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Disclosing and cooling-off: An analysis of insider trading rules ☆

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ABSTRACT

We analyze two insider-trading regulations recently introduced by the Securities and Exchange Commission: mandatory disclosure and "cooling-off period". The former requires insiders disclose trading plans at adoption, while the latter mandates a delay period before trading. These policies affect investors' trading profits, risk sharing, and hence their welfare. If the insider has sufficiently large hedging needs, in contrast to the conventional wisdom from "sunshine trading", disclosure reduces the welfare of all investors. In our calibration, a longer cooling-off period benefits speculators, and its implications for the insider and hedgers depend on whether the disclosure policy is already in place.

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 creates an affirmative defense for a corporate executive to charges 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

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[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.

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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 the concern that this opacity invites opportunistic insider trading.[3] The new rule requires insiders publicly disclose their trading plans upon adoption, modification, and cancellation.

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 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.

Mandatory disclosure. The disclosure policy essentially provides the market maker and outside investors additional information: the insider's trading plan. We characterize the equilibria under both the disclosure and non-disclosure regimes, and compare the two equilibria to analyze the implications of mandatory disclosure. We first show analytically that in a limiting 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.

To understand our result, we note that, in general, policies affect investor welfare both through a profit channel and a risk-sharing channel. The sunshine trading intuition concerns an investor's trading profits and it continues to hold in our setting. Indeed, we show that when an investor's hedging need is sufficiently large, disclosure increases the insider's expected trading profit. However, the risk-sharing channel works against the insider in this case. Specifically, disclosure makes the stock price more informative about the fundamental value. This reduces the insider's risk-sharing opportunities in the market (Hirshleifer, 1971). When the insider has a strong hedging need, the Hirshleifer effect dominates, and disclosure makes the insider worse off.[5] Similarly, the reduction in risk-sharing opportunities harms hedgers (i.e., outside investors whose primary trading goal is risk sharing). Moreover, disclosure also harms speculators (i.e., informed outside investors) because their aggregate 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.

To calibrate our model, 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 obtain the estimates of our model parameters to match those trading activities. Our estimates suggests that the insider's hedging need is modest.

Our calibration shows that the welfare implications of mandatory disclosure for the hedger are the "mirror image" of those for the insider, i.e., one being better off tends to imply the other being worse off. The reason is that, since the insider's hedging need is modest, welfare implications are dominated by the effect from trading profits. When the insider is better off, it is at the expense of the hedger, and vice versa. Hence, the welfare implications for the insider and hedger tend to be the opposite of each other.

More specifically, when the insider's information advantage is large, the insider is worse off under the disclosure regime because it neutralizes the insider's information advantage. When the insider's information advantage is small, however, disclosure makes the insider better off because, as suggested by the sunshine trading intuition, his trade has a smaller price impact. This implication is different from the result in the limiting case because the insider's hedging need is modest here and hence the risk-sharing effect does not play a dominant role.

Cooling-off period. 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 private information about his firm. If he can trade right away, he would have a large advantage over outside investors. If, however, there is a mandatory waiting period, then, 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. Hence, 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. Second, the insider's information might have been leaked during the cooling-off period. Hence, our second formulation is based on the idea of information leakage: 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 our calibrations, the welfare patterns are qualitatively the same across the two formulations of a cooling-off period.

Our analysis shows that the welfare implication of the cooling-off policy depends on whether the disclosure policy is already in place.

[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 is 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 are conducting". "How Insider Trading Hides Behind a Barely Noticed Rule", *Knowledge at Wharton*, April 20, 2021.

[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).

[5] In general, the insider's risk-sharing channel works through two effects. The first is the Hirshleifer effect, which is related to price informativeness and determines the risk-sharing opportunities available in the market. The second effect, dubbed "trading aggressiveness effect", is related to the liquidity faced by the insider, because the insider as a large trader behaves strategically and hence, market liquidity affects how aggressively he utilizes the existing risk-sharing opportunities. When the insider's hedging need is high, the Hirshleifer effect dominates. When the insider's hedging need is low, the trading aggressiveness effect may dominate.

Under the non-disclosure regime, the insider can utilize his information advantage for trading profits and a longer cooling-off period reduces this advantage. Under the disclosure regime, however, the insider cannot exploit his private information for trading profits, leading to different welfare implications of the cooling-off period.

Similar to mandatory disclosure, the cooling-off period also affects investor welfare through the two channels: expected trading profit and risk sharing. In our calibrations, since the insider's hedging need is modest, the profit channel tends to dominate. Under the non-disclosure regime, a longer cooling-off period reduces the insider's information advantage, which decreases the insider's profits and welfare, but increases the profits and welfare of outside investors (i.e., speculators and the hedger).

Under the disclosure regime, the insider's information is partly revealed through disclosure. A longer cooling-off period means less information is revealed, and hence speculators are in a better position to take advantage of hedgers. Therefore, a longer cooling-off period increases speculators' expected trading profits and welfare, while the opposite is true for the hedger. Interestingly, the insider benefits from a longer cooling-off period under the disclosure regime. The reason is as follows. The insider's profit channel is "shut down" in this case because his *ex ante* expected trading profit is always zero. Intuitively, the insider's trade is public information, and the pricing-rule set by the risk-neutral market maker implies that the expected net return of any trading strategy based on public information is zero. Hence, the effect of the cooling-off period on the insider's welfare operates through the risk-sharing channel. A longer cooling-off period reduces the insider's information advantage, and hence his order becomes less toxic and has a lower price impact. In response, the insider trades more aggressively to better utilize hedging opportunities, which makes the insider better off from a longer cooling-off period under the disclosure regime.

Related literature. Our analysis of the pre-announcement of insider trading, one of the newly introduced SEC rules, is related to the extensive theoretical literature on insider trading.[6] Most closely, our paper is related to the studies on disclosure of tradings by insiders. Huddart et al. (2001), Buffa (2014) 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.

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). The insight identified by the existing sunshine-trading literature concerns trading profits and works through market liquidity. That is, if an investor creditably declares that his trading is uninformed, then he can avoid adverse selection and get a better trading price, which lowers his trading losses. Our analysis complements the existing literature by highlighting two novel insights from a risk-sharing perspective. First, declaration of uninformed trade necessarily reveals informed trades (from other investors) in the market, which improves price informativeness and reduces the ex-ante risk-sharing function of the market via the Hirshleifer effect. Second, for a large trader such as a corporate insider, market liquidity not only affects his trading profits, as highlighted by the existing sunshine-trading literature, but also affects the effectiveness of his risk-sharing through its effect on the aggressiveness of his hedging trade. This second insight is one key driver in determining how a cooling-off period affects the insider's welfare in our analysis.

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 $\tilde{f} \sim N(\bar{f}, \Sigma_f)$ with constants $\bar{f} \in \mathbb{R}$ 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 rebalancing (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 $\tilde{f}_b$:

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

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:

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

[6] 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), Kacperczyk and Pagnotta (2020), Mele and Sangiorgi (2021), and Carré et al. (2022).

