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

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December 23, 2023

*We thank Snehal Banerjee, Tobias Berg, Ing-Haw Cheng, Jérôme Dugast, Thomas Ernst, Sivan Frenkel, Itay Goldstein, Vahid Irani, Chao Jiang, Anastasios Kagkadis, Xuelin Li, Xiaomeng Lu, Chang Ma, Liang Ma, Roberto Pinto, Francesco Sangiorgi, Sergey Tsyplakov, Zacharias Sautner, Kevin Colby Smith, Grigory Volkov, Yafei Zhang, and participants at the 2023 Midwest Finance Association (MFA) Conference 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. The research of Jun Deng is supported by National Natural Science Foundation of China (Grant No. 72371073).

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Abstract

We analyze two insider-trading regulations recently introduced by the SEC: mandatory disclosure and "cooling-off period." The former requires insiders to disclose trading plans at adoption, while the latter mandates a delay period before execution. Disclosure increases price informativeness but has mixed welfare implications. If the insider has sufficiently large liquidity needs, in contrast to the conventional wisdom from "sunshine trading," disclosure reduces welfare of all investors. A cooling-off period affects welfare through its effects on relative information advantages among investors and the market's risk-sharing effectiveness. Calibrations suggest that an insider benefits from a longer cooling-off period under the disclosure regime.

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 accommodate those trading activities. In the U.S., for example, the Securities and Exchange Commission (SEC) Rule 10b5-1 created an affirmative defense for a corporate executive to charge of insider trading if the transactions are executed according to a predetermined plan that is created before the person becomes aware of the relevant MNPI.

Soon after the rule's implementation in 2000, however, researchers and regulators became concerned about its abuse by corporate insiders (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 proposals to regulate Rule 10b5-1 plans, some of which have been adopted recently.[2]

Two major rule changes stand out. The first is about the disclosure of 10b5-1 plans. Before the rule changes, an insider did not need to pre-disclose his trading plans. Some researchers expressed concern that this opacity invites opportunistic insider trading.[3] The new rule requires insiders publicly disclose their trading plans upon adoption, modification, and cancellation.

[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. See the press release of the adoption at https://www.sec.gov/news/press-release/2022-222.

[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.

The other rule change is a mandatory "cooling-off period," the minimum waiting period from the initiation of a 10b5-1 plan to the first trade under that plan. Before the rule changes, there was no SEC 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, the new regulation imposes a mandatory cooling-off period ranging from 30 to 120 days, depending on the insider's positions.[4]

In this paper, we analyze these two new rule changes 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, with the same risk aversion coefficient, and submit market orders. A risk-neutral market maker sets the stock price to its expected fundamental value.

The disclosure policy essentially 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. We find that disclosure increases stock price informativeness but has mixed welfare implications.

Price informativeness 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 can also interpret outside speculators' information better, since their orders are separate from the insider's under the disclosure regime.

[4] See "Insider Trading Arrangements and Related Disclosures", [SEC Release Nos. 33-11138; 34-96492; File No. S7-20-21] (https://www.sec.gov/rules/final/2022/33-11138.pdf) and "Fact Sheet: Rule 10b5-1: Insider Trading Arrangements and Related Disclosure" (https://www.sec.gov/files/33-11138-fact-sheet.pdf).

However, disclosure does not always improve investors' welfare. In fact, we show analytically that in a limit case in which the insider's hedging need is sufficiently large, the disclosure policy makes all investors worse off. At the first sight, this result appears contradictory to the standard intuition from "sunshine trading." Admati and Pfleiderer (1991) show that if an investor's trade is mostly informationless, the investor would receive favorable execution prices from disclosing his trade in advance (i.e., sunshine trading). 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. This 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 by 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.

The improvement in price informativeness leads to a reduction in risk-sharing opportunities and hence harm hedgers (i.e., outside investors whose primary goal is risk sharing). The disclosure also harm speculators (i.e., informed outside investors) because their trades can no longer be mixed with the insider's large hedging trades and hence have a higher price impact under the disclosure regime. Taken together, when the insider's hedging need is sufficiently large, disclosure makes all investors worse off.

Our analysis on profits versus welfare highlights a novel aspect of sunshine trading. The existing literature (e.g., Hawke Jr et al., 1988; Admati and Pfleiderer, 1991) has so far focused primarily on the intuition that an uninformed sunshine trader can get better trading terms and avoid higher trading losses *ex post*. However, our analysis shows that from an *ex-ante* perspective, sunshine trading necessarily reduces the effectiveness of risk sharing, which can harm all investors.

We conduct a calibration exercise to examine our model implications in empirically relevant parameter regions. In particular, we estimate the trading activities of corporate insiders and institutional investors and use them as proxies for the trading activities of the insider and speculators in our model, respectively. We then choose our model parameters to match those estimates. Our calibration shows, as expected, disclosure improves price informativeness. The welfare implications are mixed. Consistent with the limit case discussed above, our calibration shows that when the insider's hedging need is relatively high, all investors are worse off. However, when the insider's hedging need is modest, he may benefit from disclosure especially if he has less private information. Moreover, outside investors tend to 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).

The mandatory cooling-off period policy is predicated on the intuition that by imposing a delay, the policy tends to reduce the insider's information advantage. Suppose, for example, the insider received some information about his firm. If he can trade right away, he would have large 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. This can happen for two reasons. First, the firm's fundamentals might have changed during the cooling-off period, and so the insider's information becomes obsolete when he trades. Second, the insider's information might have leaked during the cooling-off period.

We analyze both scenarios. In the baseline model, we use the amount of the insider's private information as a proxy that is inversely related to the length of a cooling-off period. This approach captures the idea that the insider's private information is about the firm's current value, and as time passes by, the firm's fundamentals would change so that the insider's information becomes less useful after the cooling-off period. The alternative formulation is based on the idea of information leakage. That is, during the cooling-off period, outside investors obtain a signal about the insider's information. The longer the cooling-off period, the higher the signal precision.

In both formulations, a longer cooling-off period decreases the insider's information advantage. But they focus on different perspectives. The baseline model focuses on the insider having less private information while the alternative formulation focuses on the idea that outsiders learn more about the insider's private information after a longer cooling-off period. Hence, a longer cooling-off period implies lower price informativeness in the former model but higher price informativeness in the latter. However, since both models are based on the same idea that a longer cooling-off period reduces the insider's relative information advantage, their implications on investors' price impacts are qualitatively the same.

In both formulations, the cooling-off period affects investor welfare through the interaction between two forces. First (information effect), it affects the relative information advantages among investors and hence their expected trading profits. Second (risk-sharing effect), it affects the effectiveness of risk-sharing among investors. The overall effect is determined by the relative strength of the two forces. Although the overall effects on investors' welfare may differ across the two formulations in general, they remain qualitatively the same in our calibrations. Under the non-disclosure regime, the information effect dominates: a longer cooling-off period reduces the insider's information advantage, which reduces the insider's welfare but increases the welfare of outside investors (i.e., speculators and the hedger).

The implications under the disclosure regime are as follows. We show, analytically, that the insider's *ex ante* expected trading profit is the risk free rate regardless of the cooling-off period length. This is because the insider's trade is public information under the disclosure regime. Since the price is set by a risk neutral market maker, the expected return of any trading strategy based on the market maker's information is the risk free rate. Our calibration shows that as the insider's information advantage diminishes after a longer cooling-off period, speculators are in a better position to take advantage of hedgers. Hence, a longer cooling-off period increases speculators' expected trading profits and welfare, while the opposite is true for the hedger.

The implications for the insider are more subtle. Note that the information channel is shut down in this case because the cooling-off period length does not affect the insider's *ex ante* expected trading profit, which is always the risk free rate. Hence, the effect of the cooling-off period is entirely from the risk-sharing channel. In both formulations, a shorter cooling-off period makes the insider's order more toxic and hence increases its price impact, which implies a lower hedging effectiveness as the insider is forced to cut back its trades. Therefore, the insider benefits from a longer cooling-off period under the disclosure regime.

Our analysis of the pre-announcement of insider trading, the newly introduced SEC rule, is related to the extensive theoretical literature on insider trading.[5] Most closely, our paper is related to the studies on disclosure of tradings by insiders. Huddart et al. (2001), Buffa (2013) and Mele and Sangiorgi (2021) examine post-trade disclosure, and Medran and Vives (2004) explore disclosure of the insider's private information. The new 10b5-1 plan disclosure rule 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), where all outside investors are uninformed. In our analysis, 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 investors' information in information aggregation). Second, neither study examines the cooling-off policy, which is a key rule change by the SEC. To the best of our knowledge, our paper is the first analysis of this rule.

[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).

Our study also sheds light on the analysis of sunshine trading, an intriguing idea that became prominent after the stock market crash in October 1987. This idea has drawn interest from practitioners, regulators, and researchers (e.g., Hawke Jr et al., 1988; Admati and Pfleiderer, 1991). However, the analysis in the literature has focused on the intuition that if an investor creditably declares that his trading is uninformed, then he can avoid adverse selection and get a better trading price. Our analysis highlights a new insight: from the ex-ante perspective, sunshine trading necessarily reduces the effectiveness of risk sharing in the market. That is, declaration of uninformed trade necessarily reveals informed trades (from other investors) in the market. This information revelation reduces the ex-ante risk sharing function of the market. We show that in a standard microstructure model, this risk-sharing effect can dominate, not only in the limit case in which the insider's hedging need is sufficiently large but also in our calibration with reasonable parameter values.

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 normally distributed cash flow $\tilde{f}$ at $t = 2$, where $\tilde{f} \sim N(p_0, \Sigma_f)$ with constants $p_0 \in \mathbb{R}$ and $\Sigma_f > 0$. There is also a risk-free asset with a net interest rate of 0.

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 mutually independent components $\tilde{f}_a$ and $\tilde{f}_b$:

$$\tilde{f} = p_0 + \rho \tilde{f}_a + \sqrt{1-\rho^2}\tilde{f}_b, \tag{1}$$

where $\rho \in [0,1)$ is a constant, $\tilde{f}_a \sim N(0, \Sigma_f)$, and $\tilde{f}_b \sim N(0, \Sigma_f)$. 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.

The insider derives 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:

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

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 distributed ($\tilde{\delta}_j \sim N(0, \Sigma_\delta)$ with $\Sigma_\delta > 0$) 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:

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

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

$$W_{S,j} = D_{S,j}(\tilde{f} - \tilde{p}), \tag{6}$$

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 we consider a representative hedger. The representative hedger has an endowment of $\tilde{u}$ shares of the stock, where $\tilde{u}$ is normally distributed ($\tilde{u} \sim N(0, \Sigma_u)$ with $\Sigma_u > 0$) 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:

$$\max_{D_H} \mathbb{E}\left[U(W_H)\big|F_H\right], \tag{7}$$

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

$$W_H = D_H(\tilde{f} - \tilde{p}) + \tilde{u}\tilde{f}, \tag{8}$$

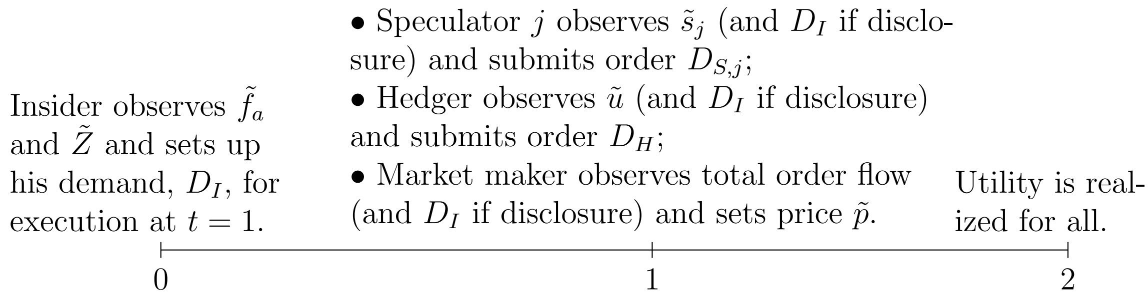
and F_H is the hedger's information set and will be described in detail in Section 2.1.

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

$$\tilde{p} = \mathbb{E}\left[\tilde{f}\ \middle| F_M\right], \tag{9}$$

where F_M is the market maker's information set and will be described in the next section. The following figure summarizes the timeline of events in our model.

Figure 1. Timeline.



2.1 Disclosure of the Insider Trading Plan

As noted in Larcker et al. (2021), until the recent SEC rule change, insiders are not required to disclose their 10b5-1 plans. Since April 1, 2023, the newly adopted SEC rule requires insiders to publicly disclose any initiation, modification, and cancellation of their 10b5-1 plans.[6] 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), (7), and (9). Under the non-disclosure regime, the insider's planned trade D_I is not publicly disclosed and thus, D_I is not in the information sets of other market participants:

$$F_{S,j} = \{\tilde{s}_j\}, \quad F_H = \{\tilde{u}\}, \quad \text{and} \quad F_M = \{\tilde{\omega}\}, \tag{10}$$

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

$$\tilde{\omega} = D_H + \int_0^1 D_{S,j}\, dj + D_I. \tag{11}$$

Under the new regime, however, the insider is required to publicly disclose his trading plan

[6] See, for example, the press release of the SEC proposal in 2021: *SEC Proposes Amendments Regarding Rule 10b5-1 Insider Trading Plans and Related Disclosures*, https://www.sec.gov/news/press-release/2021-256, and the press release after the proposal was adopted in 2022 https://www.sec.gov/news/press-release/2022-222.

D_I at $t = 0$. Hence, other market participants' information sets become:

$$F_{S,j} = \{\tilde{s}_j, D_I\}, \quad F_H = \{\tilde{u}, D_I\}, \quad \text{and} \quad F_M = \{\tilde{\omega}, D_I\}. \tag{12}$$

2.2 Cooling-Off Period

Until the recent policy change, there has been no SEC requirement for a cooling-off period, the period between the initiation of a 10b5-1 plan and the execution of the first trade. 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, the recent regulatory change by the SEC makes mandatory a cooling-off period of 30 to 120 days.

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. The rule of a mandatory cooling-off period aims to reduce the insider's information advantage. In our model, the cooling-off period corresponds to the period from $t = 0$ (plan adoption time) to $t = 1$ (execution time) and so the way to capture the effect of a cooling-off period in our setting is to model how the insider's information advantage changes between $t = 0$ and $t = 1$. We consider two approaches in this paper. In the first, the insider's private information becomes partially obsolete by the time of execution. In the second, the insider's information partially leaks out before the execution time.

Information obsolescence. As discussed in the Introduction, there are various reasons why a cooling-off period reduces the insider's information value. One is simply that the firm's fundamental value can change over time and so the insider's private information will naturally become obsolete over time. This perspective can be captured by parameter ρ in our model, which directly controls the amount of the insider's private information. Intuitively, the longer the cooling-off period is, the smaller the parameter ρ is. In Appendix A, we provide a stylized dynamic setting to illustrate how parameter ρ can serve as a proxy for the length of the cooling-off period. In that setting, the firm value evolves according to an AR(1) process, as in Admati and Pfleiderer (1988). The insider has private information about the current firm value. If he has to wait some time to trade, his information becomes less relevant at the trading time since the firm's value would have changed by then. This formulation is consistent with Cohen et al. (2012) who find that insiders have private information about shorter-term news events as opposed to long-term firm-level measures such as annual employment or inventory changes.

