\left[\tilde{f} - \tilde{p}^* \middle| \tilde{u}, D_I^*\right] &= (n^*)^2 Var\left[\tilde{f}\middle|D_I^*\right] = (n^*)^2 k_1 (\rho^2+k)^{-1}, \\
Cov(\tilde{f} - \tilde{p}^*, \tilde{f}\middle|\tilde{u}, D_I^*) &= n^* Var\left[\tilde{f}\middle|D_I^*\right] = n^* k_1(\rho^2+k)^{-1}.
\end{aligned}$$

Then, it leads to

$$\begin{aligned}
\phi_I^* &= \gamma^{-1}(n^*)^{-2}(k+\rho^2)k_1^{-1}\left[n^*(\alpha_X^*)^{-1}\rho^2(\rho^2+k)^{-1} - \lambda_I^*\right], \\
\phi_H^* &= -\gamma^{-1}(n^*)^{-2}\lambda_O^*\phi_H^*(k+\rho^2)k_1^{-1} - (n^*)^{-1}.
\end{aligned}$$

As a result (later, we could show that $\phi_I^* = 0$),

$$\begin{aligned}
&-\gamma\mathbb{E}\left[W_H^*\middle|\tilde{u}, D_I^*\right] + \frac{1}{2}\gamma^2 Var(W_H^*\middle|\tilde{u}, D_I^*) = -\frac{1}{2}\gamma^2 \frac{\left(-\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}^*\middle|\tilde{u}, D_I^*\right] + Cov(\tilde{f} - \tilde{p}^*, \tilde{f}\middle|\tilde{u}, D_I^*)\cdot\tilde{u}\right)^2}{Var(\tilde{f} - \tilde{p}^*\middle|\tilde{u}, D_I^*)} \\
&-\gamma\tilde{u}\cdot\mathbb{E}\left[\tilde{f}\middle|D_I^*\right] + \frac{1}{2}\gamma^2\tilde{u}^2 Var(\tilde{f}\middle|\tilde{u}, D_I^*) \\
&= -\frac{1}{2}\gamma^2\left(\frac{-\gamma^{-1}\mathbb{E}\left[\tilde{f} - \tilde{p}^*\middle|\tilde{u}, D_I^*\right]}{Cov(\tilde{f} - \tilde{p}^*, \tilde{f}\middle|\tilde{u}, D_I^*)} + \tilde{u}\right)^2 \frac{Cov(\tilde{f} - \tilde{p}^*, \tilde{f}\middle|\tilde{u}, D_I^*)^2}{Var(\tilde{f} - \tilde{p}^*\middle|\tilde{u}, D_I^*)} - \gamma\tilde{u}\cdot\mathbb{E}\left[\tilde{f}\middle|D_I^*\right] + \frac{1}{2}\gamma^2\tilde{u}^2 Var(\tilde{f}\middle|\tilde{u}, D_I^*).
\end{aligned}$$

The market maker sets price: After observing the total order flow $\tilde{\omega} = D_I^* + D_H^* + \int_0^1 D_{S,j}^* dj$ and the insider disclosed trade D_I^* (equivalent to the information set $\{D_I^*, \beta_S^*\tilde{f} + \phi_H^*\tilde{u}\}$), the risk-neutral market marker sets the price according to

$$\tilde{p}^* = \mathbb{E}[\tilde{f}|\tilde{\omega}^*, D_I^*] = \mathbb{E}[\tilde{f} \mid \beta_S^*\tilde{f} + \phi_H^*\tilde{u}, D_I^*] = \lambda_O^*\left(\beta_S^*\tilde{f} + \phi_H^*\tilde{u}\right) + \lambda_I^* D_I^*.$$

Using normality and projection of conditional expectation, simple calculations give us

$$\lambda_O^* = \frac{\beta_S^* k_1}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2\Sigma_u(\rho^2+k)}, \quad \lambda_I^* = \frac{(\alpha_X^*)^{-1}\rho^2(\phi_H^*)^2\Sigma_u}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2\Sigma_u(\rho^2+k)}.$$

Taking together, we solve the following equations for the equilibrium parameters .

$$\phi_H^* = -\gamma^{-1}(n^*)^{-2}\lambda_O^*\phi_H^*(k+\rho^2)k_1^{-1} - (n^*)^{-1}, \tag{A20}$$

$$\phi_I^* = \gamma^{-1}(n^*)^{-2}(k+\rho^2)k_1^{-1}\left[n^*(\alpha_X^*)^{-1}\frac{\rho^2}{\rho^2+k} - \lambda_I^*\right], \tag{A21}$$

$$\beta_S^* = \frac{n^* a_s}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}, \tag{A22}$$

$$\beta_I^* = \frac{-\lambda_I^* + n^* a_I}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}, \tag{A23}$$

$$\alpha_X^* = \frac{1-\lambda_O^*\beta_S^*}{2\lambda_I^* + \gamma\left((1-\lambda_O^*\beta_S^*)^2(1-\rho^2) + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right)}, \tag{A24}$$

$$\alpha_Z^* = -\alpha_X^*\gamma(1-\rho^2), \tag{A25}$$

$$\lambda_O^* = \frac{\beta_S^* k_1}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2\Sigma_u(\rho^2+k)}, \tag{A26}$$

$$\lambda_I^* = \frac{(\alpha_X^*)^{-1}\rho^2(\phi_H^*)^2\Sigma_u}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2\Sigma_u(\rho^2+k)}. \tag{A27}$$