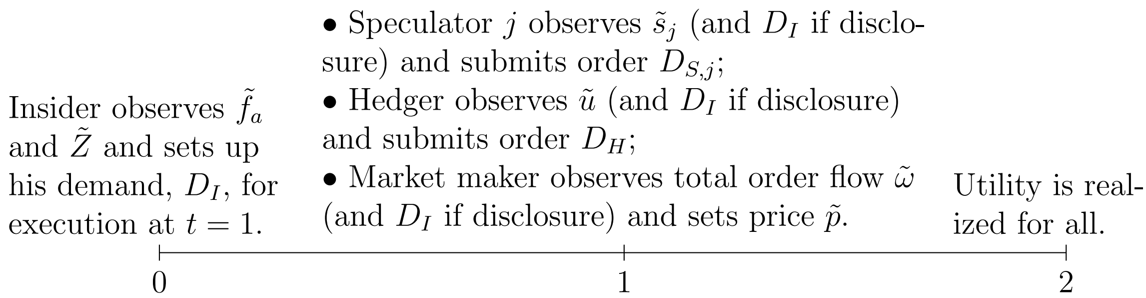

Fig. 1. Timeline.

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:

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

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 subsection. The following figure summarizes the timeline of events in our model (see Fig. 1).

2.1. Disclosure of the insider's 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.[7] In our setup, this policy change alters the information sets of 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 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 about some aspects of 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. There are various reasons why a cooling-off period reduces the insider's relative information advantage. One is simply that the firm's fundamental value changes over time and so the insider's private information will naturally become obsolete after a cooling-off period. This perspective can be captured by the 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 the 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 before trading, his information becomes less relevant at the trading time since the firm's value would have changed by then. This formulation is consistent with the evidence that insiders tend to have private information about shorter-term news events as opposed to long-term firm-level measures such as annual employment or inventory changes (Cohen et al., 2012).

Information leakage. An alternative 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

[7] 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.

information-leakage perspective. In that setting, the amount of insider information is fixed and outside investors can observe a garbled signal about the insider's information. A longer cooling-off period offers 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 the signal is.

2.3. Discussions

We make five 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 the insider does not observe new information 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 insider 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".[8]

Third, our two formulations of the cooling-off period in Section 2.2 focus on the fact that a longer cooling-off period reduces the insider's information advantage. We note that a cooling-off period can also have an effect on the insider's hedging need because it makes the insider's holding temporarily non-tradable. As suggested by the analysis in Longstaff (2009), this restriction can potentially impose a substantial welfare cost. Analyzing this cost and the insider's potential responses (e.g., using its holdings as collateral to borrow) is an important research topic and we leave it for future research.

Fourth, 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 for 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. We have analyzed an extension of our baseline model by introducing an additional round of trading for outside investors at $t = 0$, which 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.

[8] 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.

3. Equilibrium and measurement

In this section, we characterize the equilibria and conduct some analytical analysis. First, we construct the equilibria with and without disclosure in Sections 3.1 and 3.2, respectively. We then discuss the measures for policy assessment in Section 3.3. Finally, we present some analytical results in Section 3.4 for a limiting case in which the insider's hedging need is sufficiently large.

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

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

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

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

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

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

Proposition 1 (*Equilibrium Characterization: Non-Disclosure Regime*)**.** *In the non-disclosure economy, the coefficients* $\{\lambda_\omega, \alpha_f, \alpha_Z, \beta_S, \phi_H\}$ *of the linear equilibrium in Eqs. (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 constants $m \in (0,1)$ *and* $n \in (0,1)$ *are determined by the following equations:*

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

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

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 Eqs. (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 under the disclosure regime:

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

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

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

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

That is, the equilibrium is determined by eight parameters $\{\alpha_f^*, \alpha_Z^*, \beta_S^*, \beta_I^*, \phi_H^*, \phi_I^*, \lambda_O^*, \lambda_I^*\}$. We use superscript "$*$" to denote these parameters for the equilibrium with disclosure to distinguish from those for the equilibrium without disclosure. Relative to the equilibrium without disclosure, which is determined by five parameters, there are three additional parameters for the equilibrium with disclosure, because 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 Eq. (27) as follows:

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

That is, λ_O^* is the stock price sensitivity to the total order flows from the outside investors and $\lambda_I^* - \lambda_O^*(\beta_I^* + \phi_I^*)$ is the sensitivity to the insider's order. We prefer to write the price function in the form of Eq. (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 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 Eqs. (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:

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

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_I^* and λ_O^* 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, Eqs. (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 Eq. (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 Eq. (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*

$$\hat{\Sigma}_u = \frac{\sqrt{(1 - k_1 k_2^{-1})^2 + 16 k_1 k_2^{-1}} + k_1 k_2^{-1} - 1}{2\gamma^2 k_1 (\rho^2\Sigma_f + k)^{-1}}.$$

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. We also analyze other relevant variables, including price informativeness, market liquidity, and investor profits, which are not only of independent interests to regulators and academia (see discussions in Easley et al. (2016)), but also useful for describing the intuitions and highlighting the novelty of the 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 equilibrium under the non-disclosure regime. 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 equilibrium under the disclosure regime:

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

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

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

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 Stein (1987) 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*

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

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

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

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

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

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

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 ex ante 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; that is,* $\pi_I^* = 0$.

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 net 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. Limiting case

As illustrated in Propositions 1 and 2, both equilibria are highly nonlinear, making analytical analysis of the general case intractable. In this subsection, we analyze a limiting 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 mechanisms. In Section 4, we will conduct a calibration exercise for empirically more relevant parameter regions.

Results. 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 price 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 Appendix C. The comparison between the two equilibria leads to the following proposition.[9]

Proposition 3 (*Limiting Case*). *When the insider's hedging need Σ_z is sufficiently large, disclosure has the following implications:*

(1) *All investors are worse off under disclosure:* $\mathbb{E}[CE_I^*] < \mathbb{E}[CE_I]$, $\mathbb{E}[CE_S^*] < \mathbb{E}[CE_S]$, *and* $\mathbb{E}[CE_H^*] < \mathbb{E}[CE_H]$.
(2) *Disclosure 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) *Disclosure improves the informativeness of the stock price:* $INF^* > INF$.
(4) *Disclosure decreases the market liquidity for outside investors:* $\lambda_O^* > \lambda_\omega$. *Moreover, when* $|\rho| \le 1/\sqrt{2}$, *disclosure 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 (the 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

[9] 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 limiting case considered in this subsection. Specifically, in Appendix C, 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.

shows that this conjecture does not always hold. 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 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 in this case. However, the conclusion in Proposition 3 is exactly the opposite.

Intuitions. We now explain the intuitions for the surprising welfare result in Part (1) of Proposition 3. Let us first start with 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. Specifically, under the disclosure regime, the insider's expected trading profit π_I^* equals 0 (see Corollary 5), while under the non-disclosure regime, the insider's expected trading profit π_I is negative for a sufficiently large hedging need Σ_z.

How does disclosure decrease the insider's welfare despite a higher trading profit? Note that the insider is risk averse in our setting, and so disclosure affects the insider's welfare not only through the profit channel as highlighted by the sunshine trading literature, but also through a risk-sharing channel. As we mentioned in Footnote 1, for the insider, we can further decompose the risk-sharing channel into two effects. The first is the Hirshleifer effect (Hirshleifer, 1971), which works through price informativeness. More informative prices reduce risk-sharing opportunities and hence harm the insider. The second is the trading aggressiveness effect and it operates through market liquidity. Being a large trader, the insider behaves strategically, and hence, a higher market liquidity increases his trading aggressiveness in utilizing hedging opportunities.