Information leakage. The other formulation is based on the idea that the insider's private information would leak out during the cooling-off period. Hence, by the time the insider' trade is executed, outside investors may have partially learned about the insider's information, which reduces the insider's information advantage. In Section 5, we present a formulation of a cooling-off period from this information-leakage perspective. In this alternative model, the total amount of the insider's information is fixed and outsider investors can observe a garbled signal about the insider's information. As the cooling-off period becomes longer, there are more chances for information leakage. Hence, the precision of the signal can be viewed as a proxy for the cooling-off period length. The longer the cooling-off period is, the more precise this signal is.

2.3 Discussions

We make four remarks about our model setup. First, the insider's trading plan utilizes his private information $\tilde{f}_a$. To be qualified for an affirmative defense against litigation of illegal insider trading, a 10b5-1 plan must be adopted at a time when the insider is not aware of MNPI. However, it is notoriously difficult for regulators to establish in a court whether a trading plan is based on MNPI. It is almost inevitable that some of the insider trading is based on MNPI. Indeed, it has been widely noted that trades under 10b5-1 plans are informed on average (see, e.g., Jagolinzer, 2009). This feature is captured by the assumption that the insider's trading plan is based on his private information $\tilde{f}_a$.

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".[7]

Third, we implicitly assume that the insider does not trade outside 10b5-1 plans. One possible reason is that the insider finds that the potential litigation is too costly and always prefers to trade under 10b5-1 plans. Alternatively, the firm may have reputation concerns and requires all senior managers to trade under 10b5-1 plans. 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 forgo the benefit of the affirmative defense and trade outside the plans. We leave this extension to future research.

Finally, there is only one round of trading in our model. This assumption greatly simplifies our analysis and makes the key intuition transparent. However, this assumption also rules out the effects of dynamic considerations by outside investors. For example, one concern about the disclosure of the insider's trading plan is that outside investors may "front run" to exploit the insider's trading. In an extension of our baseline model (presented in Online Appendix), we introduce an additional round of trading for outside investors at $t = 0$, which

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

gives speculators an opportunity to front run the insider's trade at $t = 1$. We show that this additional feature of multiple trading rounds does capture the intuition on front running but makes the analysis substantially more tedious. Moreover, the welfare implications in this extended model remain similar to those in the baseline model.

3 Equilibrium and Measurement

We construct the equilibria with and without disclosure in Sections 3.1 and 3.2, respectively. In Section 3.3, we discuss the measures for policy assessment.

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 (10). We conjecture and verify the following linear demand and price functions:

$$D_I = \alpha_f \tilde{f}_a + \alpha_Z \tilde{Z}, \tag{13}$$

$$D_{S,j} = \beta_S(\tilde{s}_j - p_0), \tag{14}$$

$$D_H = \phi_H \tilde{u}, \tag{15}$$

$$\tilde{p} = p_0 + \lambda_\omega \tilde{\omega}. \tag{16}$$

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

Proposition 1. (Equilibrium characterization: Non-disclosure regime) *In the non-disclosure economy, the coefficients* $\{\lambda_\omega, \alpha_f, \alpha_Z, \beta_S, \phi_H\}$ *of the linear equilibrium in equations* (13)–(16)

are characterized as follows:

$$\lambda_\omega = \gamma(1-n)M, \tag{17}$$

$$\alpha_f = \lambda_\omega^{-1}(n-m)\rho, \tag{18}$$

$$\alpha_Z = -\alpha_f \gamma \Sigma_f (1-\rho^2)\rho^{-1}, \tag{19}$$

$$\beta_S = \gamma^{-1}M^{-1}, \tag{20}$$

$$\phi_H = \frac{m\rho^2\Sigma_f + n(1-\rho^2)\Sigma_f}{N - \gamma^{-1}\lambda_\omega - m\rho^2\Sigma_f - n(1-\rho^2)\Sigma_f}, \tag{21}$$

where

$$M \equiv \Sigma_f(1 - m\rho^2 - n(1-\rho^2)) + \Sigma_\delta,$$
$$N \equiv \Sigma_f\left(m(1-m)\rho^2 + n(1-n)(1-\rho^2)\right) - \gamma^2(1-\rho^2)^2\Sigma_f^2\Sigma_z(n-m)^2.$$

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

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

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

The above proposition characterizes all five parameters for the equilibrium. Its proof, reported in Appendix B, 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.

The proposition shows that the equilibrium is fully determined by two endogenous constants, m and n, which are the solutions to the two polynomials (22) and (23). With m and n, we can fully pin down the equilibrium parameters $\{\alpha_f, \alpha_Z, \beta_S, \phi_H, \lambda_\omega\}$. 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:*

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

(2) *If γ is sufficiently small, there is no linear 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 a linear equilibrium. By the same logic, if the risk aversion γ is sufficiently small, there are not enough risk-sharing motives to sustain a linear 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 (12). We conjecture and verify the following linear demand and price functions in the equilibrium with advance disclosure:

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

$$D_{S,j}^* = \beta_S^*(\tilde{s}_j - p_0) + \beta_I^* D_I^*, \tag{25}$$

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

$$\tilde{p}^* = p_0 + \lambda_O^*\Big(\beta_S^*(\tilde{f} - p_0) + \phi_H^* \tilde{u}\Big) + \lambda_I^* D_I^*. \tag{27}$$

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:

$$\tilde{p}^* = p_0 + \lambda_O^* \left(D_H^* + \int_0^1 D_{S,j}^* dj \right) + \Big(\lambda_I^* - \lambda_O^* (\beta_I^* + \phi_I^*) \Big) D_I^*.$$

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 $D_{S,j}^*$ and D_H^* from the speculators and the hedger, which then affect the price as highlighted in (27).

The following proposition characterizes the equilibrium under the disclosure regime.

Proposition 2. (Equilibrium characterization: Disclosure regime) *In the disclosure economy, the coefficients* $\{\alpha_f^*, \alpha_Z^*, \beta_S^*, \beta_I^*, \phi_H^*, \phi_I^*, \lambda_O^*, \lambda_I^*\}$ *of the linear equilibrium in equations*

(24)–(27) *are characterized as follows:*

$$\alpha_f^* = \gamma^{-1}(k_1 - \rho^2\Sigma_f k n^*)^{-1}\left(k - \rho^2\Sigma_f\right)\rho, \tag{28}$$

$$\alpha_Z^* = -\alpha_f^*\gamma\Sigma_f(1-\rho^2)\rho^{-1}, \tag{29}$$

$$\beta_S^* = (1-n^*)(\lambda_O^*)^{-1}, \tag{30}$$

$$\beta_I^* = -\beta_S^*\gamma(k_1 - \rho^2\Sigma_f k n^*)(1+\rho^{-2}\Sigma_f^{-1}k)^{-1}\left(k-\rho^2\Sigma_f\right)^{-1}, \tag{31}$$

$$\phi_H^* = -(n^*)^{-1}\left[1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}k_1^{-1/2}(\rho^2\Sigma_f + k)^{\frac{1}{2}}\right], \tag{32}$$

$$\phi_I^* = 0, \tag{33}$$

$$\lambda_O^* = (n^*)^2\left[\Sigma_u^{1/2}(n_0^*)^{-1}k_1^{-\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{1}{2}} - \gamma^{-1}(\rho^2\Sigma_f + k)k_1^{-1}\right]^{-1}, \tag{34}$$

$$\lambda_I^* = -n^*\beta_I^*(\beta_S^*)^{-1}, \tag{35}$$

where

$$k = \gamma^2(1-\rho^2)^2\Sigma_f^2\Sigma_z, \quad k_1 = k\Sigma_f + \rho^2(1-\rho^2)\Sigma_f^2, \quad k_2 = k_1 + (k+\rho^2\Sigma_f)\Sigma_\delta.$$

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

$$x^4 - \gamma\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2\Sigma_f + k)^{-\frac{1}{2}}x^3 + (\rho^2\Sigma_f + k)\Sigma_\delta k_2^{-1}x^2 - \gamma\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{1}{2}}\Sigma_\delta k_2^{-1}x + k_1k_2^{-1} = 0. \tag{36}$$

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 B 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 (31) and (33) 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 constant n^*. Hence, the existence and uniqueness of the equilibrium is determined by the properties of equation (36), as summarized in the following corollary.

Corollary 2. *In the disclosure economy:*

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

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

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

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

3.3 Measures for Policy Assessment

Our analysis focuses on investor welfare, since one primary goal of policy interventions is to improve investor welfare. In addition, it is also theory's relative strength to conduct a normative analysis given that welfare is mainly a theoretical concept. We also analyze other relevant variables, including price informativeness, market liquidity, and investor profit, because these variables are useful for us to describe the intuitions and highlight the novelty of the results. Specifically, price informativeness is one important force of policies affecting welfare through the risk-sharing channel. Investor profit is the key variable that differentiates our analysis from the sunshine trading literature, and market liquidity is the key variable explaining the difference. We now define these variables and present some preliminary results.

Investor welfare. Since the market maker always breaks even in equilibrium, we focus on the welfare of the other three types of investors. 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. We obtain those certainty equivalents from the following:

$$U(CE_I) = \mathbb{E}\left[U(W_I)|\tilde{Z}, \tilde{f}_a\right], \tag{37}$$

$$U(CE_H) = \mathbb{E}\left[U(W_H)|\tilde{u}\right], \tag{38}$$

$$U(CE_{S,j}) = \mathbb{E}\left[U(W_{S,j})|\tilde{s}_j\right]. \tag{39}$$

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:

$$U(CE_I^*) = \mathbb{E}\left[U(W_I^*)|\tilde{Z}, \tilde{f}_a\right], \tag{40}$$

$$U(CE_H^*) = \mathbb{E}\left[U(W_H^*)|\tilde{u}, D_I^*\right], \tag{41}$$

$$U(CE_{S,j}^*) = \mathbb{E}\left[U(W_{S,j}^*)|\tilde{s}_j, D_I^*\right]. \tag{42}$$

Note that an investor's certainty equivalent is a function of his 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, we follow Morris and Shin (2002) and Van Nieuwerburgh and Veldkamp (2010) and compute the *ex ante* expectations of those certainty equivalents. Since all speculators are ex ante identical, 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. The expressions of these welfare variables are presented in the following corollary.

Corollary 3. *The ex ante expectations of the certainty equivalents in the two economies are*

$$\mathbb{E}[CE_I] = -\frac{1}{2}\gamma(1-\rho^2)\Sigma_f(1+\alpha_Z n)\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\alpha_Z n, \tag{43}$$

$$\mathbb{E}[CE_I^*] = -\frac{1}{2}\gamma(1-\rho^2)\Sigma_f(1+\alpha_Z^* n^*)\Sigma_z - \frac{1}{2}(1-\rho^2)^{-1}\gamma^{-1}\rho^2\alpha_Z^* n^*, \tag{44}$$

$$\mathbb{E}[CE_{S,j}] = \frac{1}{2}(m\rho^2 + n(1-\rho^2))\Sigma_f\beta_S, \tag{45}$$

$$\mathbb{E}[CE_{S,j}^*] = \frac{1}{2}k_1(\rho^2\Sigma_f + k)^{-1}n^*\beta_S^*, \tag{46}$$

$$\mathbb{E}[CE_H] = -\frac{1}{2}\gamma\left[\Sigma_f + \phi_H(m\rho^2\Sigma_f + n(1-\rho^2)\Sigma_f + \gamma^{-1}\lambda_\omega\phi_H)\right]\Sigma_u, \tag{47}$$

$$\mathbb{E}[CE_H^*] = \frac{1}{2}\gamma k_1(\rho^2\Sigma_f + k)^{-1}\left[(\phi_H^*)^2(n^*)^2 - 1\right]\Sigma_u. \tag{48}$$

Price informativeness. Price informativeness refers to the precision of the signal about the stock cash flow revealed by the stock price and thus, it is measured as follows:

$$INF \equiv \left(Var(\tilde{f}|\tilde{p})\right)^{-1} \quad \text{and} \quad INF^* \equiv \left(Var(\tilde{f}|\tilde{p}^*)\right)^{-1},$$

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

Corollary 4. *The price informativeness under the two regimes is given by*

$$INF = \Sigma_f^{-1}(\rho^2 m + (1-\rho^2)n)^{-1} \; \textit{and} \quad INF^* = (n^*)^{-1}k_1^{-1}(\rho^2\Sigma_f + k).$$

Market liquidity. In the economy without disclosure, the stock market illiquidity (Kyle's lambda) can be measured by λ_ω, which is given by (17). In the economy with disclosure, the stock market illiquidity is captured by two measures, λ_O^* and λ_I^*, which are given by (34) and (35), respectively. The former is the price sensitivity to the total order flow from outside investors, while the latter is the price sensitivity to the insider's order flow.

Investor profit. We use π_I, π_S, and π_H to denote the expected trading profits of the insider, speculators, and the hedger, respectively, in the non-disclosure economy. That is, $\pi_I = \mathbb{E}[D_I(\tilde{f} - \tilde{p})]$, $\pi_S = \mathbb{E}[D_{S,j}(\tilde{f} - \tilde{p})]$, and $\pi_H = \mathbb{E}[D_H(\tilde{f} - \tilde{p})]$. Similarly, we can define and compute the expected trading profits π_I^*, π_S^*, and π_H^* in the disclosure economy.

Corollary 5. *Under the disclosure regime, the insider's ex ante expected trading profit is zero:* $\pi_I^* = 0$

The intuition is as follows. In our model, the stock price is set by a risk neutral market maker. Hence, any trading strategy that is observable to the market maker has an expected return of the risk free rate, which is normalized to zero in our model. Under the disclosure regime, the insider's trade is public information and hence observable to the market maker. Therefore, the insider's *ex ante* expected trading profit is zero under the disclosure regime.

3.4 Limit Case

As illustrated in Propositions 1 and 2, both equilibria are highly non-linear, making analytical analysis of the general case intractable. In this section, we analyse a limit case in which the insider's hedging need Σ_z is sufficiently large. This case allows for explicit analytical results and hence can better illustrate the intuition. Then, we conduct a calibration exercise in Section 4 to discuss model implications in empirically relevant parameter regions.

We follow the spirit of Peress (2004) and derive an equilibrium based on a first-order approximation for the case with a sufficient large insider's hedging need. Formally, suppose that $\Sigma_z \to \infty$, or equivalently, $1/\Sigma_z \to 0$. We keep the $1/\Sigma_z$ terms and neglect higher order terms when computing an equilibrium. Under this approximation, the equilibrium coefficients of trading strategies and pricing function (α, β, ϕ, and λ) are linear in $1/\Sigma_z$. For the non-disclosure economy, we can fully compute these coefficients and express them in terms of exogenous parameters. For the disclosure economy, we can characterize these coefficients up to one unknown constant, which is a solution to a quartic equation. The detailed computations and characterizations are delegated to the Online Appendix. The comparison between the two equilibria leads to the following proposition.[8]

Proposition 3. (Limit case) *When the insider's hedging need 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 outside investors' expected trading profits:* $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, *and* $\pi_H^* < \pi_H$.

(3) *It improves the informativeness of the stock price:* $INF^* > INF$.

(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 appears surprising for two reasons. First, the disclosure partially reveals the insider's private information and hence one might expect outside investors (hedger 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 always the case. Second, the result that the insider also becomes 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

[8]Note that the equilibrium quantities under approximation explicitly include $1/\Sigma_z$ terms. This allows us to illustrate precisely the meaning of Σ_z being "sufficiently large" in the approximation equilibrium. Specifically, in the Online Appendix, we derive a threshold $\bar{\Sigma}_z$, which is a function of exogenous parameters, such that the results in Proposition 3 hold if $\Sigma_z > \bar{\Sigma}_z$ in the approximation equilibrium.