Denote

$$k_1 = k + \rho^2(1-\rho^2), \quad k_2 = k_1(1+\Sigma_\delta) + \rho^4\Sigma_\delta, \quad \text{and,} \quad n^* = 1 - \lambda_O^*\beta_S^*.$$

From (A26), we have

$$\lambda_O^* = \frac{k_1(1-n^*)\lambda_O^*}{(1-n^*)^2 k_1 + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u(\rho^2+k)}.$$

It gives

$$(\lambda_O^*)^2(\phi_H^*)^2\Sigma_u = n^*(1-n^*)k_1(\rho^2+k)^{-1}. \tag{A28}$$

Plugging in $\phi_H^* = -(n^*)^{-1}\left[1+\gamma^{-1}n^{-2}\lambda_O^*(k+\rho^2)k_1^{-1}\right]^{-1}$ of (A20), we arrive at

$$(\lambda_O^*)^{-1} = \Sigma_u^{\frac{1}{2}}(n^*)^{-\frac{3}{2}}(1-n^*)^{-\frac{1}{2}}k_1^{-\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} - \gamma^{-1}(n^*)^{-2}(\rho^2+k)k_1^{-1}. \tag{A29}$$

Using (A22), it yields

$$(1-n^*)(\lambda_O^*)^{-1} = \frac{n^* a_s \gamma^{-1}}{(n^*)^2 \Sigma_\delta a_s + (\lambda_O^*)^2 (\phi_H^*)^2 \Sigma_u}$$
$$= \frac{n^* a_s \gamma^{-1}}{(n^*)^2 \Sigma_\delta a_s + n^*(1-n^*) k_1 (\rho^2+k)^{-1}} = \frac{a_s \gamma^{-1}}{n^* \Sigma_\delta a_s + (1-n^*) k_1 (\rho^2+k)^{-1}}$$
$$\Leftrightarrow$$
$$(1-n^*)\left[\Sigma_u^{1/2}(n^*)^{-\frac{3}{2}}(1-n^*)^{-\frac{1}{2}} k_1^{-\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} - \gamma^{-1}(n^*)^{-2}(\rho^2+k)k_1^{-1}\right] = \frac{a_s \gamma^{-1}}{n^* \Sigma_\delta a_s + (1-n^*) k_1 (\rho^2+k)^{-1}}$$
$$\Leftrightarrow$$
$$\Sigma_u^{1/2}(n^*)^{-\frac{1}{2}}(1-n^*)^{\frac{1}{2}} k_1^{-\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} - \gamma^{-1}(n^*)^{-1}(1-n^*)(\rho^2+k)k_1^{-1} = \frac{a_s \gamma^{-1}}{\Sigma_\delta a_s + (1-n^*)(n^*)^{-1} k_1 (\rho^2+k)^{-1}}$$
$$\Leftrightarrow$$
$$\Sigma_u^{1/2} k_1^{-\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} \cdot n_0^* - \gamma^{-1}(\rho^2+k)k_1^{-1} \cdot (n_0^*)^2 = \frac{a_s \gamma^{-1}}{\Sigma_\delta a_s + k_1(\rho^2+k)^{-1} \cdot (n_0^*)^2}.$$

Here, $n_0^* = (n^*)^{\frac{-1}{2}}(1-n^*)^{\frac{1}{2}}$ and is the roots of the following quartic equation $f(x)$

$$\begin{aligned}
f(x) &= \gamma^{-1} \cdot x^4 - \Sigma_u^{1/2} k_1^{\frac{1}{2}}(\rho^2+k)^{-\frac{1}{2}} \cdot x^3 \\
&\quad + \gamma^{-1}(\rho^2+k)k_1^{-1}\Sigma_\delta a_s \cdot x^2 - \Sigma_u^{1/2} k_1^{-\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} \Sigma_\delta a_s \cdot x + a_s \gamma^{-1} \\
&= \gamma^{-1} \cdot x^4 - \Sigma_u^{1/2} k_1^{\frac{1}{2}}(\rho^2+k)^{-\frac{1}{2}} \cdot x^3 \\
&\quad + \gamma^{-1}(\rho^2+k)\Sigma_\delta k_2^{-1} \cdot x^2 - \Sigma_u^{1/2} k_1^{\frac{1}{2}}(\rho^2+k)^{\frac{1}{2}} \Sigma_\delta k_2^{-1} \cdot x + k_1 k_2^{-1} \gamma^{-1} = 0.
\end{aligned}$$