When the insider's hedging need Σ_z is large, the risk-sharing channel—in particular, the Hirshleifer effect—dominates the profit channel in determining the insider's welfare. Specifically, as shown in Part (3) of Proposition 3, disclosure increases the stock price informativeness. Intuitively, 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 outside investors, in particular of 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 improves price informativeness, which harms the insider through the Hirshleifer effect. Part (4) of Proposition 3 shows that the insider faces better liquidity under the disclosure regime (i.e., $\lambda_I^* < \lambda_\omega$), because disclosure allows the market maker to separate the insider's order – which is primarily informationless when Σ_z is large – from outside investors' orders. This better liquidity improves the insider's trading aggressiveness and hence hedging effectiveness. However, this positive trading aggressiveness effect is dominated by the negative Hirshleifer effect when the insider's hedging need Σ_z is large.

We next discuss why outside investors also become worse off in Part (1) of Proposition 3. Again, disclosure affects outside investors' welfare through both a profit channel and a risk-sharing channel, and both channels harm outside investors. First, disclosure reduces outside investors' profits (i.e., $\pi_S^* < \pi_S$ and $\pi_H^* < \pi_H$ in Part (2) of Proposition 3). For speculators, this occurs for two reasons: (a) the more informative price system under the disclosure regime makes it less effective for speculators to exploit their private information; (b) under the disclosure regime, speculators' orders can no longer hide behind the insider's – which is mostly uniformed when Σ_z is large – and thus, speculators' trades in aggregate have a larger price impact (i.e., $\lambda_O^* > \lambda_\omega$ in Part (4)), further eroding speculators' equilibrium profits. For the hedger, who is uniformed, it is the worsened market liquidity through which disclosure harms his trading profits. Second, the improvement in price informativeness due to disclosure further harms the hedger via the Hirshleifer effect.

Remarks. We conclude this subsection with two remarks. First, 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 expected trading profit: if an investor creditably declares that his trading is uninformed, then he can avoid adverse selection and hence execute trades at a lower trading cost. Our analysis highlights a new insight from the ex-ante welfare perspective by showing that disclosure can reduce risk sharing and harm all risk-averse market participants.

Second, our analysis reveals two effects via which a policy affects a large trader's welfare through the risk-sharing channel: one works via the Hirshleifer effect, which determines how many risk-sharing opportunities are available in the market; the other works via the trading aggressiveness effect, which determines how effectively a large trader can utilize the existing risk-sharing opportunities. When the insider's hedging need Σ_z is large, as is the case in this subsection, the Hirshleifer effect dominates. By contrast, when Σ_z is relatively small, as will be the case in our calibrations in Sections 4 and 5, the trading aggressiveness effect can dominate.

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 $\bar{f}$ 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, since 82% of 10b5-1 plans start trading within 6 months (Larcker et al., 2021). 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 ratio 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 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 increasing the cooling-off period length (i.e., lowering the value of ρ), 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, 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

Table 1
Parameter values.

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

appears informed, while the rest of the insider trading is "routine" and uninformed. Note that, under the non-disclosure regime, the insider's 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:

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

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 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 Eqs. (13) and (14), we obtain the following equation:

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

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

4.2. Mandatory disclosure

With the parameter values in Table 1, we use Fig. 2 to illustrate the welfare implications of mandatory disclosure by varying the insider's hedging need, Σ_z, in a narrow range around its estimate, and his information amount, ρ. In each panel, we compare the welfare for one type of investor and use red cross "+" (blue circles "∘", respectively) to mark the region where the investor's welfare is higher (lower, respectively) under the disclosure regime than under the non-disclosure regime.

One pattern that immediately jumps out of this figure is that the implication for the hedger tends to be the "mirror image" of that for the insider, i.e., one being better off tends to imply the other being worse off. The reason is that, under the parameters in our calibration, risk sharing needs are modest and welfare implications are dominated by the effect from trading profits. When the insider is better off, it is at the expense of the hedger, and vice versa. Hence the welfare implications for the insider and hedger are the opposite of each other.

As shown by the left panel of Fig. 2, when the insider's information advantage ρ is large, the insider is worse off under the disclosure regime (as indicated by the area marked with blue circles "∘") because disclosure neutralizes the insider's information advantage. When the insider's information advantage is small, however, disclosure makes the insider better off (as indicated by the area marked with red crosses "+") because, as suggested by the sunshine trading intuition, his trade has a smaller price impact under the disclosure regime.[10] The right panel shows that the welfare implication for the hedger is the opposite of that for the insider. The disclosure makes the hedger worse off if ρ is small and better off if ρ is large.

Finally, let us look at speculators in the middle panel. Speculators are better off under the disclosure only when ρ takes intermediate values. Intuitively, when ρ is small, under the disclosure regime, the market maker can separate the insider's not-so-informed order from the rest. Hence, the speculator's information is revealed more, making the speculator worse off. When ρ is large, however, the insider's information has significant overlaps with speculators'. Hence, disclosure of the insider's trade neutralizes the speculator's information advantage, making the speculator worse off as well. In the intermediate region, where these two forces are not dominant, the speculator can benefit from the information revealed from the insider's trade.

The above results suggest that the welfare effect of the mandatory disclosure requirement varies according to the information structure. If information about the firm evolves at a fast pace (e.g., one possible example is firms in the information technology industry), private information decays at a fast pace (ρ is small). In this case, disclosure makes the insider better off and the hedger worse off. However, for a firm in industries that are more mature and stable (e.g., one possible example is utility companies), private information decays at a slow pace (ρ is large), disclosure makes the insider worse off and the hedger better off.

Fig. 2 focuses on the cases in which the insider's hedging need Σ_z is near its estimated value. By increasing the value of Σ_z, we find that, consistent with the analytical results in Proposition 3, all three types of investors are worse off under the disclosure regime if Σ_z larger than 5.[11]

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. We report the results in Fig. 3.

The first row of Fig. 3 plots the ex ante expected certainty equivalents against ρ, one for each type of investors. The certainty equivalents under the non-disclosure regime are plotted in solid lines, while those under the disclosure regime are plotted in dashed lines. In the previous subsection, we compare these two lines to analyze the welfare implications of mandatory disclosure. In this subsection, instead, we examine the pattern of each line and focus on how investor welfare changes with parameter ρ to study the implications of increasing the length of the cooling-off period (i.e., decreasing the value of ρ).

Again, similar to the discussions in Section 3.4, a regulation policy – increasing the cooling-off period length in this case – affects investor

[10] Note that, in this case, the insider's hedging need is modest and hence the risk-sharing effect does not play a dominant role. This is why the implication here is different from that in the limiting case.

[11] We note that this is an order of magnitude larger than the estimated value of Σ_z. To assess the empirical relevance of the limiting case, we explore the idea that, due to under-diversification, the insider may have a higher risk aversion than outside investors. Hence, we set the insider's risk aversion to 100 and keep the rest of the parameters the same as in Table 1 of the paper. We find that Σ_z needs to be over 0.3 to generate the welfare implication in the limiting case in Proposition 3. This is still larger than the estimated value of 0.08. Nevertheless, the welfare implication of the limiting case is perhaps no longer completely infeasible. Interestingly, even in this alternative calibration, the welfare implications for the region around $\Sigma_z = 0.08$ remain similar to those in our baseline calibration.