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 when Σ_z is large. 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. Part (2) of Proposition 3 shows that consistent with the intuition on sunshine trading, disclosure identifies the insider's trade as mostly informationless and hence indeed increases his expected trading profit.

How does the disclosure decrease the insider's welfare despite a higher trading profit? It turns out that the result is due to the Hirshleifer effect (Hirshleifer, 1971). Specifically, as shown in Part (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 (i.e., Part (3) of Proposition 3). As pointed out by Hirshleifer (1971), revelation of information destroys risk-sharing opportunities. Recall that the insider has a strong hedging need in this case. The reduced risk sharing makes the insider worse off despite his higher expected trading profit.

We next discuss why outside investors also become worse off in Part (1) of Proposition 3. Along our discussions, we also explain the remaining parts of Proposition 3 regarding profits and liquidity. Specifically, outside investors are harmed by disclosure in two ways.

First, the improvement in price informativeness is detrimental to them. Both the hedger and speculators are hurt via the Hirshleifer effect. In addition, the more informative price system makes it less effective for speculators to exploit their private information. Second, outside investors face worsened market liquidity, which reduces their trading profits (i.e., $\lambda_O^* > \lambda_\omega$ in Part (4); $\pi_S^* < \pi_S$ and $\pi_H^* < \pi_H$ in Part (2)). Specifically, under the non-disclosure regime, outsider investors' orders are mixed with the insider's—which is mostly uniformed when Σ_z is large—and thus, outsiders' trades have a smaller price impact. Under the disclosure regime, however, outsiders' orders can no longer hide behind the insider's, and hence have a larger price impact, eroding outsiders' profits.

Although our model is designed to analyze insider trading, it unexpectedly reveals new intuitions on sunshine trading, an intriguing idea that has become prominent after the stock market crash in October 1987. This idea has drawn interest from practitioners, regulators, and researchers (e.g., Hawke Jr et al., 1988; Admati and Pfleiderer, 1991). The analysis in the prior literature has focused primarily on the intuition that if an investor creditably declares that his trading is uninformed, then he can avoid adverse selection, get a better trading price from the market, and hence execute his trade at a lower trading cost ex post disclosing his uninformed trades. Our analysis highlights a new insight from the ex-ante welfare perspective by pointing out that sunshine trading necessarily reduces the effectiveness of risk sharing in the market, which harms all risk-averse market participants. Intuitively, the declaration of uninformed trades necessarily reveals informed trades (from other investors) in the market, and this information revelation impairs the ex-ante risk sharing function of the market.

4 Calibration Analysis

In this section, we conduct a calibration exercise to evaluate the recent SEC policy changes for empirically plausible parameter values. Section 4.1 describes how the parameter values are chosen for our calibration. Sections 4.2 and 4.3 analyze the effects of the mandatory disclosure and cooling-off period polices, respectively.

4.1 Parameter Values

We interpret the risky asset as an individual stock since insider trading is typically discussed in the context of a single firm. We follow Leland (1992) and normalize the expected price level p_0 at 1. Under this normalization, we can interpret $\tilde{f}$ as the gross return and Σ_f as the return variance. We interpret the time between dates 0 and 2 in our model as 6 months.[9] Hence, to set the annualized stock return volatility to 40%, we set $\Sigma_f = 0.4^2/2 = 0.08$.

As estimated by Dávila and Parlatore (2023), the average information signal-to-payoff for a typical U.S. stock in the recent decade is around 0.07 (i.e., $\Sigma_\delta^{-1}/\Sigma_f^{-1} \approx 0.07$). To match this ratio for the speculators' private information, we set $\Sigma_\delta = \Sigma_f/0.07 \approx 1.14$. We set the risk aversion $\gamma = 10$ according to the S&P 500 option-implied risk-aversion of Aıt-Sahalia and Lo (2000) and Bliss and Panigirtzoglou (2004) and the estimation of exponential utility risk-aversion of optimal portfolio allocation in Bodnar et al. (2018) and commodity futures market in Goldstein and Yang (2022). We set $\rho = 0.5$, which implies that the insider observes 25% of the variance of the fundamental value of $\tilde{f}$. To evaluate the effect of the cooling-off period length, we vary the value of ρ in the range of $[0.01, 0.55]$.

The calibration of Σ_z and Σ_u is as follows. Since the disclosure policy is not in place until recently adopted, we choose (Σ_u, Σ_z) such that the model-implied trading activities under the non-disclosure regime match the data. Specifically, according to Cohen et al. (2012), 45% of the total insider trading in their sample is classified as "opportunistic" and appears informed, while the rest of the insider trading is "routine" and uninformed. Note that, under the non-disclosure regime, the insider's the information-driven order flow is $\alpha_f \tilde{f}_a$, and his uninformed order flow is $\alpha_Z \tilde{Z}$. Hence, we obtain the following equation

$$\sqrt{\frac{Var(\alpha_f \tilde{f}_a)}{Var(\alpha_Z \tilde{Z})}} = \frac{\alpha_f \sqrt{\Sigma_f}}{|\alpha_Z| \sqrt{\Sigma_z}} = \frac{45\%}{55\%}. \tag{49}$$

[9] As shown in Larcker et al. (2021), 82% of 10b5-1 plans start trading within 6 months.

To estimate the insider's trading activities, we obtain from Thomson Reuters the transactions by corporate insiders from 1986 to 2021. For each year, we aggregate the total number of shares traded by all corporate insiders for each stock, normalized by the stock's total number of shares outstanding. We then compute the cross-sectional standard deviation of the aggregate trades across stocks for each year. The time series average of this cross-sectional standard deviation is 3.11%. We interpret the institutional investors as the informed speculators in our model. To estimate the aggregate trading activities by institutions, we obtain the holdings data of all 13f institutions from Thomson Reuters from 1981 to 2022. For each year, we obtain the aggregate holding change, as a percentage of the total number of shares outstanding, for each stock. We then compute the cross-sectional standard deviation of the aggregate holdings change across stocks for each year. The time series average of this cross-sectional standard deviation is 9.48%. Matching these estimates with the model-implied volatility of the trades by speculators and the insider in equations (13) and (14), we obtain the following equation:

$$\frac{Var(\int_0^1 D_{S,j}dj)}{Var\,(D_I)} = \frac{\beta_S^2\Sigma_f}{\alpha_f^2\Sigma_f + \alpha_Z^2\Sigma_z} = \frac{9.48^2}{3.11^2}. \tag{50}$$

Solving equations (49) and (50), we obtain $\Sigma_u = 0.17$ and $\Sigma_z = 0.08$. All calibration parameters are summarized in Table 1 below.

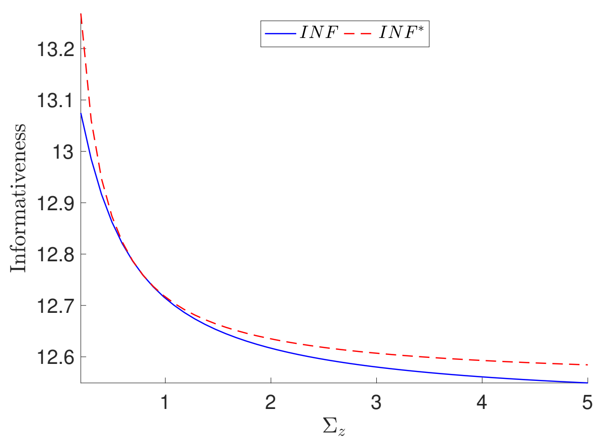
Table 1. Parameter values

Parameter	Description	Value
p_0	Mean of asset fundamental	1
Σ_f	Variance of asset fundamental	0.08
Σ_δ	Variance of noises in speculator's information	1.14
Σ_u	Variance of the hedger's endowment	0.17
Σ_z	Variance of insider's endowment	0.08
γ	Absolute risk aversion	10
ρ	Insider's information advantage	$[0.01, 0.55]$

4.2 Mandatory Disclosure

With the parameter values in Table 1, we examine the implications of mandatory disclosure in this section. To examine the effect of disclosure on stock price informativeness, we plot the informativeness measure under both regimes against Σ_z in Figure 2. It shows that the stock price informativeness under the disclosure regime is always higher than that under the non-disclosure regime. This result is consistent with Part (3) of Proposition 3, which shows that disclosure increases the stock price informativeness when Σ_z is sufficiently large. Our numerical results suggest that this result holds more generally.

Figure 2. Stock price informativeness.

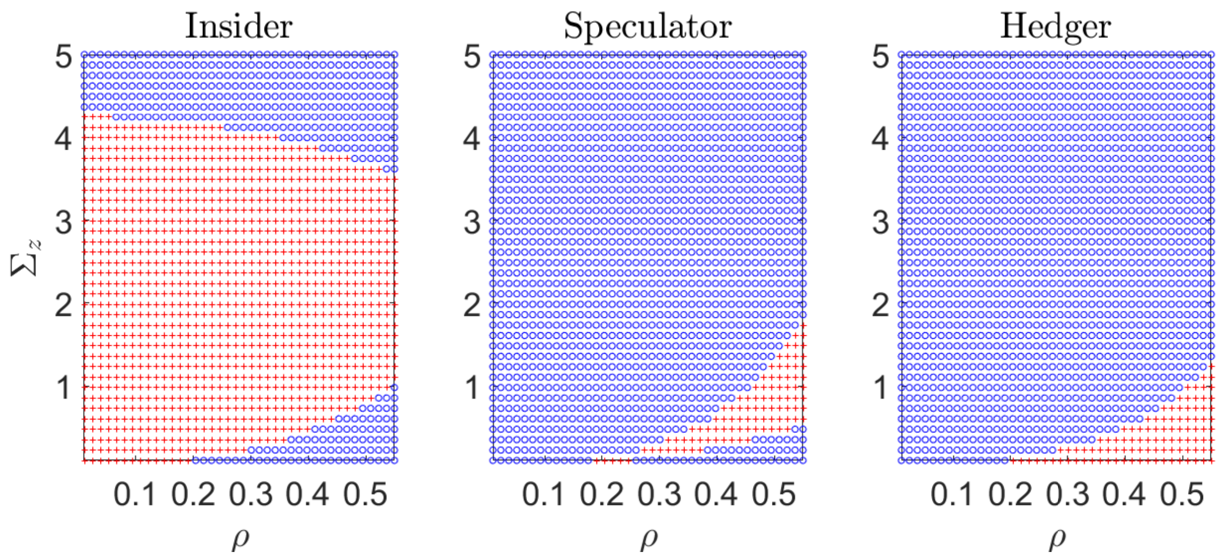


This figure plots the price informativeness against the insider's hedge variance Σ_z. The solid blue and dashed red lines are for the non-disclosure and disclosure regimes, respectively. Parameter values: $\gamma = 10, \rho = 0.5, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

Figure 3 illustrates welfare implications by varying the insider's information advantage, ρ, and hedging need, Σ_z. In each panel, we compare the welfare for one type of investor and use blue circles "$\circ$" (red cross "$+$", respectively) to mark the region where the investor's welfare is higher under the non-disclosure regime (under the disclosure regime, respectively).

Proposition 3 shows that disclosure makes all investors worse off if Σ_z is sufficiently large. Consistent with this analytical result in the limit case, all three panels in 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.

Figure 3. Disclosure and investor welfare.



This figure plots welfare comparisons under disclosure and non-disclosure regimes against the insider's information precision ρ and hedging needs Σ_z. 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: $\gamma = 10, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

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 on trading profits. 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 (i.e., the insider behaves more like an informed speculator than an uninformed hedger), 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 lower right corners of the middle and right plots of Figure 3 show that disclosure reduces speculators welfare but increases the hedger's welfare.

4.3 Cooling-off Period

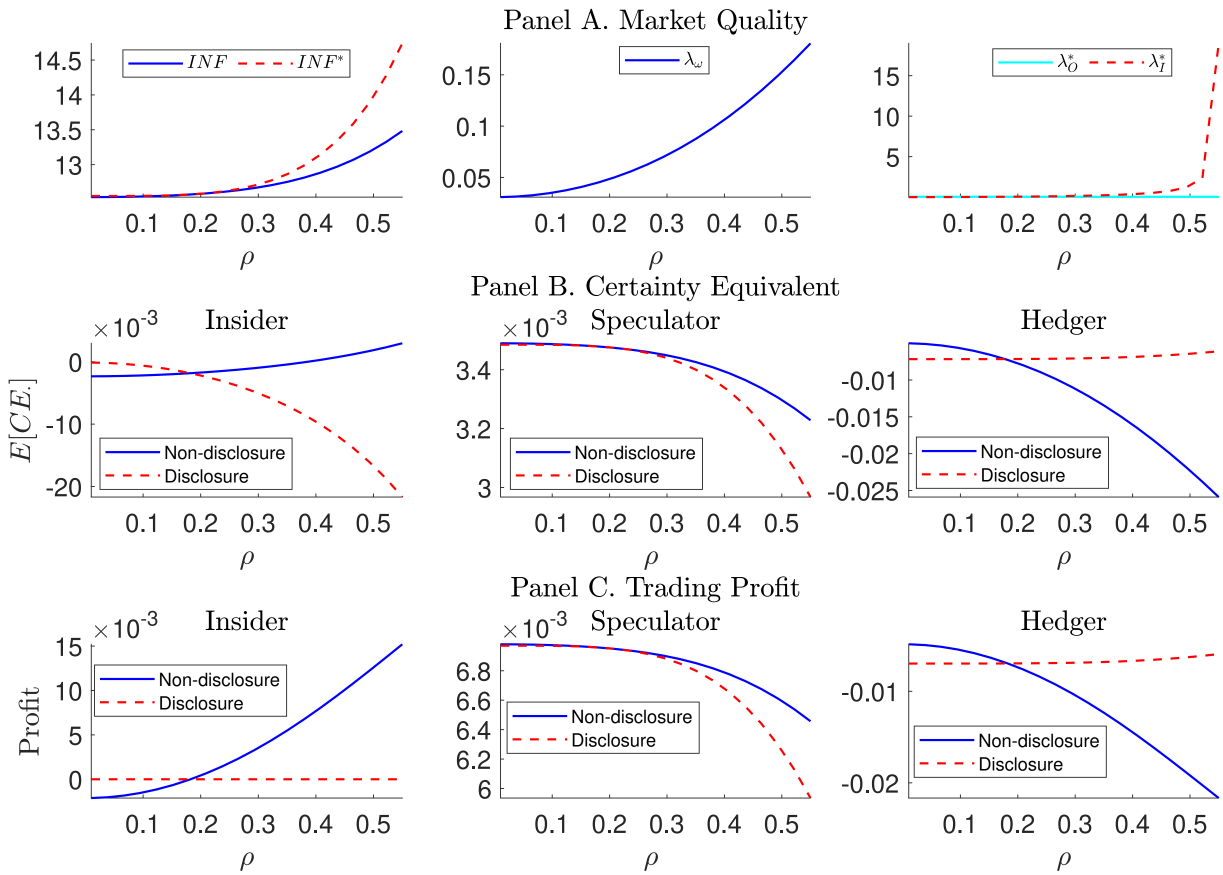
As noted in Section 2.2, ρ can be viewed as a proxy for and is inversely related to the cooling-off period length. Hence, we conduct a calibration analysis of the effects of the cooling-off period by varying ρ and setting the rest parameters according to Table 1.