Then, from (A23), we have

$$\lambda_I^* = n^* a_I - n^* a_s \beta_I^* (\beta_S^*)^{-1}, \tag{A30}$$

Then, combing with (A30) and (A27) gives

$$\begin{aligned}
\lambda_I^* &= (\alpha_X^*)^{-1} \rho^2 (\phi_H^*)^2 \Sigma_u \lambda_O^* (\beta_S^*)^{-1} k_1^{-1} \\
&= (\alpha_X^*)^{-1} \rho^2 (\phi_H^*)^2 \Sigma_u (\lambda_O^*)^2 (1-n^*)^{-1} k_1^{-1} = (\alpha_X^*)^{-1} \rho^2 n^* (\rho^2+k)^{-1}.
\end{aligned}$$

Plugging into (A21) yields $\phi_I^* = 0$. Furthermore,

$$(\alpha_X^*)^{-1} \rho^2 (\rho^2+k)^{-1} = a_I - a_s \beta_I^* (\beta_S^*)^{-1} \tag{A31}$$

Using a_s and a_I from (A18), it gives

$$(\alpha_X^*)^{-1} = -\beta_I^*(1+\rho^{-2}k)(\beta_S^*)^{-1}, \quad \lambda_I^* = -n^* \beta_I^* (\beta_S^*)^{-1}. \tag{A32}$$

Equation (A24) combing with (A28) gives us

$$(\alpha_X^*)^{-1} = (n^*)^{-1} \cdot \left[2(\alpha_X^*)^{-1} n^* \rho^2 (\rho^2+k)^{-1} + \gamma\left((n^*)^2(1-\rho^2) + n^*(1-n^*)k_1(\rho^2+k)^{-1}\right)\right],$$

which implies

$$(\alpha_X^*)^{-1} = \gamma(\rho^2+k)\cdot\left(n^*(1-\rho^2)+(1-n^*)k_1(\rho^2+k)^{-1}\right)\cdot\left(k-\rho^2\right)^{-1} = \gamma(k_1-\rho^2kn^*)\left(k-\rho^2\right)^{-1}.$$

Therefore,

$$\beta_I^* = -\beta_S^*\gamma\cdot(k_1-\rho^2kn^*)(1+\rho^{-2}k)^{-1}\left(k-\rho^2\right)^{-1}.$$

The second-order-condition for the insider and speculators are

$$0<\lambda_O^* \Leftrightarrow n_0^*\in\left(0,\gamma\Sigma_u^{1/2}k_1^{1/2}(\rho^2+k)^{-1/2}\right), \qquad \text{and}$$
$$0<\alpha_X^*\Leftrightarrow \beta_I^*<0\Leftrightarrow k>\rho^2\Leftrightarrow \Sigma_z>\gamma^{-2}\rho^2(1-\rho^2)^{-2}.$$

□

Proof of Corollary 2: The polynomial (38) can be rewritten as

$$F(x) := \gamma^{-1}x\left[\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2+k)^{\frac{-1}{2}}-\gamma^{-1}x\right] = \frac{k_1k_2^{-1}\gamma^{-1}\gamma^{-1}}{x^2+(\rho^2+k)\Sigma_\delta k_2^{-1}} := G(x). \tag{A33}$$

It is easy to see that the quadratic function $F(x)$ satisfies

$$F(0)=F(x^*)=0,\quad x^*=\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2+k)^{\frac{-1}{2}}\gamma,\quad F_{max}=\Sigma_uk_1(\rho^2+k)^{-1}/4.$$

Since the function $G(x)$ is decreasing to 0 as $x\to+\infty$, $G(x)$ would intersect with $F(x)$ in the interval $[0,x^*]$ as long as $G(0)\le F_{max}$. This gives us the condition $\Sigma_u\ge 4\gamma^{-1}\gamma^{-1}\Sigma_\delta^{-1}$.

In the meanwhile, if $G(x^*)\ge F_{max}$, there is no solution. This is equivalent to have

$$\begin{aligned}\Sigma_u \le \hat{\Sigma}_u &= \frac{\sqrt{(\rho^2+k)^2\Sigma_\delta^2k_2^{-2}+16kk_2^{-1}}-(\rho^2+k)\Sigma_\delta k_2^{-1}}{2\gamma^2k_1(\rho^2+k)^{-1}}\\ &= \frac{\sqrt{(1-k_1k_2^{-1})^2+16kk_2^{-1}}+k_1k_2^{-1}-1}{2\gamma^2k_1(\rho^2+k)^{-1}}.\end{aligned}$$

□

Proof of Corollary 3: Under non-disclosure regime, recall that $\tilde{\omega}=(\alpha_X+\beta_S)\rho\tilde{f}_a+\beta_S\sqrt{1-\rho^2}\tilde{f}_b+\alpha_Z\tilde{Z}+\phi_H\tilde{u}$. Then

$$Var(\tilde{f}|\tilde{p}) = Var(\tilde{f}|\tilde{\omega}) = 1-Cov(\tilde{f},\tilde{\omega})\frac{Cov(\tilde{f},\tilde{\omega})}{Var(\tilde{\omega})} = \rho^2m+(1-\rho^2)n.$$