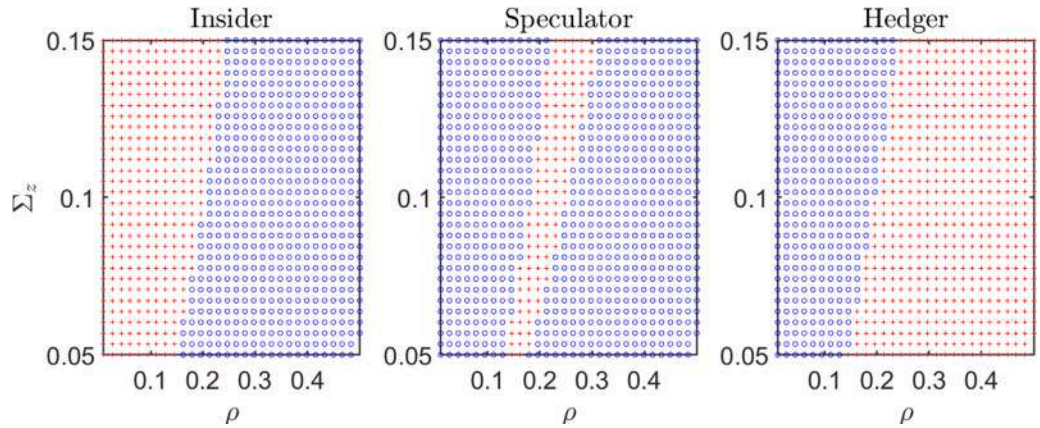

Fig. 2. Disclosure and investor welfare.
This figure plots welfare comparisons under disclosure and non-disclosure regimes against the insider's information amount ρ and hedging need Σ_z. The left, middle, and right panels are for the insider, a representative speculator, and the hedger, respectively. 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 from disclosure. Parameter values: $\gamma = 10$, $\Sigma_u = 0.17$, $\Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

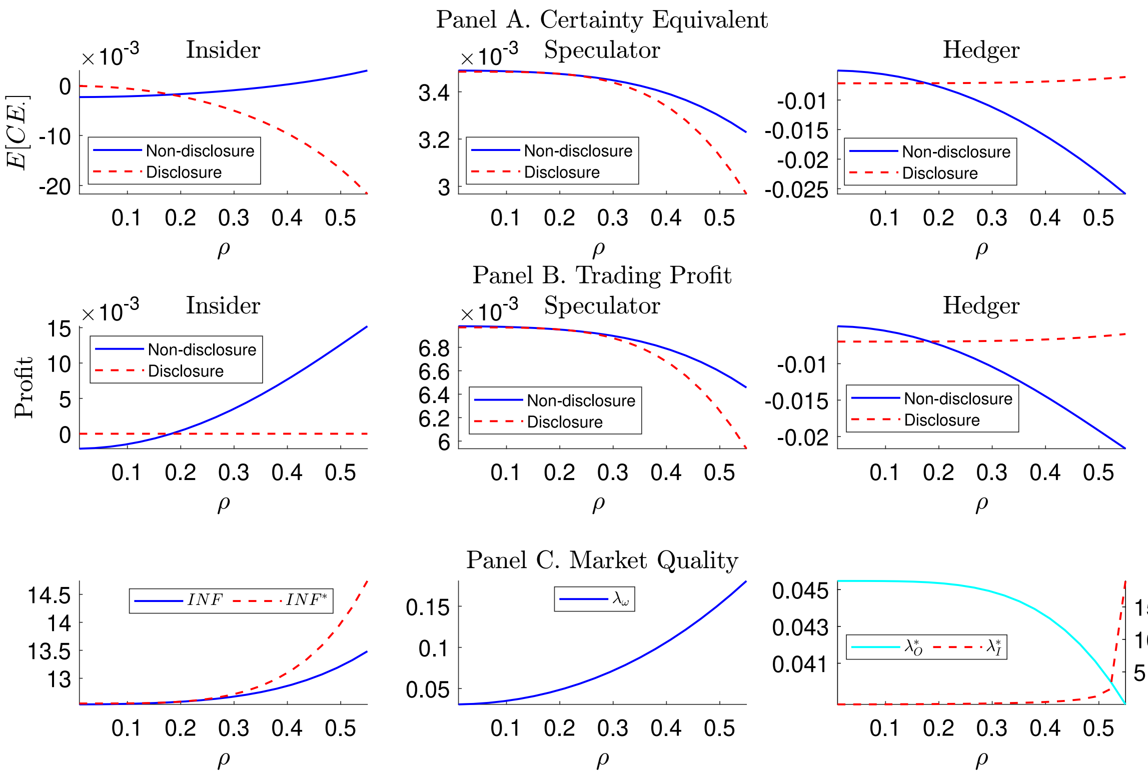

Fig. 3. The effects of a cooling-off period.
Panels A and B respectively plot the ex ante expected certainty equivalents and trading profits for each type of investors against the insider's information amount ρ. Panel C plots market quality in terms of price informativeness and Kyle's lambda. Parameter values: $\gamma = 10$, $\Sigma_z = 0.08$, $\Sigma_u = 0.17$, $\Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

welfare through two channels: the profit channel and the risk-sharing channel. The second row of Fig. 3 plots the expected trading profits for each type of investors under both regimes. Comparing the first and second rows, we observe that, under this calibration parameter configuration, the welfare patterns and the profit patterns are the same except for the insider under the disclosure regime. So, other than this exception, the welfare implications can be primarily understood from the profit channel. The exception is due to the fact that under the disclosure regime, the insider's expected trading profit is equal to 0 (see Corollary 5), independent of the value of ρ, and thus, any effect of ρ must work through the risk-sharing channel.

We now explain these welfare patterns and start with speculators. We observe that speculators' profits and hence welfare decrease with ρ under both the non-disclosure and disclosure regimes. Under the non-disclosure regime, a higher ρ means that the insider has more private information. His trading injects more information into the price, leading to a higher INF in the left plot of Panel C; meanwhile, the market maker faces stronger adverse selection, generating a higher λ_ω in the middle plot of Panel C. In turn, the increased price informativeness lowers speculators' information advantage and the worsened market liquidity increases speculators' price impact, both of which reduce speculators' profits. Under the disclosure regime, a higher ρ means that the insider's information has more overlaps with speculators' and thus, the disclosure of the insider's order reduces speculators' information advantage through making the price more informative (i.e., a higher INF^* in the left plot of Panel C). Hence, a longer cooling-off period (a smaller ρ) increases speculators' welfare under both non-disclosure and disclosure regimes.

The implications for the hedger and insider depend 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 benefits the insider and hurts the hedger. As shown in the Panel B of Fig. 3, 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 the hedger. Consistent with this intuition, the right plot of Panel B shows that the hedger's expected trading profit is increasing in ρ under the disclosure regime.

Interestingly, the insider benefits from a longer cooling-off period under the disclosure regime (i.e., the dashed line decreases with ρ in the left plot of Panel A). To see the intuition, note that the profit channel is "shut down" in this case. Specifically, as shown in Corollary 5 and the left plot of Panel B, the insider's expected trading profit under the disclosure regime is zero, regardless of the value of ρ. Hence, we can focus on the risk-sharing channel in this case. As shown in the right plot of Panel C, a higher ρ increases the insider's price impact λ_I^*. Facing a larger price impact, the insider cuts back his hedging trades, making hedging less effective and reducing the insider's welfare. As a result, under the disclosure regime, the insider's welfare decreases with ρ (i.e., the insider benefits from a longer cooling-off period).

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.[12] 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 $\tilde{f}_a$, in the form of $\tilde{y} = \tilde{f}_a + \tilde{\varepsilon}$, where $\tilde{\varepsilon} \sim N(0, \Sigma_\varepsilon)$ and it is independent of other random shocks. Intuitively, outside investors (speculators and the hedger) are active traders in the economy and may also have the ability to acquire information. As the cooling-off period becomes longer, they may have more chances to learn about the information observed by the insider. Hence, the parameter Σ_ε in this alternative model reflects 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 the baseline model in Section 2.