The left panel of the first row in Figure 4 shows that, as expected, the stock price informativeness is increasing in ρ under both the disclosure and non-disclosure regimes. Hence, a longer cooling-off period leads to lower stock price informativeness under both regimes. The middle panel shows that, under the non-disclosure regime, the price impact is increasing in ρ. When the insider has more private information, the aggregate order flow has a larger price impact. The right panel plots the price impact of the insider and outsiders in the disclosure regime. As expected, the insider has a larger price impact if he has more private information. However, a larger ρ has only an indirect and negligible effect on outsiders' price impact.

How about the welfare implications? Intuitively, the cooling-off period affects investor welfare through the interaction between two forces. First (information effect), it affects the relative information advantages among investors and hence their trading profits. Second (risk-sharing effect), it affects the effectiveness of risk-sharing among investors. The overall effect is determined by the relative strength of the two forces.

This intuition is highlighted in the second row of Figure 4. They plot the *ex ante* expected certainty equivalent against ρ, one for each type of investors. It is easy to see why speculators' welfare is decreasing in ρ. If the insider has more private information, it reduces speculators information advantage. Indeed, as shown in the middle panel in the third row of Figure 4, speculators' expected trading profit is decreasing in ρ. Hence, a longer cooling-off period (a smaller ρ) increases speculators' welfare.

Figure 4. The effects of a cooling-off period.



Panel A plots market quality, informativeness and Kyle's lambda. Panels B and C plot the ex ante expected trading profit and expected certainty equivalent for each type of investors against the insider's information precision ρ, respectively. Parameter values: Parameter values: $\gamma = 10, \Sigma_z = 0.08, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

The implications for the hedger and insider depends on whether the disclosure regime is already in place. This is because the cooling-off period has different information implications under the two regimes. Under the non-disclosure regime, a larger ρ increases the insider's information advantage and hence hurts the hedger. As shown in the third role of Figure 4, as ρ increases, the insider's expected trading profit increases while the hedger's decreases. Under the disclosure regime, however, the insider's order becomes public knowledge. Hence, a higher ρ reveals more information to the hedger and reduces his information disadvantage relative to speculators. Consistent with this intuition, the right panel of the third row shows that the hedger's expected trading profit is increasing in ρ under the disclosure regime.

Under the disclosure regime, the implications for the insider are more subtle. Why does the insider benefit from a longer cooling off period (i.e., a smaller ρ)? Note that, consistent with Corollary 5, the left panel of the third row shows that the insider's expected trading profit is zero, regardless of the value of ρ. Hence, The decrease in the insider's welfare can only be attributed to the decreases in hedging effectiveness. Indeed, as shown in the right panel of the first row, a higher ρ increases the insider's price impact λ_I^*. In response to a larger price impact, the insider would cut back his hedging trades. This makes hedging less effective, leading to a lower welfare. Moreover, a higher ρ increases the price informativeness, which hinders risk sharing (Hirshleifer, 1971) and reduces the insider's welfare.

5 Information Leakage

In this section, we consider an alternative formulation of the cooling-off period based on the idea that the insider's information is partially leaked to outside investors during the cooling-off period. As the cooling-off period becomes longer, there are more chances for information leakage.

Specifically, we consider an extension of the baseline model in Section 2. The only modification is that, before time 1, speculators and the hedger, but not the market maker, observe a signal about the insider's private information $\tilde{y} = \tilde{f}_a + \tilde{\varepsilon}$, where $\tilde{\varepsilon} \sim N(0, \Sigma_\varepsilon)$. Hence, Σ_ε can be viewed as a proxy for the cooling-off period length. The smaller the Σ_ε, the longer the cooling-off period. The rest of the model is the same as described in Section

2. We show in Appendix that the equilibrium under the non-disclosure regime is given by

$$\begin{aligned} D_I &= \alpha_f \tilde{f}_a + \alpha_Z \tilde{Z}, \\ D_{S,j} &= \beta_S(\tilde{s}_j - p_0) + \beta_y \tilde{y}, \\ D_H &= \phi_H \tilde{u} + \phi_y \tilde{y}, \\ \tilde{p} &= p_0 + \lambda_\omega \tilde{\omega}. \end{aligned}$$

and the equilibrium under the disclosure regime is given by:

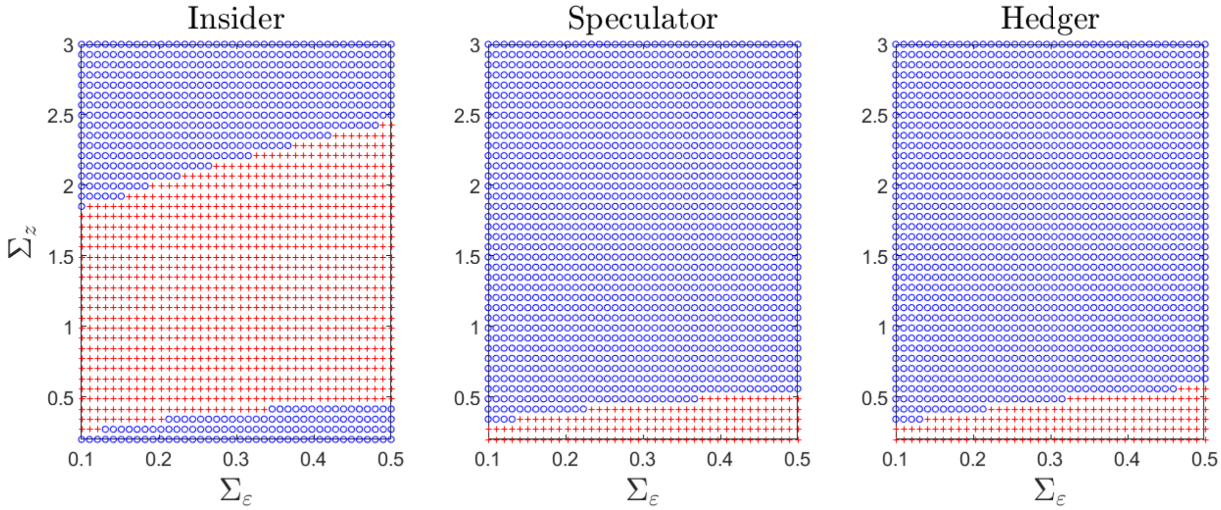
$$\begin{aligned} D_I^* &= \alpha_f^* \tilde{f}_a + \alpha_Z^* \tilde{Z}, \\ D_S^* &= \beta_S^*(\tilde{s}_j - p_0) + \beta_I^* D_I^* + \beta_y^* \tilde{y}, \\ D_H^* &= \phi_H^* \tilde{u} + \phi_I^* D_I^* + \phi_y^* \tilde{y}, \\ \tilde{p}^* &= p_0 + \lambda_O^*(\beta_S^* \tilde{f} + \phi_H^* \tilde{u} + (\beta_y^* + \phi_y^*)\tilde{y}) + \lambda_I^* D_I^*. \end{aligned}$$

where the parameters $\{\alpha_f, \alpha_Z, \beta_S, \beta_y, \phi_H, \phi_y, \lambda_\omega\}$ and $(\alpha_f^*, \alpha_Z^*, \beta_S^*, \beta_I^*, \beta_y^*, \phi_H^*, \phi_I^*, \phi_y^*, \lambda_O^*, \lambda_I^*)$ are given in the appendix.

We conduct a similar calibration analysis as in the previous section to evaluate the two new SEC policies. Specifically, we adopt the parameters in Table 1. To examine the welfare implications of the disclosure policy, we compare the welfare measures for each type of investor across the two equilibria by varying Σ_z and Σ_ε. The results, reported in Figure 5, are similar to those in the baseline model. In particular, all investors are worse off when Σ_z is sufficiently large. Outside investors can benefit from disclosure if the insider has a small hedging need Σ_z. Finally, the insider benefits from disclosure for intermediate Σ_z but is worse off if Σ_z reduces further.

To examine the effect of cooling-off period, we re-generate Figure 4 in this new model with Σ_ε, instead of ρ, as the proxy for the cooling-off period length. The results, reported in Figure 6, demonstrate that the welfare implications remain similar to those in the baseline

Figure 5. Model Variation One: Disclosure and investor welfare.



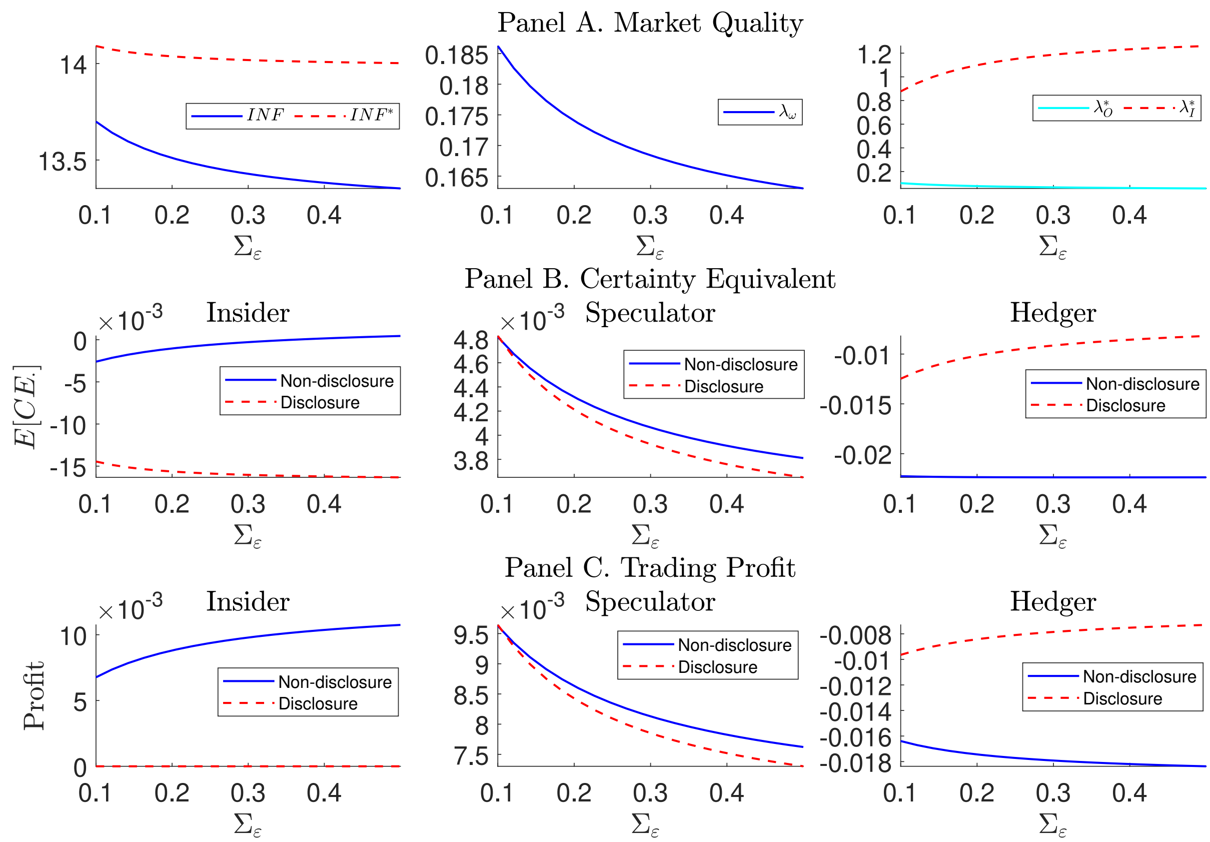
This figure plots welfare comparisons under disclosure and non-disclosure regimes against the speculators and hedger's information variance Σ_ε. The plots in the left, middle, and right columns are for the insider, a representative speculator, and the hedger, respectively. Blue circles "∘" mark the region where the investor is worse off from disclosure, while red crosses "+" mark the region where the investor is better off. Parameter values: $\gamma = 10, \rho = 0.5, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

mode. Moreover, they also highlight some interesting differences on other dimensions. For example, the left panel of the first row shows that a longer cooling-off period (i.e., a smaller Σ_ε) implies a higher informativeness. The baseline model in the previous section focus on the perspective that the insider's information is less relevant after a longer cooling-off period. This alternative model, however, highlights the perspective that during a longer cooling-off period, outside investors obtain more precise signals about the insider's private information. Hence, the two models have opposite implications on the price informativeness. However, their shared feature is that the insider's information advantage is smaller after a longer cooling-off period. As shown in the middle and right panel of in the first row, the implications on price impact (i.e., λ_ω, λ_O^*, and λ_I^*) are the qualitatively the same as in the baseline model.

The second and third rows of Figure 6 show that the implications on welfare and trading profits in this alternative model are also qualitatively the same as those in the baseline model. For example, speculators benefit from a longer cooling-off period under both regimes.

Under the non-disclosure regime, a longer cooling-off period reduces the insider's welfare but increases the hedger's. The opposite is true under the disclosure regime. Hence, although this alternative formulation focuses on a different perspective of the cooling-off period, it captures essentially the same economic forces and has qualitatively the same implications on welfare and trading profits in our calibrations.

Figure 6. Model Variation One: The effects of a cooling-off period.



Panel A plots market quality, informativeness and Kyle's lambda. Panels B and C plot the ex ante expected trading profit and expected certainty equivalent for each type of investors against the information variance Σ_ε, respectively. Parameter values: $\gamma = 10, \rho = 0.5, \Sigma_z = 0.08, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$ as in the baseline model.

6 Conclusion

We analyze the implications of insider trading regulations in a standard Kyle-type model, focusing on two features that are recently adopted by the SEC: mandatory disclosure and cooling-off period. The former requires an insider to make a public disclosure upon the adoption, modification, and 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 advance disclosure improves stock price informativeness but its welfare implication is mixed. In particular, if the insider has a large liquidity need, in contrast to the conventional wisdom from sunshine trading, disclosure may reduce the welfare of all investors. A cooling-off period affects investor welfare through two effects. The first is the policy's intended purpose of reducing the insider's information advantage, which harms the insider. The second effect concerns how the cooling-off period affects risk-sharing among investors. Our analysis offers novel insights about insider trading and sunshine trading.

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A A Dynamic Formulation of the Cooling-off Period

In this appendix, we provide a stylized dynamic setting to illustrate the idea that the parameter ρ inversely measures the length of a cooling-off period in our baseline model. The payoff structure in this dynamic setting is similar to that in Admati and Pfleiderer (1988). The economy lasts for $T+1$ periods. There is a risky asset, which is a claim to the liquidation value of $\tilde{v}_{T+1}$ at the final date, $T+1$. The liquidation value evolves according to an AR(1) process as follows:

$$\tilde{v}_{\tau+1} = (1-g)p_0 + g \cdot \tilde{v}_\tau + \tilde{\varepsilon}_{\tau+1}, \tag{A1}$$

for $\tau = 0, 1, ..., T$, where $p_0 \in \mathbb{R}$, $g \in (0,1)$, $\tilde{v}_0 \sim N(0, \Sigma_v)$, and $\tilde{\varepsilon}_{\tau+1} \sim N(0, \Sigma_\varepsilon)$ is independent over time. We assume that $\Sigma_v = \Sigma_\varepsilon/(1-g^2)$, which implies that $\tilde{v}_\tau$ is a stationary process, and $Var(\tilde{v}_\tau) = \Sigma_v$ for any τ.