Under disclosure regime, it is

$$Var(\tilde{f}|\tilde{p}^*) = Var(\tilde{f})-\frac{Cov^2(\tilde{f},\tilde{p}^*)}{Var(\tilde{p}^*)}.$$

After some long and tedious simplifications, we have

$$Var(\tilde{f})Var(\tilde{p}^*)-Cov^2(\tilde{f},\tilde{p}^*) = n^*k_1(\rho^2+k)^{-1}\left[1-n^*k_1(\rho^2+k)^{-1}\right],$$
$$Var(\tilde{p}^*) = 1-n^*k_1(\rho^2+k)^{-1}.$$

Hence, $Var(\tilde{f}|\tilde{p}^*) = n^* k_1(\rho^2 + k)^{-1}$. □

Proof of Corollary 4: From the definitions of certainty equivalents in (43)-(48), for all traders $t \in \{I, S, H\}$ under corresponding information set F_t, his wealth W_t is normal distributed and the certainty equivalent is given by

$$CE_t = \mathbb{E}\left[W_t \big| F_t\right] - \frac{1}{2}\gamma Var(W_t|F_t).$$

From the proofs of Propositions 1 and 2, we could show the certainty equivalents in the two economies are:

$$\begin{aligned}
CE_I &= \frac{-\gamma}{2}(1-\rho^2)(\tilde{Z} - \rho\tilde{f}_a\gamma^{-1}(1-\rho^2)^{-1})^2\alpha_Z n + \mathbb{E}\left[\tilde{f}\middle|\tilde{f}_a\right]\tilde{Z} - \frac{\gamma}{2}Var(\tilde{f}|\tilde{f}_a)\cdot\tilde{Z}^2,\\
CE_S &= \frac{1}{2}\beta_S(m\rho^2 + n(1-\rho^2)(1+\Sigma_\delta)^{-1}\tilde{s}_j^2,\\
CE_H &= \frac{1}{2}\gamma\left[-1 - \phi_H(m\rho^2 + n(1-\rho^2) + \gamma^{-1}\lambda_\omega\phi_H)\right]\tilde{u}^2,\\
CE_I^* &= \frac{-\gamma}{2}(1-\rho^2)(\tilde{Z} - \rho\tilde{f}_a\gamma^{-1}(1-\rho^2)^{-1})^2\alpha_Z^* n^* + \mathbb{E}\left[\tilde{f}\middle|\tilde{f}_a\right]\tilde{Z} - \frac{\gamma}{2}Var(\tilde{f}|\tilde{f}_a)\cdot\tilde{Z}^2,\\
CE_S^* &= \frac{1}{2}n^*\beta_S^* k_1 k_2^{-1}\cdot\left(\tilde{s}_j - (1+\rho^{-2}k)^{-1}(\rho\tilde{f}_a - \tilde{Z}\gamma(1-\rho^2))\right)^2,\\
CE_H^* &= \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2 k_1(\rho^2+k)^{-1} - 1\right]\tilde{u}^2.
\end{aligned}$$

Then, the proposition follows by taking expectation in the above equations. □

Proof of Proposition 3: Assertions (1) and (2) are simple consequences of Propositions B2 and B3 in Appendix B.

Assertion (3): From Propositions 3 and B1, we deduce when $\Sigma_z \to +\infty$,

$$EEF \to 1 < EEF^* = (n^*)^{-1}.$$

Assertion (4): When Σ_z is sufficient large, Proposition B1 in Appendix B shows

$$\begin{aligned}
\lambda_O^* &\to (n^*)^2\left[\Sigma_u^{1/2}(n_0^*)^{-1} - \gamma^{-1}\right]^{-1} > 0,\\
\lambda_\omega &\to (\alpha_X\rho^2 + \beta_S)\Sigma_z^{-1} \to (\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1})\gamma^{-1}\Sigma_z^{-1} \to 0,\\
\lambda_I^* &\to \rho^2(1-\rho^2)^{-2}(1-\rho^2 n^*)n^*\gamma^{-1}\Sigma_z^{-1} \to 0.
\end{aligned}$$

Here, n_0^* is the positive root of equation (B1). When $|\rho| \le 1/\sqrt{2}$, it gives $\lambda_I^* < \lambda_\omega$. □

Proof of Proposition 4: First, from Proposition B2 in Appendix B, the claims (55) and (57) are obvious by taking derivatives with respect to ρ.

Second, from Proposition 3, we know

$$EFF = \frac{1}{n - \rho^2(n-m)}, \quad EEF^* = (n^*)^{-1}(k+\rho^2)k_1^{-1}.$$

When Σ_z is sufficient large, the constant n, m, and n^* are irrelevant to ρ. Therefore, it is easy to show that $\partial EFF/\partial\rho > 0$ and $\partial EFF^*/\partial\rho > 0$ by observing that $\partial(k+\rho^2)k_1^{-1}/\partial\rho > 0$.