In the Online Appendix, we characterize the linear equilibria of this extension model under the non-disclosure and disclosure regimes. In these equilibria, the trading strategies and price functions take similar forms as those in the baseline model, except that the trading strategies of speculators' and the hedger are also sensitive to signal $\tilde{y}$. We then adopt the parameter values in Table 1 to conduct a similar calibration analysis as in the previous section to evaluate the two new SEC policy changes.

Mandatory disclosure. To examine the welfare implications of the disclosure policy, we compare the welfare measures for each type of investor across the two regimes by varying Σ_z and Σ_ε. The results, reported in Fig. 4, are qualitatively similar to those in the baseline model as reported in Fig. 2. First, the welfare implication for the insider tends to be the "mirror image" of that for the outside hedger. Second, although the welfare implications for speculators are not exactly the same across Figs. 2 and 4, disclosure tends to harm speculators when the cooling off period becomes shorter in both figures (higher ρ in Fig. 2 and higher Σ_ε in Fig. 4). Finally, when Σ_z is sufficiently large (which is unreported in Fig. 4), all investors are worse off under the disclosure regime.

Cooling-off period. To examine the effect of cooling off, we regenerate Fig. 3 in this new model with Σ_ε, instead of ρ, as the proxy for the cooling-off period length. The results are reported in Fig. 5. The first and second rows of Fig. 5 show that the implications on welfare and trading profits in this alternative model are 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.

We also highlight an interesting difference regarding the price-informativeness implication of increasing the cooling-period length. Specifically, the left plot of the third row of Fig. 5 shows that a longer cooling-off period (i.e., a smaller Σ_ε) implies a higher informativeness in this information-leakage model. This differs from the result in the baseline model in the previous section. The baseline model focuses 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, these two formulations of the cooling-off period have opposite implications for price informativeness, offering a way to test which formulation is more relevant in practice.

Comparing the two formulations further highlights the novel trading aggressiveness effect for risk sharing. Specifically, under the disclosure regime, in both formulations, the profit channel is "shut down" for the insider, because his expected trading profit is zero regardless of the cooling-off period length. In the baseline model, a longer cooling-off period *reduces* price informativeness and improves the insider's liquidity, which benefit the insider's risk sharing through both the Hirshleifer effect and the trading aggressiveness effect. In the information-leakage model, however, a longer cooling-off period *improves* both price informativeness and the insider's liquidity. The former harms risk sharing through the Hirshleifer effect while the latter benefits it through the trading aggressiveness effect. The fact that the insider benefits from a longer cooling-off period suggests that the novel trading aggressiveness effect dominates the standard Hirshleifer effect in determining the insider's risk sharing.

Both formulations share the common feature that a longer cooling-off period implies a smaller information advantage for the insider's trade. They also have some subtle differences. For example, the baseline model in Section 2 is perhaps more suitable for industries with a fast pace (e.g., information technology), where private information becomes obsolete quickly (ρ is small). The information leakage model in this section is perhaps more suitable for the firms where there are many investors actively seeking non-public information. Hence, a longer cooling-off period means more opportunities for information leakage. For example, in regulated industries (e.g., financial, pharmaceutical, and utility industries), regulators themselves may serve as a source of information leakage (Reeb et al., 2014). A longer cooling-off period reduces the insider's information advantage relative to the investors with access to those regulators.

[12] We thank the associate editor and an anonymous referee for offering this alternative setting for formulating a cooling-off period.

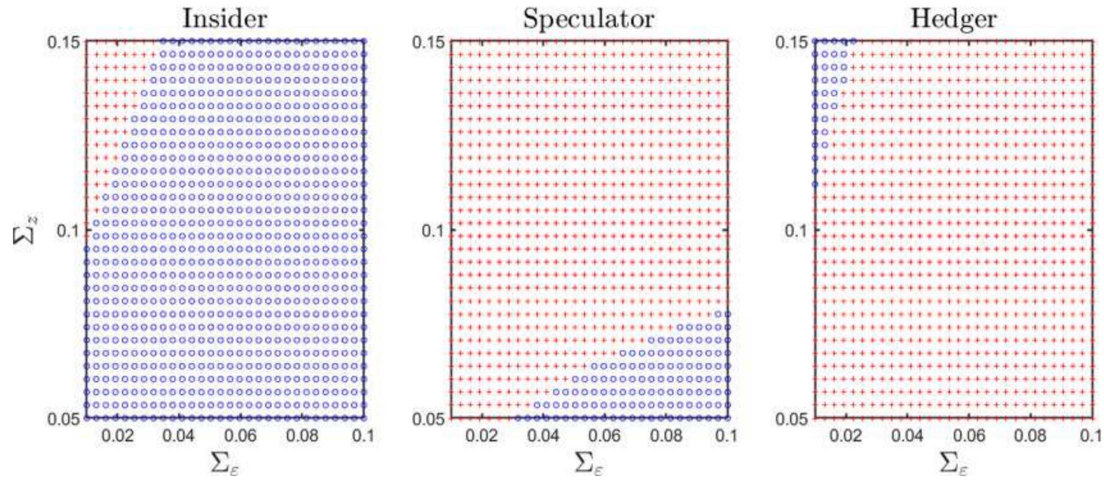

Fig. 4. Disclosure and investor welfare in the model with information leakage.
This figure plots welfare comparisons under disclosure and non-disclosure regimes against the information variance Σ_ε. The plots in the left, middle, and right columns are for the insider, a representative speculator, and 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 from disclosure. Parameter values: $\gamma = 10, \rho = 0.5, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