The economy is still populated by four types of traders: one insider, one representative hedger, a continuum of speculators, and one risk-neutral market maker. The insider and outsiders (the hedger and speculators) are still risk averse with a CARA utility function defined over the total wealth at date $T+1$. At each date, the market maker sets the price as the expectation of the asset's liquidation value conditional on public information, which is the total order flows received from the insider and outside investors (and the insider's order flow in the regime of disclosure).

At time 0, the insider learns the value of $\tilde{v}_0$. To exploit this information, the insider has to set up a trading plan D_I with a T-period cooling-off period, i.e., his trading cannot start until date T. To closely match the baseline model presented in Section 2, we specify that the interesting trading only occurs on at date T in this dynamic setting. Specifically, at date T, speculator j receives private information regarding the asset's fundamental at the final date $\tilde{v}_{T+1}$ in the form of $\tilde{s}_j = \tilde{v}_{T+1} + \tilde{\delta}_j$, where $\tilde{\delta}_j \sim N(0, \Sigma_\delta)$. Also, at date T, the hedger learns about his hedging need $\tilde{u}$. Since the market maker is risk neutral and observes the same information as outside investors at dates before T, risk-averse outsiders do not participate in the market before date T, and the market maker simply sets the price as $\tilde{p}_\tau = p_0$ (under the non-disclosure regime) and $\tilde{p}_\tau = \mathbb{E}\left[\tilde{v}_{T+1} \middle| D_I\right]$ (under the disclosure regime), for $\tau = 0, 1, ..., T-1$.

Hence, this dynamic model resembles the baseline model in the paper closely as follows. Dates 0, T, and $T+1$ in this dynamic setting correspond to dates 0, 1, and 2 in our baseline model, respectively. The asset's fundamental value $\tilde{v}_{T+1}$ in this dynamic setting, can be interpreted as the liquidation value of the asset at date $T+1$, as in Admati and Pfleiderer (1988). So, $\tilde{v}_{T+1}$ corresponds to $\tilde{f}$ in the baseline model. Moreover, the insider's information structure (and the notion of cooling-off period) closely resembles that in our baseline model. Specifically, equation (A1) implies

$$\tilde{v}_{T+1} = (1-g^{T+1})p_0 + g^{T+1}\tilde{v}_0 + g^T\tilde{\varepsilon}_1 + ... + g\tilde{\varepsilon}_T + \tilde{\varepsilon}_{T+1}.$$

Hence, the insider's information $g^{T+1}\tilde{v}_0$ corresponds to $\rho\tilde{f}_a$ in the baseline model. The parameter ρ in the baseline model corresponds to g^{T+1} and hence can be viewed as a proxy for the length of a cooling-off period. The longer the cooling-off period (larger T), the smaller the parameter ρ. The following table summarizes the correspondence between this dynamic setup and our baseline model:

Table A1. Mapping the dynamic setting to the baseline model.

	Baseline Model	Dynamic Setting
Time		
Insider sets up a trading plan	$t = 0$	$\tau = 0$
Active trading period	$t = 1$	$\tau = T$
Final outcome realization	$t = 2$	$\tau = T + 1$
Variables and parameters		
Cooling-off period proxy	ρ	g^{T+1}
Total fundamental value	$\tilde{f}$	$\tilde{v}_{T+1}$
Insider's information	$\rho \tilde{f}_a$	$g^{T+1}\tilde{v}_0$
Remaining uncertainty to the insider	$\sqrt{1-\rho^2}\tilde{f}_b$	$g^T\tilde{\varepsilon}_1 + ... + g\tilde{\varepsilon}_T + \tilde{\varepsilon}_{T+1}$

B Proofs

In the proof, with a slight abuse of notation, we use demeaned random variables , i.e. $\tilde{f}$ as $\tilde{f} - p_0$, and $\tilde{s}_j$ as $\tilde{s}_j - p_0$. For notation simplicity, we denote

$$\tilde{X} = \rho \tilde{f}_a, \quad \tilde{Y} = \sqrt{1-\rho^2}\tilde{f}_b, \quad \Sigma_X = \rho^2 \Sigma_f, \quad \Sigma_Y = (1-\rho^2)\Sigma_f, \quad k = \gamma^2 \Sigma_Y^2 \Sigma_z.$$

Proof of Proposition 1 for Non-disclosure Equilibrium. Denote

$$\alpha_X = \rho^{-1}\alpha_f, \quad n = 1 - \lambda_\omega \beta_S, \quad m = 1 - \lambda_\omega(\alpha_X + \beta_S). \tag{B1}$$

Under the postulated linear equilibrium (13)-(16), the total order flow and return are

$$\tilde{\omega} = D_I + \int_0^1 D_{S,j} \mathrm{d}_j + D_H = D_I + \beta_S \tilde{f} + \phi_H \tilde{u} = (\alpha_X + \beta_S)\tilde{X} + \beta_S \tilde{Y} + \alpha_Z \tilde{Z} + \phi_H \tilde{u},$$
$$\tilde{f} - \tilde{p} = n\tilde{f} - \lambda_\omega D_I - \lambda_\omega \phi_H \tilde{u} = m\tilde{X} + n\tilde{Y} - \lambda_\omega \alpha_Z \tilde{Z} - \lambda_\omega \phi_H \tilde{u}.$$

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 $\{\tilde{f}_a, \tilde{Z}\}$ or equivalently $\{\tilde{X}, \tilde{Z}\}$, the maximization problem (4) is equivalent to

$$\max_{D_I} \qquad \mathbb{E}\left[W_I \middle| \tilde{X}, \tilde{Z}\right] - \frac{1}{2}\gamma Var(W_I \middle| \tilde{X}, \tilde{Z}). \tag{B2}$$

Since $\tilde{f} - \tilde{p} = n\tilde{f} - \lambda_\omega D_I - \lambda_\omega \phi_H \tilde{u}$, using his information $\{\tilde{X}, \tilde{Z}\}$, the insider's inferences on the asset value $\tilde{f}$ and return $\tilde{f} - \tilde{p}$ are

$$\mathbb{E}\left[\tilde{f} \,|\, \tilde{X}, \tilde{Z}\right] = \tilde{X}, \quad \mathbb{E}\left[\tilde{f} - \tilde{p} \,|\, \tilde{X}, \tilde{Z}\right] = n\tilde{X} - \lambda_\omega D_I,$$
$$Var(\tilde{f} \,|\, \tilde{X}, \tilde{Z}) = \Sigma_Y, \quad Var(\tilde{f} - \tilde{p} \middle| \tilde{X}, \tilde{Z}) = \lambda_\omega^2 \phi_H^2 \Sigma_u + n^2 \Sigma_Y, \quad Cov(\tilde{f} - \tilde{p}, \tilde{f} \middle| \tilde{X}, \tilde{Z}) = n\Sigma_Y.$$

Since $W_I = D_I(\tilde{f} - \tilde{p}) + \tilde{Z}\tilde{f}$, standard calculations yield

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

Here, the constant Λ_I is given by

$$\Lambda_I = \lambda_\omega + \frac{1}{2}\gamma Var(\tilde{f} - \tilde{p}\big|\tilde{X}, \tilde{Z}) = \lambda_\omega + \frac{1}{2}\gamma\left(\lambda_\omega^2\phi_H^2\Sigma_u + n^2\Sigma_Y\right).$$

Then, the first-order-condition gives

$$D_I = \frac{n\tilde{X} - \gamma n\Sigma_Y\tilde{Z}}{2\Lambda_I} = \alpha_X\tilde{X} + \alpha_Z\tilde{Z}, \tag{B3}$$

where

$$\alpha_X = \frac{n}{2\lambda_\omega + \gamma\lambda_\omega^2\phi_H^2\Sigma_u + \gamma n^2\Sigma_Y}, \quad \alpha_Z = -\alpha_X\gamma\Sigma_Y.$$

As a result, the optimal problem (B2) takes the form of

$$\begin{aligned}
&\mathbb{E}\left[W_I\big|\tilde{X}, \tilde{Z}\right] - \frac{1}{2}\gamma Var(W_I\big|\tilde{X}, \tilde{Z}) = D_I^2\Lambda_I + \tilde{Z}\mathbb{E}\left[\tilde{f}\big|\tilde{X}\right] - \frac{1}{2}\gamma\tilde{Z}^2 Var(\tilde{f}\big|\tilde{X})\\
&= (\alpha_X\tilde{X} + \alpha_Z\tilde{Z})^2\Lambda_I + \tilde{Z}\tilde{X} - \frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\
&= \frac{1}{2}(\alpha_X\tilde{X} + \alpha_Z\tilde{Z})^2 \cdot r_Z\alpha_Z^{-1} + \tilde{Z}\tilde{X} - \frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\
&= \frac{1}{2}(\tilde{X}\alpha_X/\alpha_Z + \tilde{Z})^2 \cdot r_Z\alpha_Z + \tilde{Z}\tilde{X} - \frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\
&= -\frac{1}{2}\gamma\Sigma_Y(-\tilde{X}\gamma^{-1}\Sigma_Y^{-1} + \tilde{Z})^2 n\alpha_Z + \tilde{Z}\tilde{X} - \frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2.
\end{aligned} \tag{B4}$$

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

$$\max_{D_{S,j}} \quad D_{S,j}\mathbb{E}\left[\tilde{f} - \tilde{p}\big|\tilde{s}_j\right] - \frac{1}{2}\gamma D_{S,j}^2 Var(\tilde{f} - \tilde{p}\big|\tilde{s}_j). \tag{B5}$$

The first-order-condition gives

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

Using the information $\tilde{s}_j$, the speculator j updates his belief of values $\tilde{X}, \tilde{Y}$ and the return $\tilde{f} - \tilde{p}$ as

$$\begin{gathered}
\mathbb{E}[\tilde{X}\big|\tilde{s}_j] = \frac{\Sigma_X}{\Sigma_f + \Sigma_\delta}\tilde{s}_j, \quad \mathbb{E}[\tilde{Y}\big|\tilde{s}_j] = \frac{\Sigma_Y}{\Sigma_f + \Sigma_\delta}\tilde{s}_j,\\
\mathbb{E}[\tilde{f} - \tilde{p}\big|\tilde{s}_j] = m\mathbb{E}[\tilde{X}\big|\tilde{s}_j] + n\mathbb{E}[\tilde{Y}\big|\tilde{s}_j] = (m\Sigma_X + n\Sigma_Y)(\Sigma_f + \Sigma_\delta)^{-1}\tilde{s}_j.
\end{gathered}$$

His inference of the return variance is

$$\begin{aligned}\Lambda_S &:= Var(\tilde{f}-\tilde{p}|\tilde{s}_j) = Var(\tilde{f}-\tilde{p}) - Var\left(\mathbb{E}[\tilde{f}-\tilde{p}\big|\tilde{s}_j]\right)\\ &= m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\left(\alpha_Z^2\Sigma_z + \phi_H^2\Sigma_u\right) - \left[m\Sigma_X + n\Sigma_Y\right]^2\left(\Sigma_f+\Sigma_\delta\right)^{-1}.\end{aligned}$$

Therefore, his optimal demand is

$$D_{S,j} = \beta_S\tilde{s}_j, \quad \text{with,} \quad \beta_S = \left(m\Sigma_X + n\Sigma_Y\right)\left(\Sigma_f+\Sigma_\delta\right)^{-1}\gamma^{-1}\Lambda_S^{-1}. \tag{B6}$$

As a result,

$$\mathbb{E}\left[W_S\big|\tilde{s}_j\right] - \frac{1}{2}\gamma Var(W_S\big|\tilde{s}_j) = \frac{1}{2}\gamma\Lambda_S\beta_S^2\tilde{s}_j^2 = \frac{1}{2}\left(m\Sigma_X + n\Sigma_Y\right)\left(\Sigma_f+\Sigma_\delta\right)^{-1}\beta_S\tilde{s}_j^2. \tag{B7}$$

The hedger's optimal demand: The maximization problem (7) of the hedger given his information set $\tilde{u}$ is equivalent to

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

The first-order-condition gives

$$D_H = \frac{\gamma^{-1}\mathbb{E}\left[\tilde{f}-\tilde{p}\big|\tilde{u}\right] - Cov(\tilde{f}-\tilde{p},\tilde{f}\big|\tilde{u})\cdot\tilde{u}}{Var(\tilde{f}-\tilde{p}\big|\tilde{u})}. \tag{B8}$$

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

$$\begin{aligned}\mathbb{E}\left[\tilde{f}-\tilde{p}\,|\,\tilde{u}\right] &= -\lambda_\omega\phi_H\tilde{u},\\ Var\left(\tilde{f}-\tilde{p}\,|\,\tilde{u}\right) &= Var\left(m\tilde{X}+n\tilde{Y}-\lambda_\omega\left(\alpha_Z\tilde{Z}+\phi_H\tilde{u}\right)\,\Big|\,\tilde{u}\right) = m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z,\\ Cov(\tilde{f}-\tilde{p},\tilde{f}\big|\tilde{u}) &= m\Sigma_X + n\Sigma_Y.\end{aligned}$$

Then, the hedger's optimal demand is

$$\phi_H = -1\cdot\frac{m\Sigma_X + n\Sigma_Y + \gamma^{-1}\lambda_\omega\phi_H}{m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z}. \tag{B9}$$

As a result,

$$\begin{aligned}\mathbb{E}\left[W_H\big|\tilde{u}\right] - \tfrac{1}{2}\gamma Var(W_H\big|\tilde{u}) &= \tfrac{1}{2}\gamma Var\left(\tilde{f}-\tilde{p}\,|\,\tilde{u}\right)D_H^2 - \tfrac{1}{2}\gamma\Sigma_f\tilde{u}^2\\ &= -\tfrac{1}{2}\gamma\left[\left(m\Sigma_X + n\Sigma_Y + \gamma^{-1}\lambda_\omega\phi_H\right)\phi_H + \Sigma_f\right]\tilde{u}^2.\end{aligned} \tag{B10}$$

The market maker sets the equilibrium price: After observing the total order flow $\tilde{\omega} = (\alpha_X + \beta_S)\tilde{X} + \beta_S\tilde{Y} + \alpha_Z\tilde{Z} + \phi_H\tilde{u}$, the risk-neutral market maker sets the price by

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

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

$$\alpha_X = \frac{n}{2\lambda_\omega + \gamma\lambda_\omega^2\phi_H^2\Sigma_u + \gamma n^2\Sigma_Y}, \quad \alpha_Z = -\alpha_X\gamma\Sigma_Y, \tag{B11}$$

$$\beta_S = (m\Sigma_X + n\Sigma_Y)\left(\Sigma_f + \Sigma_\delta\right)^{-1}\gamma^{-1}\Lambda_S^{-1}, \tag{B12}$$

$$\phi_H = -1 \cdot \frac{m\Sigma_X + n\Sigma_Y + \gamma^{-1}\lambda_\omega\phi_H}{m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z}, \tag{B13}$$

$$\lambda_\omega = \frac{(\alpha_X + \beta_S)\Sigma_X + \beta_S\Sigma_Y}{(\alpha_X + \beta_S)^2\Sigma_X + \beta_S^2\Sigma_Y + \alpha_Z^2\Sigma_z + \phi_H^2\Sigma_u}. \tag{B14}$$