Last, due to $\lambda_\omega \to (\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1})\gamma^{-1}\Sigma_z^{-1}$, it gives $\partial\lambda_\omega/\partial\rho > 0$. From Proposition 2, by taking higher order of Σ_z, we have

$$\lambda_O^* \to (n^*)^2 \left(\Sigma_u^{1/2}(n_0^*)^{-1}k_1^{-1/2}(k+\rho^2)^{1/2} - \gamma^{-1}\right)^{-1}$$

which implies $\partial\lambda_O^*/\partial\rho < 0$. From $\lambda_I^* \to \rho^2(1-\rho^2)^{-2}(1-\rho^2 n^*)n^*\gamma^{-1}\Sigma_z^{-1}$, we deduce $\partial\lambda_I^*/\partial\rho > 0$. □

Proof of Proposition 5:
Claim (1): It is a simple consequence of Proposition B2 in Appendix B.
Claim (2): From Propositions 3 and B1, we deduce when $\Sigma_u \to +\infty$,

$$EEF \to 1 < EEF^* = (n^*)^{-1}.$$

Claim (3): The limits $\lambda_\omega, \lambda_I^*$ and λ_O^* in Proposition B1 clearly shows $\lambda_O^* < \lambda_\omega < \lambda_I^*$. □

Proof of Proposition 6: First, from Proposition B2 in Appendix B, the claims (59) and (61) are obvious by taking derivatives with respect to ρ.

Second, from Proposition 3, we know

$$EFF = \frac{1}{n - \rho^2(n-m)}, \quad EEF^* = (n^*)^{-1}(k+\rho^2)k_1^{-1}.$$

When Σ_u is sufficient large, the constant n, m, and n^* are irrelevant to ρ. Therefore, it is easy to show $\partial EFF/\partial\rho > 0$ and $\partial EFF^*/\partial\rho > 0$ by observing that $\partial(k+\rho^2)k_1^{-1}/\partial\rho > 0$.

Last, by taking derivative for $\lambda_\omega, \lambda_I^*$ and λ_O^* with respect to ρ in Proposition B1, it shows $\partial\lambda_\omega/\partial\rho > 0$, $\partial\lambda_I^*/\partial\rho > 0$, and $\partial\lambda_O^*/\partial\rho < 0$. □

Appendix B: Supplementary Propositions

To prove proceeding propositions, we need a supplementary characterization for the equilibrium when the insider or the hedger's hedge demand is sufficient large.

Proposition B1. *When the insider or the hedger's hedge demand goes to infinity, the equilibrium is characterized as:*

Case 1: *When $\Sigma_z \to \infty$, the non-disclosure equilibrium parameters are given by*

$$\alpha_f \to \gamma^{-1}(1-\rho^2)^{-1}\rho, \quad \alpha_Z \to -1, \quad \beta_S \to \gamma^{-1}\Sigma_\delta^{-1}, \quad \phi_H \to -1,$$
$$\lambda_\omega \to (\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1})\gamma^{-1}\Sigma_z^{-1} \to 0, \quad n = m \to 1.$$

The disclosure equilibrium parameters are given by

$$\alpha_f^* \to \gamma^{-1}(1-n^*\rho^2)^{-1}\rho, \quad \alpha_Z^* \to -(1-\rho^2)(1-n^*\rho^2)^{-1},$$
$$\beta_S^* \to \frac{\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}}, \quad \beta_I^* \to 0,$$
$$\phi_H^* \to -(n^*)^{-1}\left[1-\Sigma_u^{1/2}n_0^*\gamma^{-1}\right], \quad \phi_I^* = 0,$$
$$\lambda_O^* \to (n^*)^2\left[\Sigma_u^{1/2}(n_0^*)^{-1}-\gamma^{-1}\right]^{-1}, \quad \lambda_I^* \to \rho^2(1-\rho^2)^{-2}(1-\rho^2 n^*)n^*\gamma^{-1}\Sigma_z^{-1} \to 0,$$

The constant $n^* = (1+(n_0^*)^2)^{-1}$ and n_0^* is the positive root of

$$f(x) = x^4 - \gamma\Sigma_u^{\frac{1}{2}} \cdot x^3 + \frac{\Sigma_\delta}{1+\Sigma_\delta}\cdot x^2 - \gamma\frac{\Sigma_u^{\frac{1}{2}}\Sigma_\delta}{1+\Sigma_\delta}\cdot x + \frac{1}{1+\Sigma_\delta} = 0. \tag{B1}$$

Case 2: *When $\Sigma_u \to \infty$, the non-disclosure equilibrium parameters are given by*

$$\alpha_f \to \gamma^{-1}(1-\rho^2)^{-1}\rho, \quad \alpha_Z \to -1, \quad \beta_S \to \gamma^{-1}\Sigma_\delta^{-1}, \quad \phi_H \to -1,$$
$$\lambda_\omega \to (\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1})\gamma^{-1}\Sigma_u^{-1} \to 0, \quad n = m \to 1.$$