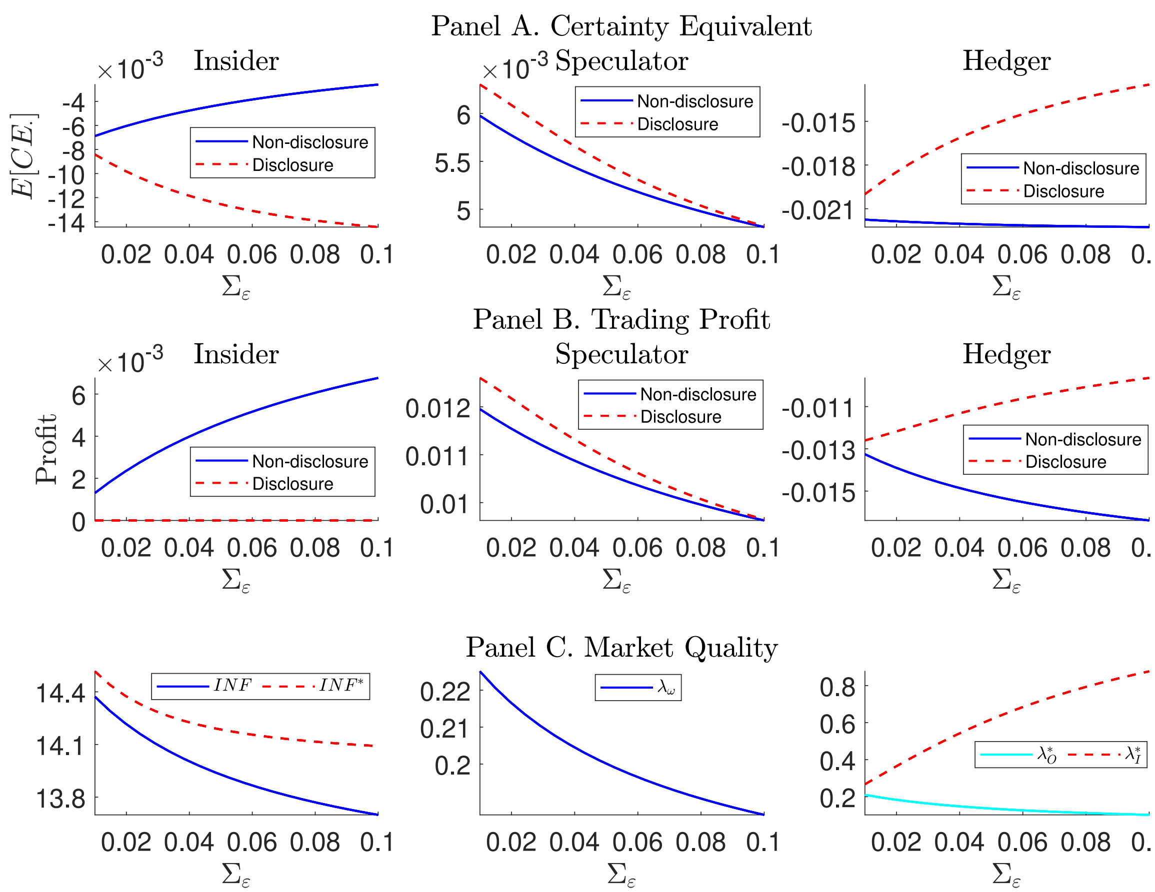

Fig. 5. The effects of a cooling-off period in the information leakage model. Panels A and B respectively plot the ex ante expected certainty equivalents and trading profits for each type of investors against the information variance Σ_ε. Panel C plots market quality in terms of price informativeness and Kyle's lambda. Parameter values: $\gamma = 10, \rho = 0.5, \Sigma_z = 0.08, \Sigma_u = 0.17, \Sigma_\delta = 1.14$, and $\Sigma_f = 0.08$.

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 these two policies affect investor welfare through two channels, the profit channel and the risk-sharing channel. If the insider's hedging need is sufficiently large, in contrast to the conventional wisdom regarding trader profits from sunshine trading, disclosure may reduce the welfare of all investors.

We also conduct a calibration exercise and find that the insider's hedging need tends to be modest in empirically relevant parameter region. We find that the welfare implication for the insider tends to be the "mirror image" of that for the outside hedger, i.e., one being better off tends to imply the other being worse off. The reason is that, in our calibration, risk sharing needs are modest and welfare implications are dominated by the effect from trading profits. When the insider is better off, it is at the expense of the hedger, and vice versa. Moreover, the implications of a cooling-off period depend on whether the disclosure policy is already in place. Under the non-disclosure regime, perhaps consistent with the SEC's motivation, a longer cooling-off period benefits outside investors but reduces the insider's welfare. Under the disclosure regime, however, a longer cooling-off period benefits the insider but harms the outside hedger. Our analysis offers novel insights about insider trading and sunshine trading.

CRediT authorship contribution statement

Jun Deng: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Huifeng Pan:** Validation, Formal analysis, Conceptualization. **Hongjun Yan:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Liyan Yang:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 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 can work as a proxy that 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:

$$\tilde{v}_{\tau+1} = (1-g)\bar{f} + g \cdot \tilde{v}_\tau + \tilde{\varepsilon}_{\tau+1}, \tag{A.1}$$

for $\tau = 0, 1, \ldots, T$, where $\bar{f} \in \mathbb{R}$, $g \in (0,1)$, $\tilde{v}_0 \sim N\left(\bar{f}, \Sigma_v\right)$, and $\tilde{\varepsilon}_{\tau+1} \sim N\left(0, \Sigma_\varepsilon\right)$ 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 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 $\tilde{p}_\tau = \bar{f}$ (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 $\tau = 0, 1, \ldots, T-1$.

Table A.1
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	$\sqrt{1-\rho^2}\tilde{f}_b$	$g^T\tilde{\varepsilon}_1 + \ldots + g\tilde{\varepsilon}_T + \tilde{\varepsilon}_{T+1}$

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, Eq. (A.1) implies

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

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 (see Table A.1).

Appendix B. Proofs

In the proof, we introduce the following notations:

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

Proof of Proposition 1. Equilibrium under the Non-disclosure Regime. Let us denote

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

Under the postulated linear equilibrium specified by Eqs. (13)–(16), the total order flow and return are

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

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

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

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

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

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

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

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

Here, the constant Λ_I is given by

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

The first-order-condition gives

$$D_I=\frac{n\tilde{X}-\gamma n\Sigma_Y\tilde{Z}}{2\Lambda_I}=\alpha_X\tilde{X}+\alpha_Z\tilde{Z},\tag{B.3}$$

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 optimization problem (B.2) takes the form of

$$\begin{aligned}&\mathbb{E}\left[W_I\Big|\tilde{X},\tilde{Z}\right]-\frac{1}{2}\gamma Var(W_I\Big|\tilde{X},\tilde{Z})=D_I^2\Lambda_I+\tilde{Z}\,\mathbb{E}\left[\tilde{f}\Big|\tilde{X}\right]-\frac{1}{2}\gamma\tilde{Z}^2Var(\tilde{f}\Big|\tilde{X})\\&=(\alpha_X\tilde{X}+\alpha_Z\tilde{Z})^2\Lambda_I+\tilde{Z}(\tilde{X}+\bar{f})-\frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\&=\frac{1}{2}(\alpha_X\tilde{X}+\alpha_Z\tilde{Z})^2\cdot r_Z\alpha_Z^{-1}+\tilde{Z}(\tilde{X}+\bar{f})-\frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\&=\frac{1}{2}(\tilde{X}\alpha_X/\alpha_Z+\tilde{Z})^2\cdot r_Z\alpha_Z+\tilde{Z}(\tilde{X}+\bar{f})-\frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2\\&=-\frac{1}{2}\gamma\Sigma_Y(-\tilde{X}\gamma^{-1}\Sigma_Y^{-1}+\tilde{Z})^2n\alpha_Z+\tilde{Z}(\tilde{X}+\bar{f})-\frac{1}{2}\gamma\Sigma_Y\tilde{Z}^2.\end{aligned}\tag{B.4}$$

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

$$\max_{D_{S,j}}\quad D_{S,j}\mathbb{E}\left[\tilde{f}-\tilde{p}\Big|\tilde{s}_j\right]-\frac{1}{2}\gamma D_{S,j}^2Var(\tilde{f}-\tilde{p}\Big|\tilde{s}_j).\tag{B.5}$$

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

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

His inference of the return variance is

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

Therefore, his optimal demand is

$$D_{S,j}=\beta_S(\tilde{s}_j-\bar{f}),\quad\text{with},\quad \beta_S=\left(m\Sigma_X+n\Sigma_Y\right)\left(\Sigma_f+\Sigma_\delta\right)^{-1}\gamma^{-1}\Lambda_S^{-1}.\tag{B.6}$$

As a result,

$$\begin{aligned}\mathbb{E}\left[W_S\Big|\tilde{s}_j\right]-\frac{1}{2}\gamma Var(W_S\Big|\tilde{s}_j)&=\frac{1}{2}\gamma\Lambda_S\beta_S^2(\tilde{s}_j-\bar{f})^2\\&=\frac{1}{2}\left(m\Sigma_X+n\Sigma_Y\right)\left(\Sigma_f+\Sigma_\delta\right)^{-1}\beta_S(\tilde{s}_j-\bar{f})^2.\end{aligned}\tag{B.7}$$