From (B14), we derive

$$\begin{aligned}
&\lambda_\omega^2(\alpha_X + \beta_S)^2\Sigma_X + \lambda_\omega^2\beta_S^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z + \lambda_\omega^2\phi_H^2\Sigma_u = \lambda_\omega(\alpha_X + \beta_S)\Sigma_X + \lambda_\omega\beta_S\Sigma_Y. \\
&\Longleftrightarrow \\
&(1-m)^2\Sigma_X + (1-n)^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z + \lambda_\omega^2\phi_H^2\Sigma_u = (1-m)\Sigma_X + (1-n)\Sigma_Y. \\
&\Longleftrightarrow \\
&\lambda_\omega^2\alpha_Z^2\Sigma_z + \lambda_\omega^2\phi_H^2\Sigma_u = \lambda_\omega^2\alpha_X^2 k + \lambda_\omega^2\phi_H^2\Sigma_u = (1-m)m\Sigma_X + (1-n)n\Sigma_Y, \\
&\Longleftrightarrow \\
&\lambda_\omega^2\phi_H^2\Sigma_u = m(1-m)\Sigma_X + n(1-n)\Sigma_Y - k(n-m)^2 := N. \qquad \text{(B15)}
\end{aligned}$$

Therefore,

$$\begin{aligned}
\Lambda_S &:= m^2\Sigma_X + n^2\Sigma_Y - (m\Sigma_X + n\Sigma_Y)^2\left(\Sigma_f + \Sigma_\delta\right)^{-1} + \lambda_\omega^2\left(\alpha_Z^2\Sigma_z + \phi_H^2\Sigma_u\right) \\
&= m^2\Sigma_X + n^2\Sigma_Y - (m\Sigma_X + n\Sigma_Y)^2\left(\Sigma_f + \Sigma_\delta\right)^{-1} + (1-m)m\Sigma_X + (1-n)n\Sigma_Y \\
&= (m\Sigma_X + n\Sigma_Y)\left[\Sigma_f + \Sigma_\delta - m\Sigma_X - n\Sigma_Y\right]\left(\Sigma_f + \Sigma_\delta\right)^{-1}.
\end{aligned}$$

Plugging Λ_S into (B12) yields

$$\beta_S = \gamma^{-1}\left[\Sigma_f + \Sigma_\delta - m\Sigma_X - n\Sigma_Y\right]^{-1} := \gamma^{-1}M^{-1}.$$

Since $\lambda_\omega = (1-n)\beta_S^{-1} = (1-n)\gamma M$ and $\alpha_X = (n-m)\lambda_\omega^{-1} = (n-m)(1-n)^{-1}\gamma^{-1}M^{-1}$, from (B11), we get

$$\begin{aligned}
(n-m)^{-1}(1-n)\gamma M &= n^{-1}\left[\gamma\lambda_\omega^2\phi_H^2\Sigma_u + 2\lambda_\omega + \gamma n^2\Sigma_Y\right] \\
&= n^{-1}\left[\gamma N + 2(1-n)\gamma M + \gamma n^2\Sigma_Y\right]. \qquad \text{(B16)}
\end{aligned}$$

From (B13), it yields

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

Plugging ϕ_H into (B15) gives

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

which is equivalent to

$$(1-n)^2\gamma^2 M^2 (m\Sigma_X + n\Sigma_Y)^2\Sigma_u = N\left(N - (1-n)M - m\Sigma_X - n\Sigma_Y\right)^2. \tag{B17}$$

Once solving m and n via two equations (B16) and (B17), we could pin down remaining parameters. Notice that the second-order-condition for the insider, speculators and the hedger require that $\alpha_f > 0$ and $m, n \in (0,1)$. □

Proof of Corollary 1: If Σ_z or Σ_u is sufficiently large, the equation system (22) and (23) has a unique solution, which pins down the entire equilibrium. Moreover, if the risk aversion γ is sufficiently small, the equation system (22) and (23) does not have a solution. Hence, the equilibrium does not exist.

Proof of Proposition 2 for Disclosure Equilibrium. Recall that $\Sigma_X = \rho^2\Sigma_f$, $\Sigma_Y = (1-\rho^2)\Sigma_f$, $k = \gamma^2\Sigma_Y^2\Sigma_z$ and for notation simplicity, we denote

$$\alpha_X^* = \rho^{-1}\alpha_f^*, \quad n^* = 1 - \lambda_O^*\beta_S^*, \quad k_1 = k\Sigma_f + \rho^2(1-\rho^2)\Sigma_f^2, \quad k_2 = k_1 + (k + \Sigma_X)\Sigma_\delta.$$

The total order flow and return are

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

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.

$$\mathbb{E}\left[\tilde{f} \,|\, \tilde{X}, \tilde{Z}\right] = \tilde{X}, \quad Var(\tilde{f} \,|\, \tilde{X}, \tilde{Z}) = \Sigma_Y.$$

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

$$\begin{aligned}
\mathbb{E}(\tilde{f}-\tilde{p}^* \,|\, \tilde{X}, \tilde{Z}) &= n^*\tilde{X} - \lambda_I^* D_I^*, \\
Var(\tilde{f}-\tilde{p}^* \,|\, \tilde{X}, \tilde{Z}) &= (n^*)^2\Sigma_Y + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u, \\
Cov(\tilde{f}-\tilde{p}^*, \tilde{f} \,|\, \tilde{X}, \tilde{Z}) &= n^*\Sigma_Y.
\end{aligned}$$

Then, after simplification, the maximization problem (4) is equivalent to

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

with the parameter Λ_I^* as,

$$\Lambda_I^* = \lambda_I^* + \frac{1}{2}\gamma\left((n^*)^2\Sigma_Y + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right).$$

Then, the first-order-condition gives

$$D_I^* = \frac{n^*\tilde{X} - \gamma n^*\Sigma_Y\tilde{Z}}{2\Lambda_I^*} = \alpha_X^*\tilde{X} + \alpha_Z^*\tilde{Z}.$$

Here,

$$\alpha_X^* = \frac{n^*}{2\lambda_I^* + \gamma\left((n^*)^2\Sigma_Y + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right)}, \quad \alpha_Z^* = -\alpha_X^*\gamma\Sigma_Y.$$

As a result,

$$\begin{aligned}
\mathbb{E}\left[W_I^* \middle| \tilde{X}, \tilde{Z}\right] &- \frac{1}{2}\gamma Var(W_I^*|\tilde{X}, \tilde{Z}) = (D_I^*)^2\Lambda_I^* + \tilde{Z}\,\mathbb{E}\left[\tilde{f}\middle|\tilde{X}\right] - \frac{1}{2}\gamma\tilde{Z}^2 Var(\tilde{f}|\tilde{X}) \\
&= \frac{1}{2}r_Z^*(\tilde{X}\alpha_X^*/\alpha_Z^* + \tilde{Z})^2\alpha_Z^* + \tilde{Z}\tilde{X} - \frac{1}{2}\gamma\tilde{Z}^2\Sigma_Y. \qquad \text{(B18)}
\end{aligned}$$

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 problem is equivalent to

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

The first-order-condition gives the optimal demand as

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

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

$$\begin{aligned}
\mathbb{E}[\tilde{f}\big|\tilde{s}_j, D_I^*] &= \frac{Cov(\tilde{f},\tilde{s}_j)Var(D_I^*) - Cov(\tilde{f},D_I^*)Cov(\tilde{s}_j,D_I^*)}{Var(\tilde{s}_j)Var(D_I^*) - Cov^2(\tilde{s}_j,D_I^*)}\tilde{s}_j \\
&\quad + \frac{Cov(\tilde{f},D_I^*)Var(\tilde{s}_j) - Cov(\tilde{f},\tilde{s}_j)Cov(\tilde{s}_j,D_I^*)}{Var(\tilde{s}_j)Var(D_I^*) - Cov^2(\tilde{s}_j,D_I^*)}D_I^* \\
&= a_s\tilde{s}_j + a_I D_I^*, \\
\mathbb{E}[\tilde{f} - \tilde{p}^*\big|\tilde{s}_j, D_I^*] &= \mathbb{E}[n^*\tilde{f} - \lambda_I^* D_I^* - \lambda_O^*\phi_H^*\tilde{u}\big|\tilde{s}_j, D_I^*] = -\lambda_I^* D_I^* + n^*\mathbb{E}[\tilde{f}\big|\tilde{s}_j, D_I^*] \\
&= -\lambda_I^* D_I^* + n^* a_s\tilde{s}_j + n^* a_I D_I^* = \left(n^* a_I - \lambda_I^*\right) D_I^* + n^* a_s \tilde{s}_j.
\end{aligned}$$

Here, the two constants a_s and a_I are given by

$$a_s = k_1 k_2^{-1}, \quad a_I = (\alpha_X^*)^{-1}\Sigma_X\Sigma_\delta k_2^{-1}. \tag{B19}$$

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

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

Then,

$$\beta_S^* = \frac{n^* a_s}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}, \quad \beta_I^* = \frac{n^* a_I - \lambda_I^*}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}. \tag{B20}$$

As a result,

$$\begin{aligned}
\mathbb{E}\left[W_S^*\big|\tilde{s}_j, D_I^*\right] - \frac{1}{2}\gamma Var(W_S^*\big|\tilde{s}_j, D_I^*) &= \frac{1}{2}\gamma\cdot Var(\tilde{f} - \tilde{p}^*\big|\tilde{s}_j, D_I^*)\cdot(D_{S,j}^*)^2 \\
&= \frac{1}{2}\gamma\cdot Var(\tilde{f} - \tilde{p}^*\big|\tilde{s}_j, D_I^*)\cdot(\beta_S^*\tilde{s}_j + \beta_I^* D_I^*)^2 \\
&= \frac{1}{2}\gamma(\beta_S^*)^2 Var(\tilde{f} - \tilde{p}^*\big|\tilde{s}_j, D_I^*)\cdot(\tilde{s}_j + \beta_I^* D_I^*/\beta_S^*)^2 \\
&= \frac{1}{2}n^* k_1 k_2^{-1}\beta_S^*\left(\tilde{s}_j + \beta_I^* D_I^*/\beta_S^*\right)^2.
\end{aligned} \tag{B21}$$

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

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

Then, the first-order-condition gives

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

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

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

Then, it leads to

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

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

$$
\begin{aligned}
& \mathbb{E}\left[W_H^* \middle| \tilde{u}, D_I^*\right] - \frac{1}{2}\gamma Var(W_H^* | \tilde{u}, D_I^*) \\
= \quad & \frac{1}{2}\gamma Var(\tilde{f} - \tilde{p}^* | \tilde{u}, D_I^*)(D_H^*)^2 + \tilde{u} \cdot \mathbb{E}\left[\tilde{f} \middle| D_I^*\right] - \frac{1}{2}\gamma \tilde{u}^2 Var(\tilde{f} | \tilde{u}, D_I^*) \\
= \quad & \frac{1}{2}\gamma k_1 (\Sigma_X + k)^{-1} \left((n^*)^2 (\phi_H^*)^2 - 1 \right) \tilde{u}^2 + \tilde{u} \left(1 + \Sigma_X^{-1} k\right)^{-1} \left(\tilde{X} + \alpha_Z^* / \alpha_X^* \tilde{Z} \right) \\
= \quad & \frac{1}{2}\gamma k_1 (\Sigma_X + k)^{-1} \left((n^*)^2 (\phi_H^*)^2 - 1 \right) \tilde{u}^2 + \tilde{u} \left(1 + \Sigma_X^{-1} k\right)^{-1} \left(\tilde{X} - \gamma \Sigma_Y \tilde{Z} \right). \qquad \text{(B22)}
\end{aligned}
$$

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

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

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

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

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

$$\phi_H^* = -\gamma^{-1} (n^*)^{-2} \lambda_O^* \phi_H^* (k + \Sigma_X) k_1^{-1} - (n^*)^{-1}, \tag{B23}$$

$$\phi_I^* = \gamma^{-1} (n^*)^{-2} (k + \Sigma_X) k_1^{-1} \left[n^* (\alpha_X^*)^{-1} \frac{\Sigma_X}{\Sigma_X + k} - \lambda_I^* \right], \tag{B24}$$

$$\beta_S^* = \frac{n^* a_s}{\gamma \left[(n^*)^2 \Sigma_\delta a_s + (\lambda_O^*)^2 (\phi_H^*)^2 \Sigma_u \right]}, \tag{B25}$$

$$\beta_I^* = \frac{n^* a_I - \lambda_I^*}{\gamma \left[(n^*)^2 \Sigma_\delta a_s + (\lambda_O^*)^2 (\phi_H^*)^2 \Sigma_u \right]}, \tag{B26}$$

$$\alpha_X^* = \frac{n^*}{2\lambda_I^* + \gamma \left((n^*)^2 \Sigma_Y + (\lambda_O^*)^2 (\phi_H^*)^2 \Sigma_u \right)}, \tag{B27}$$

$$\alpha_Z^* = -\alpha_X^* \gamma \Sigma_Y, \tag{B28}$$

$$\lambda_O^* = \frac{\beta_S^* k_1}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2 \Sigma_u (\Sigma_X + k)}, \tag{B29}$$

$$\lambda_I^* = \frac{(\alpha_X^*)^{-1} \Sigma_X (\phi_H^*)^2 \Sigma_u}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2 \Sigma_u (\Sigma_X + k)}. \tag{B30}$$

From (B29) and $n^* = 1 - \lambda_O^* \beta_S^*$, we have

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

It gives

$$(\lambda_O^*)^2 (\phi_H^*)^2 \Sigma_u = n^* (1 - n^*) k_1 (\Sigma_X + k)^{-1}. \tag{B31}$$

Plugging in $\phi_H^* = -(n^*)^{-1} \left[1 + \gamma^{-1} (n^*)^{-2} \lambda_O^* (k + \Sigma_X) k_1^{-1} \right]^{-1}$ of (B23), we arrive at

$$(\lambda_O^*)^{-1} = \Sigma_u^{\frac{1}{2}} (n^*)^{-\frac{3}{2}} (1 - n^*)^{-\frac{1}{2}} k_1^{-\frac{1}{2}} (\Sigma_X + k)^{\frac{1}{2}} - \gamma^{-1} (n^*)^{-2} (\Sigma_X + k) k_1^{-1}. \tag{B32}$$

Using (B25), it yields

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

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

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

Noticing $\lambda_O^* > 0$ and $\phi_H^* < 0$, from (B31) and (B23), we derive that

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

Then, from (B25) and (B26), we have

$$
\lambda_I^* = n^* a_I - n^* a_s \beta_I^* (\beta_S^*)^{-1}, \tag{B33}
$$

Then, combing with (B33) and (B30) gives

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

Plugging into (B24) yields $\phi_I^* = 0$. Furthermore,

$$(\alpha_X^*)^{-1}\Sigma_X(\Sigma_X + k)^{-1} = a_I - a_s\beta_I^*(\beta_S^*)^{-1} \tag{B34}$$

Using a_s and a_I from (B19), it gives

$$(\alpha_X^*)^{-1} = -\beta_I^*(1 + \Sigma_X^{-1}k)(\beta_S^*)^{-1}, \quad \lambda_I^* = -n^*\beta_I^*(\beta_S^*)^{-1}. \tag{B35}$$

Equation (B27) combing with (B31) gives us

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

which implies

$$(\alpha_X^*)^{-1} = \gamma(\Sigma_X + k) \cdot \left(n^*\Sigma_Y + (1-n^*)k_1(\Sigma_X + k)^{-1}\right) \cdot (k - \Sigma_X)^{-1} = \gamma(k_1 - \Sigma_X k n^*)\,(k - \Sigma_X)^{-1}.$$

Therefore, from (B35), we have

$$\beta_I^* = -\beta_S^*\gamma \cdot (k_1 - \Sigma_X k n^*)(1 + \Sigma_X^{-1}k)^{-1}\,(k - \Sigma_X)^{-1}.$$

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

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

This completes the proof of the proposition. □

Proof of Corollary 2: The polynomial (36) can be rewritten as

$$F(x) := x\left[\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{-1}{2}} - \gamma^{-1}x\right] = \frac{k_1k_2^{-1}\gamma^{-1}}{x^2 + (\rho^2\Sigma_f + k)\Sigma_\delta k_2^{-1}} := G(x). \tag{B36}$$

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

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

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 $\Sigma_u \ge 4\gamma^{-2}\Sigma_\delta^{-1}$.