The disclosure equilibrium parameters are given by

$$\alpha_f^* \to \gamma^{-1}(k+\rho^2)^{-1}(1-\rho^2)^{-1}(k-\rho^2)\rho, \; \alpha_Z^* \to -(k+\rho^2)^{-1}(k-\rho^2)$$
$$\beta_S^* \to \gamma^{-1}\Sigma_\delta^{-1}, \quad \beta_I^* \to -\gamma\gamma^{-1}\Sigma_\delta^{-1}\rho^2(1-\rho^2)(k-\rho^2)^{-1},$$
$$\phi_H^* \to -1, \quad \phi_I^* = 0,$$
$$\lambda_O^* \to \gamma^{-1}\Sigma_\delta^{-1}k_1(k+\rho^2)^{-1}\Sigma_u^{-1} \to 0, \quad \lambda_I^* \to \gamma\rho^2(1-\rho^2)(k-\rho^2)^{-1}.$$

Proof. It follows from the proofs of Propositions 1 and 2. We omitted the details. □

Proposition B2. *When the insider or the hedger's hedge demand goes to infinity, all investors' welfare under two regimes are:*

- *When* $\Sigma_z \to \infty$,

$$\mathbb{E}[CE_I] \to -\frac{1}{2\gamma}\rho^2(1-\rho^2)^{-1} - \gamma^{-1}\Sigma_\delta^{-1},$$
$$\mathbb{E}[CE_I^*] \to -\frac{1}{2}\gamma(1-\rho^2)\frac{1-n^*}{1-n^*\rho^2}\Sigma_z + \frac{1}{2}\frac{\gamma^{-1}n^*\rho^2}{1-n^*\rho^2} \to -\infty,$$
$$\mathbb{E}[CE_S] \to \frac{1}{2}\gamma^{-1}\frac{1+(n-m)(1-\rho^2)}{\Sigma_\delta-(n-m)(1-\rho^2)} \to \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1},$$
$$\mathbb{E}[CE_S^*] \to \frac{1}{2}\frac{\gamma^{-1}\Sigma_\delta^{-1}n^*}{1+(1-n^*)\Sigma_\delta^{-1}}\left(1-\frac{\rho^4}{\gamma^2\Sigma_z(1-\rho^2)^2+\rho^2}\right) \to \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}\frac{n^*}{1+(1-n^*)\Sigma_\delta^{-1}},$$
$$\mathbb{E}[CE_H] \to \frac{1}{2}\gamma(n-m)(1-\rho^2)\Sigma_u \to 0,$$
$$\mathbb{E}[CE_H^*] \to \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2\left(1-\frac{\rho^4}{\gamma^2\Sigma_z(1-\rho^2)^2+\rho^2}\right)-1\right]\Sigma_u \to \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2-1\right]\Sigma_u.$$

- *When* $\Sigma_u \to \infty$,

$$\mathbb{E}[CE_I] \to \frac{1}{2\gamma}\rho^2(1-\rho^2)^{-1},$$
$$\mathbb{E}[CE_I^*] \to \frac{-1}{2\gamma}\rho^2(1-\rho^2)^{-1},$$
$$\mathbb{E}[CE_S] \to \frac{1}{2}\gamma^{-1}\frac{1+(n-m)(1-\rho^2)}{\Sigma_\delta-(n-m)(1-\rho^2)} \to \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1},$$
$$\mathbb{E}[CE_S^*] \to \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}\left(1-\frac{\rho^4}{\gamma^2\Sigma_z(1-\rho^2)^2+\rho^2}\right),$$
$$\mathbb{E}[CE_H] \to -\left(\gamma^{-1}\rho^2(1-\rho^2)^{-1}+\gamma^{-1}\Sigma_\delta^{-1}\right),$$
$$\mathbb{E}[CE_H^*] \to -\frac{1}{2}\gamma\frac{\rho^4}{\gamma^2\Sigma_z(1-\rho^2)^2+\rho^2}\Sigma_u \to -\infty.$$

Proof. **Case 1:** $\Sigma_z \to \infty$. From Proposition B1, when the insider's hedge demand $\Sigma_z \to \infty$, for the insider, we have

$$\Sigma_z(1+n\alpha_Z) = \Sigma_z\left(1-n\gamma(1-\rho^2)\frac{n}{\gamma\lambda_\omega^2\phi_H^2\Sigma_u+2\lambda_\omega+\gamma n^2(1-\rho^2)}\right)$$
$$= \Sigma_z\frac{\gamma\lambda_\omega^2\phi_H^2\Sigma_u+2\lambda_\omega}{\gamma\lambda_\omega^2\phi_H^2\Sigma_u+2\lambda_\omega+\gamma n^2(1-\rho^2)} \to 2\frac{\lambda_\omega\Sigma_z}{\gamma(1-\rho^2)}.$$