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

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

The first-order-condition gives

$$D_H=\frac{\gamma^{-1}\mathbb{E}\left[\tilde{f}-\tilde{p}\Big|\tilde{u}\right]-Cov(\tilde{f}-\tilde{p},\tilde{f}\Big|\tilde{u})\cdot\tilde{u}}{Var(\tilde{f}-\tilde{p}\Big|\tilde{u})}.\tag{B.8}$$

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

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

Then, the hedger's optimal demand is

$$\phi_H=-1\cdot\frac{m\Sigma_X+n\Sigma_Y+\gamma^{-1}\lambda_\omega\phi_H}{m^2\Sigma_X+n^2\Sigma_Y+\lambda_\omega^2\alpha_Z^2\Sigma_z}.\tag{B.9}$$

As a result,

$$\begin{aligned}\mathbb{E}\left[W_H\Big|\tilde{u}\right]-\frac{1}{2}\gamma Var(W_H\Big|\tilde{u})&=\frac{1}{2}\gamma Var\left(\tilde{f}-\tilde{p}\mid\tilde{u}\right)D_H^2-\frac{1}{2}\gamma\Sigma_f\tilde{u}^2\\&=-\frac{1}{2}\gamma\left[\left(m\Sigma_X+n\Sigma_Y+\gamma^{-1}\lambda_\omega\phi_H\right)\phi_H+\Sigma_f\right]\tilde{u}^2.\end{aligned}\tag{B.10}$$

The market maker's price function: 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

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

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

$$\alpha_X=\frac{n}{2\lambda_\omega+\gamma\lambda_\omega^2\phi_H^2\Sigma_u+\gamma n^2\Sigma_Y},\quad\alpha_Z=-\alpha_X\gamma\Sigma_Y,\tag{B.11}$$

$$\beta_S=\left(m\Sigma_X+n\Sigma_Y\right)\left(\Sigma_f+\Sigma_\delta\right)^{-1}\gamma^{-1}\Lambda_S^{-1},\tag{B.12}$$

$$\phi_H=-1\cdot\frac{m\Sigma_X+n\Sigma_Y+\gamma^{-1}\lambda_\omega\phi_H}{m^2\Sigma_X+n^2\Sigma_Y+\lambda_\omega^2\alpha_Z^2\Sigma_z},\tag{B.13}$$

$$\lambda_\omega=\frac{(\alpha_X+\beta_S)\Sigma_X+\beta_S\Sigma_Y}{(\alpha_X+\beta_S)^2\Sigma_X+\beta_S^2\Sigma_Y+\alpha_Z^2\Sigma_z+\phi_H^2\Sigma_u}.\tag{B.14}$$

From (B.14), we derive

$$\lambda_\omega^2(\alpha_X+\beta_S)^2\Sigma_X+\lambda_\omega^2\beta_S^2\Sigma_Y+\lambda_\omega^2\alpha_Z^2\Sigma_z+\lambda_\omega^2\phi_H^2\Sigma_u=\lambda_\omega(\alpha_X+\beta_S)\Sigma_X+\lambda_\omega\beta_S\Sigma_Y.$$
$$\Longleftrightarrow$$
$$(1-m)^2\Sigma_X+(1-n)^2\Sigma_Y+\lambda_\omega^2\alpha_Z^2\Sigma_z+\lambda_\omega^2\phi_H^2\Sigma_u=(1-m)\Sigma_X+(1-n)\Sigma_Y.$$
$$\Longleftrightarrow$$
$$\lambda_\omega^2\alpha_Z^2\Sigma_z+\lambda_\omega^2\phi_H^2\Sigma_u=\lambda_\omega^2\alpha_X^2k+\lambda_\omega^2\phi_H^2\Sigma_u=(1-m)m\Sigma_X+(1-n)n\Sigma_Y.$$
$$\Longleftrightarrow$$
$$\lambda_\omega^2\phi_H^2\Sigma_u=m(1-m)\Sigma_X+n(1-n)\Sigma_Y-k(n-m)^2\equiv N.\tag{B.15}$$

Therefore,

$$\Lambda_S=m^2\Sigma_X+n^2\Sigma_Y-(m\Sigma_X+n\Sigma_Y)^2\left(\Sigma_f+\Sigma_\delta\right)^{-1}+\lambda_\omega^2\left(\alpha_Z^2\Sigma_z+\phi_H^2\Sigma_u\right)$$

$$= m^2\Sigma_X + n^2\Sigma_Y - (m\Sigma_X + n\Sigma_Y)^2 \left(\Sigma_f + \Sigma_\delta\right)^{-1} + (1-m)m\Sigma_X + (1-n)n\Sigma_Y$$
$$= (m\Sigma_X + n\Sigma_Y)\left[\Sigma_f + \Sigma_\delta - m\Sigma_X - n\Sigma_Y\right]\left(\Sigma_f + \Sigma_\delta\right)^{-1}.$$

Plugging Λ_S into (B.12) yields

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

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 (B.11), we get

$$(n-m)^{-1}(1-n)\gamma M = n^{-1}\left[\gamma\lambda_\omega^2\phi_H^2\Sigma_u + 2\lambda_\omega + \gamma n^2\Sigma_Y\right]$$
$$= n^{-1}\left[\gamma N + 2(1-n)\gamma M + \gamma n^2\Sigma_Y\right]. \quad \text{(B.16)}$$

From (B.13), we obtain

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

Plugging ϕ_H into (B.15) gives

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

which is equivalent to

$$(1-n)^2\gamma^2M^2(m\Sigma_X + n\Sigma_Y)^2\Sigma_u = N\left(N - (1-n)M - m\Sigma_X - n\Sigma_Y\right)^2. \quad \text{(B.17)}$$

Once solving m and n via two Eqs. (B.16) and (B.17), we could pin down the remaining parameters. Also note 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 composed of (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 composed of (22) and (23) does not have a solution. Hence, the equilibrium does not exist. □

Proof of Proposition 2. Equilibrium under the Disclosure Regime. To ease expressions, we introduce the following notations:

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

where we recall that $\Sigma_X = \rho^2\Sigma_f$, $\Sigma_Y = (1-\rho^2)\Sigma_f$, $k = \gamma^2\Sigma_Y^2\Sigma_z$.

The total order flow and return are

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

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 as follows:

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

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

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

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

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

with the parameter Λ_I^* defined 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

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

where

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

As a result,

$$\mathbb{E}\left[W_I^*\middle|\tilde X, \tilde Z\right] - \frac{1}{2}\gamma Var(W_I^*\middle|\tilde X, \tilde Z) = (D_I^*)^2\Lambda_I^* + \tilde Z\,\mathbb{E}\left[\tilde f\middle|\tilde X\right]$$
$$- \frac{1}{2}\gamma\tilde Z^2 Var(\tilde f\middle|\tilde X)$$
$$= \frac{1}{2}r_Z^*(\tilde X\alpha_X^*/\alpha_Z^* + \tilde Z)^2\alpha_Z^* + \tilde Z(\bar f + \tilde X) - \frac{1}{2}\gamma\tilde Z^2\Sigma_Y. \quad \text{(B.18)}$$

Speculator j's optimal demand: Under disclosure regime, the information set of speculator j is $\{\tilde s_j, D_I^*\}$. With normal distributions of all random variables, speculator j's problem is equivalent to