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

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

□

Proof of Corollary 3: From the definitions of certainty equivalents in (37)-(42), 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

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

From equations (B4), (B7), (B10), (B18), (B21) and (B22) in the proofs of Propositions 1 and 2, we could show the certainty equivalents in the two economies are:

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

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

Proof of Corollary 4: 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

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

Under disclosure regime, we have

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

After some long and tedious simplifications, we have

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

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

Proof of Corollary 5:

$\pi_I^* = \mathbb{E}[D_I^*(\tilde{f} - \tilde{p}^*)] = \mathbb{E}[\mathbb{E}[D_I^*(\tilde{f} - \tilde{p}^*)|\tilde{\omega}, D_I^*]] = \mathbb{E}[D_I^*\mathbb{E}[(\tilde{f} - \tilde{p}^*)|\tilde{\omega}, D_I^*]] = \mathbb{E}[D_I^* 0] = 0$ □

Proof of Proposition 3: Parts (1) and (2) follow from Proposition C4 in Appendix C.

Part (3): From Corollary 4 and Proposition C1, we can show that when Σ_z is sufficiently large,

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

Part (4): When Σ_z is sufficiently large, Proposition C1 in Appendix C shows

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

Here, n_0^* is the positive root of equation (C1). When $|\rho| \le 1/\sqrt{2}$, it gives $\lambda_I^* < \lambda_\omega$. □

Proof of Proposition ??: First, from Proposition C3 in Appendix C, the claims (**??**) and (**??**) are obvious by taking derivatives with respect to ρ.

Second, from Corollary 4, we know

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

When Σ_z is sufficiently large, the constants n, m, and n^* are irrelevant to ρ. Therefore, it is easy to show that $\partial INF/\partial\rho > 0$ and $\partial INF^*/\partial\rho > 0$ by observing that $\partial(k+\rho^2\Sigma_f)k_1^{-1}/\partial\rho > 0$. Last, due to $\lambda_\omega \approx (\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1}\Sigma_f)\gamma^{-1}\Sigma_z^{-1}$, it gives $\partial\lambda_\omega/\partial\rho > 0$. The results $\partial\lambda_O^*/\partial\rho < 0$ and $\partial\lambda_I^*/\partial\rho > 0$ follow from Proposition C1. □

C Equilibrium under First-order Approximation

In this appendix, we follow the same spirit as Peress (2004) and compute an equilibrium under the first-order approximation as $1/\Sigma_z$ approaches 0. In the approximation, we keep all the $1/\Sigma_z$ terms and omit higher order terms. Proposition C1 characterizes the approximation equilibrium and Proposition C3 computes investors' welfare. Proposition C4 shows that all investors are worse off under the disclosure regime if Σ_z is higher than a certain threshold that is determined by primitive parameters of the model. Proposition C2 characterizes the investors' profits.

Proposition C1. *When the insider's hedge need Σ_z is sufficiently large, under the first-order approximation (i.e., when $1/\Sigma_z^2$ and higher order terms are ignored), the non-disclosure equilibrium is given by*

$$\alpha_f \approx \gamma^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}\rho + q_1\Sigma_z^{-1}, \quad \alpha_Z \approx -1 + q_2\Sigma_z^{-1},$$
$$\beta_S \approx \gamma^{-1}\Sigma_\delta^{-1} + q_3\Sigma_z^{-1}, \quad \phi_H \approx -1 + q_4\Sigma_z^{-1}, \quad \lambda_\omega \approx q_5\Sigma_z^{-1},$$
$$n \approx 1 - \gamma^{-1}\Sigma_\delta^{-1}q_5\Sigma_z^{-1}, \quad m \approx 1 - \gamma^{-1}[\Sigma_\delta^{-1} + (1-\rho^2)^{-1}\Sigma_f^{-1}]q_5\Sigma_z^{-1}, \quad n - m \approx \gamma^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}q_5\Sigma_z^{-1}.$$

Here, the constants $q_1, q_2, \cdots, q_5$ are

$$q_1 = \rho((1-\rho^2)\Sigma_f\Sigma_\delta^{-1} - 2)\gamma^{-2}(1-\rho^2)^{-2}\Sigma_f^{-2}q_5, \quad q_2 = -(\Sigma_f(1-\rho^2)\Sigma_\delta^{-1} - 2)\gamma^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}q_5,$$
$$q_3 = -\gamma^{-1}\Sigma_\delta^{-2}q_5^2, \quad q_4 = \gamma^{-1}\Sigma_f^{-1}q_5, \quad q_5 = \left(\rho^2(1-\rho^2)^{-1} + \Sigma_\delta^{-1}\Sigma_f\right)\gamma^{-1}.$$

The disclosure equilibrium parameters are given by

$$\alpha_f^* \approx \gamma^{-1}\Sigma_f^{-1}(1-n^*\rho^2)^{-1}\rho + q_1^*\Sigma_z^{-1}, \quad \alpha_Z^* \approx -(1-\rho^2)(1-n^*\rho^2)^{-1} + q_2^*\Sigma_z^{-1},$$
$$\beta_S^* \approx \frac{\gamma^{-1}\Sigma_\delta^{-1}}{1 + (1-n^*)\Sigma_f\Sigma_\delta^{-1}} + q_3^*\Sigma_z^{-1}, \quad \beta_I^* \approx q_4^*\Sigma_z^{-1},$$
$$\phi_H^* \approx -(n^*)^{-1}\left[1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2}\right] + q_5^*\Sigma_z^{-1}, \quad \phi_I^* = 0,$$
$$\lambda_O^* \approx (n^*)^2\left[\Sigma_u^{1/2}(n_0^*)^{-1}\Sigma_f^{-1/2} - \gamma^{-1}\Sigma_f^{-1}\right]^{-1} + q_6^*\Sigma_z^{-1}, \quad \lambda_I^* \approx q_7^*\Sigma_z^{-1}.$$

Here, the constants $q_1^*, q_2^*, \cdots, q_7^*$ are

$$
\begin{aligned}
q_1^* &= \gamma^{-3}\Sigma_f^{-2}\rho^3(1-\rho^2)^{-2}(n^*\rho^2+\rho^2-2)(1-n^*\rho^2)^{-2},\\
q_2^* &= -\gamma^{-2}\Sigma_f^{-1}\rho^2(n^*\rho^2+\rho^2-2)(1-\rho^2)^{-1}(1-n^*\rho^2)^{-2},\\
q_3^* &= \gamma^{-3}\rho^4\Sigma_f^{-2}(1-\rho^2)^{-2}(1-n^*)(\Sigma_\delta+\Sigma_f-\Sigma_\delta\Sigma_f)\left((1-n^*)\Sigma_f+\Sigma_\delta\right)^{-2},\\
q_4^* &= -\frac{(n^*)^{-1}\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}q_7^*,\\
q_5^* &= \frac{1}{2}\gamma^{-3}\Sigma_f^{-3/2}\rho^4(1-\rho^2)^{-2}(n^*)^{-1}n_0^*\Sigma_u^{-1/2},\\
q_6^* &= \gamma^{-2}(1-\rho^2)^{-2}\rho^4\left(\gamma^{-1}-\frac{1}{2}\Sigma_f^{1/2}\Sigma_u^{1/2}(n_0^*)^{-1}\right)\left[\Sigma_f^{1/2}\Sigma_u^{1/2}(n_0^*)^{-1}-\gamma^{-1}\right]^{-2}(n^*)^2,\\
q_7^* &= \rho^2(1-\rho^2)^{-2}(1-\rho^2n^*)n^*\gamma^{-1}.
\end{aligned}
$$

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

$$
f(x) = x^4 - \gamma\Sigma_u^{\frac{1}{2}}\cdot x^3 + \frac{\Sigma_\delta}{1+\Sigma_\delta}\cdot x^2 - \gamma\frac{\Sigma_u^{\frac{1}{2}}\Sigma_\delta}{1+\Sigma_\delta}\cdot x + \frac{1}{1+\Sigma_\delta} = 0. \tag{C1}
$$

Proof. We only keep dominating terms and ignore high orders for approximations below.

Non-disclosure regime. Since the two constants m and n in equations (22) and (23) do not admit explicit solutions, we approach the approximation directly from the proof of Proposition 1. Also, in that proof, we have defined the following notations:

$$
\Sigma_X = \rho^2\Sigma_f, \quad \Sigma_Y = (1-\rho^2)\Sigma_f, \quad k = \gamma^2\Sigma_Y^2\Sigma_z, \tag{C2}
$$

$$
\alpha_X = \rho^{-1}\alpha_f, \quad n = 1-\lambda_\omega\beta_S, \quad m = 1-\lambda_\omega(\alpha_X+\beta_S). \tag{C3}
$$

First, we analyze the Kyle's lambda λ_ω. Intuitively, when the insider's hedge motive Σ_z goes to infinity, the market becomes infinitely liquid, i.e., $\lambda_\omega \to 0$. This can be seen from (B14) in the proof of Proposition 1 since α_Z goes to a non-zero constant. From the definition in (C3), this also implies the two constants m and n both go to one when Σ_z goes to infinity. Then, from (B11) and (B12), we deduce that $\alpha_X \to \gamma^{-1}\Sigma_Y^{-1}$ and $\beta_S \to \gamma^{-1}\Sigma_\delta^{-1}$ as $\Sigma_z \to +\infty$. Again from equation (B14), we derive that first-order approximation of λ_ω is

$$
\lambda_\omega \approx (\alpha_X\Sigma_X + \beta_S\Sigma_f)\Sigma_z^{-1} = \gamma^{-1}(\rho^2(1-\rho^2)^{-1}+\Sigma_f\Sigma_\delta^{-1})\Sigma_z^{-1} := q_5\Sigma_z^{-1}.
$$

For the insider's demand, from equations (B11) and (C3), we have

$$
\begin{aligned}
\alpha_f - \rho\gamma^{-1}\Sigma_Y^{-1} &= \rho\frac{1-\lambda_\omega\beta_S}{\gamma\lambda_\omega^2\phi_H^2\Sigma_u + 2\lambda_\omega + \gamma(1-\lambda_\omega\beta_S)^2\Sigma_Y} - \rho\gamma^{-1}\Sigma_Y^{-1}\\
&\approx \rho\lambda_\omega\frac{\Sigma_Y\Sigma_\delta^{-1}-2}{\gamma\Sigma_Y\left[\gamma\lambda_\omega^2\phi_H^2\Sigma_u + 2\lambda_\omega + \gamma(1-\lambda_\omega\beta_S)^2\Sigma_Y\right]}\\
&\approx \rho\lambda_\omega(\Sigma_Y\Sigma_\delta^{-1}-2)\gamma^{-2}\Sigma_Y^{-2} = \rho(\Sigma_Y\Sigma_\delta^{-1}-2)\gamma^{-2}\Sigma_Y^{-2}q_5\Sigma_z^{-1},\\
\alpha_Z &= -\gamma\Sigma_Y\alpha_X \approx -1 + (\Sigma_Y\Sigma_\delta^{-1}-2)\gamma^{-1}\Sigma_Y^{-1}q_5\Sigma_z^{-1}.
\end{aligned}
$$

For the speculator's demand, from equation (B12), we derive

$$\begin{aligned}\beta_S - \gamma^{-1}\Sigma_\delta^{-1} &= \gamma^{-1}\left(\frac{1}{\Sigma_f + \Sigma_\delta - m\Sigma_X - n\Sigma_Y} - \Sigma_\delta^{-1}\right)\\ &= \gamma^{-1}\Sigma_f \frac{-1 + n - \lambda_\omega \alpha_X \rho^2}{(\Sigma_f + \Sigma_\delta - m\Sigma_X - n\Sigma_Y)\Sigma_\delta}\\ &\approx -\lambda_\omega \gamma^{-1}\Sigma_\delta^{-2}(\alpha_X\rho^2 + \beta_S)\Sigma_f \approx -\gamma^{-1}\Sigma_\delta^{-2} q_5^2 \Sigma_z^{-1}.\end{aligned}$$

For the hedger's demand, from equation (B13), we have

$$\begin{aligned}\phi_H + 1 &= 1 - \frac{m\Sigma_X + n\Sigma_Y}{m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z + \gamma^{-1}\lambda_\omega}\\ &= \lambda_\omega \frac{-(\rho^2\alpha_X + \beta_S)\Sigma_f + \gamma^{-1} + \lambda_\omega\alpha_Z^2\Sigma_z}{m^2\Sigma_X + n^2\Sigma_Y + \lambda_\omega^2\alpha_Z^2\Sigma_z + \gamma^{-1}\lambda_\omega} \approx \gamma^{-1}\Sigma_f^{-1} q_5 \Sigma_z^{-1}.\end{aligned}$$

Disclosure regime. Recall that

$$k = \gamma^2(1-\rho^2)^2\Sigma_f^2\Sigma_z,\ \ k_1 = k\Sigma_f + \rho^2(1-\rho^2)\Sigma_f^2,\ \ k_2 = k_1 + (k + \Sigma_X)\Sigma_\delta. \tag{C4}$$

When Σ_z goes to infinity, the positive root n_0^* of quartic function (36) in Proposition 2 reduces to (C1).