As $\lambda_\omega \to 0$, equation (A26) gives

$$\lambda_\omega\Sigma_z \to \alpha_X\rho^2+\beta_S = \gamma^{-1}(1-\rho^2)^{-1}\rho^2+\gamma^{-1}\Sigma_\delta^{-1}.$$

Then,

$$
\begin{aligned}
\mathbb{E}[CE_I] &= -\frac{1}{2}\gamma(1-\rho^2)(1+\alpha_Z n)\cdot\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\alpha_Z n \\
&\to -\frac{1}{2\gamma}\rho^2(1-\rho^2)^{-1} - \gamma^{-1}\Sigma_\delta^{-1}, \\
\mathbb{E}[CE_I^*] &= -\frac{1}{2}\gamma(1-\rho^2)(1+n^*\alpha_Z^*)\cdot\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\cdot n^*\alpha_Z^* \\
&\to -\frac{1}{2}\gamma(1-\rho^2)\left(1-\frac{1-\rho^2}{1-n^*\rho^2}n^*\right)\cdot\Sigma_z + \frac{1}{2}\frac{\gamma^{-1}\rho^2 n^*}{1-n^*\rho^2} \\
&= -\frac{1}{2}\gamma(1-\rho^2)\frac{1-n^*}{1-n^*\rho^2}\Sigma_z + \frac{1}{2}\frac{\gamma^{-1}n^*\rho^2}{1-n^*\rho^2} \to -\infty.
\end{aligned}
$$

For speculators, we have

$$
\begin{aligned}
\mathbb{E}[CE_S] &= \frac{1}{2}(m\rho^2+n(1-\rho^2))\beta_S = \frac{1}{2}\gamma^{-1}\frac{m\rho^2+n(1-\rho^2)}{1+\Sigma_\delta-m\rho^2-n(1-\rho^2)} \\
&= \frac{1}{2}\gamma^{-1}\frac{m+(n-m)(1-\rho^2)}{1-m+\Sigma_\delta-(n-m)(1-\rho^2)} \to \frac{1}{2}\gamma^{-1}\frac{1+(n-m)(1-\rho^2)}{\Sigma_\delta-(n-m)(1-\rho^2)} \to \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}, \\
\mathbb{E}[CE_S^*] &= \frac{1}{2}k_1(\rho^2+k)^{-1}n^*\beta_S^* \to \frac{1}{2}k_1(\rho^2+k)^{-1}\frac{n^*\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}} \to \frac{1}{2}\frac{n^*\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}}.
\end{aligned}
$$

For the hedger, we have

$$
\begin{aligned}
\mathbb{E}[CE_H] &= \frac{1}{2}\gamma\left[-1-\phi_H(m\rho^2+n(1-\rho^2)+\gamma^{-1}\lambda_\omega\phi_H)\right]\Sigma_u \\
&= \frac{1}{2}\gamma\left[-1-\phi_H(m+(n-m)(1-\rho^2)+\gamma^{-1}\lambda_\omega\phi_H)\right]\Sigma_u \\
&\to \frac{1}{2}\gamma(n-m)(1-\rho^2)\Sigma_u \to 0, \\
\mathbb{E}[CE_H^*] &= \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2k_1(\rho^2+k)^{-1}-1\right]\Sigma_u \to \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2-1\right]\Sigma_u < 0.
\end{aligned}
$$

Case 2: $\Sigma_u \to \infty$. From Proposition B1, when the hedger's hedge demand $\Sigma_u \to \infty$, for the insider, we have

$$
\begin{aligned}
\mathbb{E}[CE_I] &\to \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2, \\
\mathbb{E}[CE_I^*] &= -\frac{1}{2}\gamma(1-\rho^2)(1+n^*\alpha_Z^*)\cdot\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\cdot n^*\alpha_Z^* \\
&\to -\frac{1}{2}\gamma(1-\rho^2)\left(1-\frac{k-\rho^2}{k+\rho^2}\right)\cdot\Sigma_z + \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\frac{k-\rho^2}{k+\rho^2} \\
&= -\frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2.
\end{aligned}
$$

For speculators, we derive

$$\begin{aligned}
\mathbb{E}[CE_S] &= \frac{1}{2}(m\rho^2 + n(1-\rho^2))\beta_S = \frac{1}{2}\gamma^{-1}\frac{m\rho^2 + n(1-\rho^2)}{1+\Sigma_\delta - m\rho^2 - n(1-\rho^2)} \\
&= \frac{1}{2}\gamma^{-1}\frac{m + (n-m)(1-\rho^2)}{1-m+\Sigma_\delta-(n-m)(1-\rho^2)} \to \frac{1}{2}\gamma^{-1}\frac{1+(n-m)(1-\rho^2)}{\Sigma_\delta-(n-m)(1-\rho^2)}, \\
\mathbb{E}[CE_S^*] &= \frac{1}{2}k_1(\rho^2+k)^{-1}n^*\beta_S^* \to \frac{1}{2}k_1(\rho^2+k)^{-1}\gamma^{-1}\Sigma_\delta^{-1}.
\end{aligned}$$