From equation (35), the first-order approximation of Kyle's lambda is

$$\begin{aligned}\lambda_I^* &= \gamma n^*(k_1 - \rho^2\Sigma_f k n^*)(1 + \rho^{-2}\Sigma_f^{-1}k)^{-1}\left(k - \rho^2\Sigma_f\right)^{-1}\\ &= \gamma n^*(k\Sigma_f + \rho^2(1-\rho^2)\Sigma_f^2 - \rho^2\Sigma_f k n^*)(1 + \rho^{-2}\Sigma_f^{-1}k)^{-1}\left(k - \rho^2\Sigma_f\right)^{-1}\\ &\approx \gamma^{-1} n^*(1 - n^*\rho^2)\rho^2(1-\rho^2)^{-2}\Sigma_z^{-1} := p_7\Sigma_z^{-1}.\end{aligned}$$

Since

$$(\rho^2\Sigma_f + k)k_1^{-1} = \Sigma_f^{-1}\left(1 + \rho^4\Sigma_f^2 k_1^{-1}\right), \quad (\rho^2\Sigma_f + k)^{1/2}k_1^{-1/2} \approx \Sigma_f^{-1/2}\left(1 + \frac{1}{2}\rho^4\Sigma_f^2 k_1^{-1}\right)$$

from equation (34), we derive that

$$\begin{aligned}\lambda_O^* &= (n^*)^2\left[\frac{1}{\Sigma_u^{1/2}(n_0^*)^{-1}k_1^{-\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{1}{2}} - \gamma^{-1}(\rho^2\Sigma_f + k)k_1^{-1}} - \frac{1}{\Sigma_u^{1/2}\Sigma_f^{-1/2}(n_0^*)^{-1} - \gamma^{-1}\Sigma_f^{-1}}\right]\\ &\approx (n^*)^2\frac{\Sigma_u^{1/2}(n_0^*)^{-1}\left(\Sigma_f^{-1/2} - (\rho^2\Sigma_f + k)^{1/2}k_1^{-1/2}\right) - \gamma^{-1}(\Sigma_f^{-1} - (\rho^2\Sigma_f + k)k_1^{-1})}{\left(\Sigma_u^{1/2}\Sigma_f^{-1/2}(n_0^*)^{-1} - \gamma^{-1}\Sigma_f^{-1}\right)^2}\\ &\approx \gamma^{-2}(1-\rho^2)^{-2}\rho^4\left(\gamma^{-1} - \frac{1}{2}\Sigma_f^{1/2}\Sigma_u^{1/2}(n_0^*)^{-1}\right)\left[\Sigma_f^{1/2}\Sigma_u^{1/2}(n_0^*)^{-1} - \gamma^{-1}\right]^{-2}(n^*)^2\Sigma_z^{-1} := p_6\Sigma_z^{-1}.\end{aligned}$$

For the insider's demand, from equation (29), we have

$$\begin{aligned}
\alpha_f^* - \frac{\gamma^{-1}\rho}{\Sigma_f(1-\rho^2 n^*)} &= \gamma^{-1}\rho\left[\frac{k-\rho^2\Sigma_f}{k_1-\rho^2\Sigma_f k n^*} - \frac{1}{\Sigma_f(1-\rho^2 n^*)}\right] \\
&= \gamma^{-1}\rho\frac{k\Sigma_f - \rho^2\Sigma_f^2(1-\rho^2 n^*) - k_1}{(k_1-\rho^2\Sigma_f k n^*)\Sigma_f(1-\rho^2 n^*)} \\
&\approx \gamma^{-3}\Sigma_f^{-2}\rho^3(1-\rho^2)^{-2}(n^*\rho^2+\rho^2-2)(1-n^*\rho^2)^{-2}\Sigma_z^{-1}. \\
\alpha_Z^* &= -\alpha_f^*\gamma(1-\rho^2)\rho^{-1}\Sigma_f \\
&\approx -(1-\rho^2)(1-n^*\rho^2)^{-1} - \gamma^{-2}\Sigma_f^{-1}\rho^2(n^*\rho^2+\rho^2-2)(1-\rho^2)^{-1}(1-n^*\rho^2)^{-2}\Sigma_z^{-1}.
\end{aligned}$$

Since $k_1 k_2^{-1} \approx (1+\Sigma_\delta\Sigma_f^{-1})^{-1} - \rho^4\Sigma_f^2\Sigma_\delta(\Sigma_f+\Sigma_\delta)^{-2}k^{-1}$, for the speculator's demand, from equations (30) and (31), we have

$$\begin{aligned}
&\beta_S^* - \frac{\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_f\Sigma_\delta^{-1}} = \frac{k_1k_2^{-1}\gamma^{-1}}{n^*\Sigma_\delta k_1 k_2^{-1} + (1-n^*)k_1(k+\rho^2\Sigma_f)^{-1}} - \frac{\gamma^{-1}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_f\Sigma_\delta^{-1}} \\
&\quad\approx \gamma^{-3}\rho^4\Sigma_f^{-2}(1-\rho^2)^{-2}(1-n^*)(\Sigma_\delta+\Sigma_f-\Sigma_\delta\Sigma_f)\left((1-n^*)\Sigma_f+\Sigma_\delta\right)^{-2}\Sigma_z^{-1} = p_3\Sigma_z^{-1}, \\
&\beta_I^* = -\lambda_I^*(n^*)^{-1}\beta_S^* \approx -\frac{(n^*)^{-1}\gamma^{-1}\Sigma_\delta^{-1}p_7}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\Sigma_z^{-1}.
\end{aligned}$$

For the hedger's demand, since $(\rho^2\Sigma_f+k)^{1/2}k_1^{-1/2} \approx \Sigma_f^{-1/2} + \frac{1}{2}\rho^4\Sigma_f^{-3/2}\gamma^{-2}(1-\rho^2)^{-2}\Sigma_z^{-1}$, from equation (32), we have

$$\begin{aligned}
\phi_H^* &= -(n^*)^{-1}\left[1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}k_1^{-1/2}(\rho^2\Sigma_f+k)^{\frac{1}{2}}\right] \\
&\approx -(n^*)^{-1}\left[1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2}\right] + \frac{1}{2}\gamma^{-3}\Sigma_f^{-3/2}\rho^4(1-\rho^2)^{-2}(n^*)^{-1}n_0^*\Sigma_u^{-1/2}\Sigma_z^{-1}.
\end{aligned}$$

This completes the proof. □

Proposition C2. *All investors' expected trading profits are given by*

$$\pi_I = m\rho\Sigma_f\alpha_f - \lambda_\omega\alpha_Z^2\Sigma_z, \quad \pi_S = \beta_S(m\rho^2 + n(1-\rho^2))\Sigma_f, \quad \pi_H = -\lambda_\omega\phi_H^2\Sigma_u, \tag{C5}$$
$$\pi_I^* = 0, \quad \pi_S^* = k_1(\rho^2\Sigma_f+k)^{-1}n^*\beta_S^*, \quad \pi_H^* = -\pi_S^*. \tag{C6}$$

Proof. We only prove the non-disclosure regime. The insider's trading profit is

$$\begin{aligned}
\pi_I &= \mathbb{E}\left[D_I(\tilde{f}-\tilde{p})\right] = \mathbb{E}\left[(\alpha_f\tilde{f}_a + \alpha_Z\tilde{Z})(\tilde{f}-\tilde{p})\right] \\
&= \mathbb{E}\left[(\alpha_f\tilde{f}_a + \alpha_Z\tilde{Z})(m\rho\tilde{f}_a + n\sqrt{1-\rho^2}\tilde{f}_b - \lambda_\omega\alpha_Z\tilde{Z})\right] \\
&= m\rho\Sigma_f\alpha_f - \lambda_\omega\alpha_Z^2\Sigma_z.
\end{aligned}$$

The speculator's trading profit is

$$\begin{aligned}\pi_S &= \mathbb{E}\left[D_{S,j}(\tilde{f}-\tilde{p})\right] = \mathbb{E}\left[D_{S,j}\mathbb{E}\left[\tilde{f}-\tilde{p}|\tilde{s}_j\right]\right] \\ &= \mathbb{E}\left[\beta_S\left(m\rho^2\Sigma_f + n(1-\rho^2)\Sigma_f\right)(\Sigma_f+\Sigma_\delta)^{-1}\tilde{s}_j^2\right] = \beta_S(m\rho^2+n(1-\rho^2))\Sigma_f.\end{aligned}$$

The hedger's trading profit is

$$\pi_H = \mathbb{E}\left[D_H(\tilde{f}-\tilde{p})\right] = \mathbb{E}\left[\phi_H\tilde{u}(\tilde{f}-\tilde{p})\right] = -\lambda_\omega\phi_H^2\Sigma_u.$$

This completes the proof. □

Proposition C3. *In the first-order approximation equilibria, investors' welfare is given by*

$$\begin{aligned}
&\mathbb{E}[CE_I] \approx -\frac{1}{2}\gamma^{-1}\rho^2(1-\rho^2)^{-1} - \gamma^{-1}\Sigma_\delta^{-1}\Sigma_f \\
&-\frac{1}{2}\gamma^{-2}\left[\Sigma_\delta^{-1}(\Sigma_f(1-\rho^2)\Sigma_\delta^{-1}-2)(\rho^2(1-\rho^2)^{-1}+\Sigma_\delta^{-1}\Sigma_f) + 2\rho^2(1-\rho^2)^{-2}\Sigma_f^{-1}\right]q_5\Sigma_z^{-1}, \\
&\mathbb{E}[CE_I^*] \approx -\frac{1}{2}\gamma(1-\rho^2)\Sigma_f\frac{1-n^*}{1-n^*\rho^2}\Sigma_z - \frac{1}{2}\frac{\gamma^{-1}n^*\rho^2(1-\rho^2)}{(1-n^*\rho^2)^2} - \frac{1}{2}\gamma^{-1}(1-\rho^2)^{-1}\rho^2 n^* q_2^*\Sigma_z^{-1}, \\
&\mathbb{E}[CE_S] \approx \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}\Sigma_f - \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}\left(1+\Sigma_\delta^{-1}\Sigma_f\right)q_5^2\Sigma_z^{-1}, \\
&\mathbb{E}[CE_S^*] \approx \frac{1}{2}\gamma^{-1}\Sigma_\delta^{-1}\frac{\Sigma_f n^*}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f} + \frac{1}{2}n^*\left[\Sigma_f q_3^* - \rho^4\gamma^{-3}(1-\rho^2)^{-2}\Sigma_\delta^{-1}(1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f)^{-1}\right]\Sigma_z^{-1}, \\
&\mathbb{E}[CE_H] \approx -\frac{1}{2}\Sigma_u q_5\left[\Sigma_f\Sigma_\delta^{-1}+1+(1-\rho^2)^{-1}\right]\Sigma_z^{-1}, \\
&\mathbb{E}[CE_H^*] = \frac{1}{2}\gamma\Sigma_f\left[(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2-1\right] \\
&-\frac{1}{2}\gamma\left[\left[(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2-1\right]\rho^4(1-\rho^2)^{-2}\gamma^{-2} - 2\Sigma_f n^* q_5^*(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})\right]\Sigma_z^{-1}
\end{aligned}$$

In the first-order approximation equilibria, investors' trading profit is

$$\begin{aligned}
&\pi_I \approx -\Sigma_\delta^{-1}\gamma^{-1}\Sigma_f + \left[\rho q_1 - \rho^2\gamma^{-2}\Sigma_\delta^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}q_5 - \gamma^{-2}(1-\rho^2)^{-2}\Sigma_f^{-2}\rho^2 q_5 - 2\gamma(1-\rho^2)\rho^{-1}q_1q_5\right]\Sigma_z^{-1} \\
&\pi_S \approx \Sigma_\delta^{-1}\gamma^{-1}\Sigma_f - \gamma^{-1}\Sigma_\delta^{-1}(1-\Sigma_f\Sigma_\delta^{-1})q_5^2\Sigma_z^{-1}, \qquad \pi_H \approx -q_5\Sigma_u\Sigma_z^{-1}, \\
&\pi_I^* = 0, \qquad \pi_S^* \approx \frac{n^*\gamma^{-1}\Sigma_\delta^{-1}\Sigma_f}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f} + n^*\left[q_3^*\Sigma_f - \frac{\rho^4(1-\rho^2)^2\gamma^{-3}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\right]\Sigma_z^{-1}, \quad \pi_H^* = -\pi_S^*.
\end{aligned}$$

Proof. It follows directly from Corollary 3, Proposition C1 and Proposition C2 in the appendix. □

Proposition C4. *In the first-order approximation equilibria,*

(a) *if $\Sigma_z > \bar{\Sigma}_1$, all investors are worse off from disclosure, that is, $CE_I \geq CE_I^*, CE_S \geq CE_S^*, CE_H \geq CE_H^*$, where $\bar{\Sigma}_1$ is given by* (C7).
(b) *if $\Sigma_z > \bar{\Sigma}_2$, it increases the insider's expected trading profit but decreases outside investors' expected trading profits from disclosure: $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$, where $\bar{\Sigma}_2$ is given by* (C8).

Proof. (a) From Proposition C3, under first-order approximation equilibrium, we could get the estimations of lower boundaries such that disclosure is worse off for the insider, speculators and hedgers, i.e. $\mathbb{E}[CE_t] > \mathbb{E}[CE_t^*]$ when $\Sigma_z > \Sigma_z^t,\ t \in \{I, S, H\}$.[10] Here,

$$\Sigma_{z,1}^I = \gamma^{-2}\Big[\rho^2\Big((1-\rho^2)^{-1} - n^*(1-\rho^2)(1-n^*\rho^2)^{-2}\Big) + 2\gamma^{-1}\Sigma_\delta^{-1}\Sigma_f\Big](1-n^*\rho^2)(1-\rho^2)^{-1}(1-n^*)^{-1}\Sigma_f^{-1},$$

$$\Sigma_{z,1}^S = \Sigma_f^{-1}(1-n^*)^{-1}(1+\Sigma_\delta^{-1}\Sigma_f)^{-1}\Big\{(1+\Sigma_f\Sigma_\delta^{-1})(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})q_5^2$$
$$+ n^*\gamma\Sigma_\delta\Big[\Sigma_f(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})p_3 - \rho^4\gamma^{-3}(1-\rho^2)^{-2}\Sigma_\delta^{-1}\Big]\Big\},$$

$$\Sigma_{z,1}^H = \Big\{\Sigma_u q_5\Big[\Sigma_f\Sigma_\delta^{-1} + 1 + (1-\rho^2)^{-1}\Big] -$$
$$\gamma\left[\left[(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2 - 1\right]\rho^4(1-\rho^2)^{-2}\gamma^{-2} - 2\Sigma_f n^* q_5^*(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})\right]\Big\}$$
$$\gamma^{-1}\Sigma_f^{-1}\left[(1-n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2 - 1\right]^{-1}.$$

Therefore, when $\Sigma_z > \bar{\Sigma}_1$, all investors are worse off from disclosure with

$$\bar{\Sigma}_1 = \max\left(\Sigma_{z,1}^I, \Sigma_{z,1}^H, \Sigma_{z,1}^S\right). \tag{C7}$$

(b) Considering investors' trading profit, from Proposition (C3), we know when the insider's hedge motive Σ_z is larger than a threshold $\bar{\Sigma}_2$ (defined in (C8)), it would increase the insider's expected trading profit but decrease these of outside investors from disclosure, i.e., $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$. Here,

$$\Sigma_{z,2}^I = \Sigma_\delta\gamma\Sigma_f^{-1}\left[\rho q_1 - \rho^2\gamma^{-2}\Sigma_\delta^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}q_5 - \gamma^{-2}(1-\rho^2)^{-2}\Sigma_f^{-2}\rho^2 q_5 - 2\gamma(1-\rho^2)\rho^{-1}q_1q_5\right],$$

$$\Sigma_{z,2}^S = \left[n^*\left[q_3^*\Sigma_f - \frac{\rho^4(1-\rho^2)^2\gamma^{-3}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\right] + \gamma^{-1}\Sigma_\delta^{-1}(1-\Sigma_f\Sigma_\delta^{-1})q_5^2\right]$$
$$\Sigma_\delta\gamma(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})\Sigma_f^{-1}(1-n^*)^{-1}(1+\Sigma_f\Sigma_\delta^{-1})^{-1},$$

$$\Sigma_{z,2}^H = \left[q_5\Sigma_u - n^*\left(q_3^*\Sigma_f - \frac{\rho^4(1-\rho^2)^2\gamma^{-3}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\right)\right](1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f)\gamma\Sigma_\delta(n^*)^{-1}\Sigma_f^{-1}$$

The threshold $\bar{\Sigma}_2$ is given by

$$\bar{\Sigma}_2 = \max\left(\Sigma_{z,2}^I, \Sigma_{z,2}^H, \Sigma_{z,2}^S\right). \tag{C8}$$

This completes the proof. □

[10] To simplify the result, we only keep dominating terms when estimating the lower boundaries.