For the hedger, when $\Sigma_u \to +\infty$, we could show that $\lambda_\omega\Sigma_u \to \alpha_X\rho^2 + \beta_S = \gamma^{-1}\rho^2(1-\rho^2) + \gamma^{-1}\Sigma_\delta^{-1}$. Under non-disclosure regime, putting $y = m\rho^2 + n(1-\rho^2)$, we derive

$$\begin{aligned}
\mathbb{E}[CE_H] &= \frac{1}{2}\gamma\left[-1 - \phi_H(m\rho^2 + n(1-\rho^2) + \gamma^{-1}\lambda_\omega\phi_H)\right]\Sigma_u \\
&= \frac{1}{2}\gamma\left[-1 - y\phi_H\right]\Sigma_u - \frac{1}{2}\phi_H^2\lambda_\omega\Sigma_u \\
&= \frac{1}{2}\gamma\left[-1 - \frac{y^2}{N - \gamma^{-1}\lambda_\omega - y}\right]\Sigma_u - \frac{1}{2}\phi_H^2\lambda_\omega\Sigma_u \\
&= -\frac{1}{2}\gamma\left[\frac{-N + \gamma^{-1}\lambda_\omega + y - y^2}{-N + \gamma^{-1}\lambda_\omega + y}\right]\Sigma_u - \frac{1}{2}\phi_H^2\lambda_\omega\Sigma_u \\
&\to -\frac{1}{2}\gamma\left[-N + \gamma^{-1}\lambda_\omega + y - y^2\right]\Sigma_u - \lambda_\omega\Sigma_u.
\end{aligned}$$

For the term $\left[-N + y - y^2\right]\Sigma_u$, we deduce

$$\begin{aligned}
\left[-N + y - y^2\right]\Sigma_u &= \left[m^2\rho^2 + n^2(1-\rho^2) + k(n-m)^2 - \left(m\rho^2 + n(1-\rho^2)\right)^2\right]\Sigma_u \\
&= (n-m)^2k_1\Sigma_u = k_1\alpha_X^2\lambda_\omega^2\Sigma_u \to 0.
\end{aligned}$$

Therefore,

$$\mathbb{E}[CE_H] \to -\lambda_\omega\Sigma_u \to -\gamma^{-1}\rho^2(1-\rho^2) - \gamma^{-1}\Sigma_\delta^{-1}. \tag{B2}$$

Under disclosure regime, we have

$$\mathbb{E}[CE_H^*] = \frac{1}{2}\gamma\left[(\phi_H^*)^2(n^*)^2k_1(\rho^2+k)^{-1} - 1\right]\Sigma_u \to \frac{1}{2}\gamma\left[k_1(\rho^2+k)^{-1} - 1\right]\Sigma_u \to -\infty.$$

□

Proposition B3. *The insider, each speculator and the hedger trading profit π_I, π_S, π_H under non-disclosure and disclosure regimes are given by*

$$\pi_I = \rho^2 n\alpha_X - \lambda_\omega(\rho^2+k)\alpha_X^2, \quad \pi_S = \beta_S(m\rho^2 + n(1-\rho^2)), \quad \pi_H = -\lambda_\omega\phi_H^2\Sigma_u, \tag{B3}$$

$$\pi_I^* = 0, \quad \pi_S^* = k_1(\rho^2+k)^{-1}n^*\beta_S^*, \quad \pi_H^* = -\pi_S^*. \tag{B4}$$

When $\Sigma_z \to \infty$, we have

$$\pi_I \to -\Sigma_\delta^{-1}\gamma^{-1}, \qquad \pi_S \to -\pi_I, \qquad \pi_H \to 0,$$
$$\pi_I^* \to 0, \qquad \pi_S^* \to \gamma^{-1}\Sigma_\delta^{-1}\frac{n^*}{1+(1-n^*)\Sigma_\delta^{-1}}, \quad \pi_H^* = -\pi_S^*.$$

When $\Sigma_u \to \infty$, we have

$$\pi_I \to \gamma^{-1}\rho^2(1-\rho^2)^{-1}, \qquad \pi_S \to \Sigma_\delta^{-1}\gamma^{-1}, \qquad \pi_H \to -\gamma^{-1}\rho^2(1-\rho^2)^{-1} - \Sigma_\delta^{-1}\gamma^{-1},$$
$$\pi_I^* \to 0, \qquad \pi_S^* \to \gamma^{-1}\Sigma_\delta^{-1}k_1(k+\rho^2)^{-1}, \quad \pi_H^* = -\pi_S^*.$$

Proof. The trading profit is straightforward to calculate and the cases of $\Sigma_z \to \infty$ and $\Sigma_u \to \infty$ follow from Proposition B1. We omit the details. □