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

The first-order-condition gives the optimal demand as

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

Speculator j's estimation of asset value and return are

$$\mathbb{E}[\tilde f - \bar f\middle|\tilde s_j, D_I^*] = \frac{Cov(\tilde f, \tilde s_j)Var(D_I^*) - Cov(\tilde f, D_I^*)Cov(\tilde s_j, D_I^*)}{Var(\tilde s_j)Var(D_I^*) - Cov^2(\tilde s_j, D_I^*)}(\tilde s_j - \bar f)$$
$$+ \frac{Cov(\tilde f, D_I^*)Var(\tilde s_j) - Cov(\tilde f, \tilde s_j)Cov(\tilde s_j, D_I^*)}{Var(\tilde s_j)Var(D_I^*) - Cov^2(\tilde s_j, D_I^*)}D_I^*$$
$$= a_s(\tilde s_j - \bar f) + a_I D_I^*,$$
$$\mathbb{E}[\tilde f - \tilde p^*\middle|\tilde s_j, D_I^*] = \mathbb{E}[n^*(\tilde f - \bar f) - \lambda_I^* D_I^* - \lambda_O^*\phi_H^*\tilde u\middle|\tilde s_j, D_I^*]$$
$$= -\lambda_I^* D_I^* + n^*\mathbb{E}[\tilde f - \bar f\middle|\tilde s_j, D_I^*]$$
$$= -\lambda_I^* D_I^* + n^* a_s(\tilde s_j - \bar f) + n^* a_I D_I^*$$
$$= \left(n^* a_I - \lambda_I^*\right)D_I^* + n^* a_s(\tilde s_j - \bar f).$$

Here, the two constants a_s and a_I are given by

$$a_s = k_1 k_2^{-1}, \quad a_I = (\alpha_X^*)^{-1}\Sigma_X\Sigma_\delta k_2^{-1}. \quad \text{(B.19)}$$

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

$$Var(\tilde f\middle|\tilde s_j, D_I^*) = Var(\tilde f) - Var(\mathbb{E}[\tilde f\middle|\tilde s_j, D_I^*]) = \Sigma_\delta a_s,$$
$$Var(\tilde f - \tilde p^*\middle|\tilde s_j, D_I^*) = Var(n^*\tilde f - \lambda_O^*\phi_H^*\tilde u\middle|\tilde s_j, D_I^*)$$
$$= (n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u.$$

Then,

$$\beta_S^* = \frac{n^* a_s}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}, \quad \beta_I^* = \frac{n^* a_I - \lambda_I^*}{\gamma\left[(n^*)^2\Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2\Sigma_u\right]}. \quad \text{(B.20)}$$

As a result,

$$\mathbb{E}\left[W_S^*\middle|\tilde s_j, D_I^*\right] - \frac{1}{2}\gamma Var(W_S^*\middle|\tilde s_j, D_I^*)$$
$$= \frac{1}{2}\gamma\cdot Var(\tilde f - \tilde p^*\middle|\tilde s_j, D_I^*)\cdot(D_{S,j}^*)^2$$
$$= \frac{1}{2}\gamma\cdot Var(\tilde f - \tilde p^*\middle|\tilde s_j, D_I^*)\cdot\left(\beta_S^*(\tilde s_j - \bar f) + \beta_I^* D_I^*\right)^2$$

$$= \frac{1}{2}\gamma(\beta_S^*)^2 Var(\tilde{f} - \tilde{p}^* | \tilde{s}_j, D_I^*) \cdot \left(\tilde{s}_j - \bar{f} + \beta_I^* D_I^*/\beta_S^*\right)^2$$
$$= \frac{1}{2} n^* k_1 k_2^{-1} \beta_S^* \left(\tilde{s}_j - \bar{f} + \beta_I^* D_I^*/\beta_S^*\right)^2. \quad (B.21)$$

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

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

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

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

Inserting these moments into the hedger's optimal demand function derived above, and comparing with the conjectured hedger's linear trading strategy, we find that

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

In addition, we could also show that

$$\mathbb{E}\left[W_H^* \middle| \tilde{u}, D_I^*\right] - \frac{1}{2}\gamma Var(W_H^* | \tilde{u}, D_I^*)$$
$$= \frac{1}{2}\gamma Var(\tilde{f} - \tilde{p}^* | \tilde{u}, D_I^*)(D_H^*)^2 + \tilde{u}\mathbb{E}\left[\tilde{f} \middle| D_I^*\right] - \frac{1}{2}\gamma \tilde{u}^2 Var(\tilde{f} | \tilde{u}, D_I^*)$$
$$= \frac{1}{2}\gamma k_1(\Sigma_X + k)^{-1}\left((n^*)^2(\phi_H^*)^2 - 1\right)\tilde{u}^2 + \tilde{u}\mathbb{E}\left[\tilde{f} \middle| D_I^*\right]. \quad (B.22)$$

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

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

Using normality and projection of conditional expectation, we can compute

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

Taken together, we solve the following equations for the equilibrium parameters:

$$\phi_H^* = -\gamma^{-1}(n^*)^{-2}\lambda_O^*\phi_H^*(k + \Sigma_X)k_1^{-1} - (n^*)^{-1}, \quad (B.23)$$
$$\phi_I^* = \gamma^{-1}(n^*)^{-2}(k + \Sigma_X)k_1^{-1}\left[n^*(\alpha_X^*)^{-1}\frac{\Sigma_X}{\Sigma_X + k} - \lambda_I^*\right], \quad (B.24)$$
$$\beta_S^* = \frac{n^* a_s}{\gamma\left[(n^*)^2 \Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2 \Sigma_u\right]}, \quad (B.25)$$
$$\beta_I^* = \frac{n^* a_I - \lambda_I^*}{\gamma\left[(n^*)^2 \Sigma_\delta a_s + (\lambda_O^*)^2(\phi_H^*)^2 \Sigma_u\right]}, \quad (B.26)$$
$$\alpha_X^* = \frac{n^*}{2\lambda_I^* + \gamma\left((n^*)^2 \Sigma_Y + (\lambda_O^*)^2(\phi_H^*)^2 \Sigma_u\right)}, \quad (B.27)$$
$$\alpha_Z^* = -\alpha_X^* \gamma \Sigma_Y, \quad (B.28)$$
$$\lambda_O^* = \frac{\beta_S^* k_1}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2 \Sigma_u (\Sigma_X + k)}, \quad (B.29)$$
$$\lambda_I^* = \frac{(\alpha_X^*)^{-1}\Sigma_X(\phi_H^*)^2 \Sigma_u}{(\beta_S^*)^2 k_1 + (\phi_H^*)^2 \Sigma_u (\Sigma_X + k)}. \quad (B.30)$$

From (B.29) and $n^* = 1 - \lambda_O^* \beta_S^*$, we have

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

which gives

$$(\lambda_O^*)^2(\phi_H^*)^2 \Sigma_u = n^*(1 - n^*)k_1(\Sigma_X + k)^{-1}. \quad (B.31)$$

Plugging in $\phi_H^* = -(n^*)^{-1}\left[1 + \gamma^{-1}(n^*)^{-2}\lambda_O^*(k + \Sigma_X)k_1^{-1}\right]^{-1}$ of (B.23), we arrive at

$$(\lambda_O^*)^{-1} = \Sigma_u^{\frac{1}{2}}(n^*)^{-\frac{3}{2}}(1 - n^*)^{-\frac{1}{2}}k_1^{-\frac{1}{2}}(\Sigma_X + k)^{\frac{1}{2}} - \gamma^{-1}(n^*)^{-2}(\Sigma_X + k)k_1^{-1}. \quad (B.32)$$

Using (B.25), we have

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

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

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

Noting $\lambda_O^* > 0$ and $\phi_H^* < 0$, from (B.23) and (B.31), we derive that

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

From (B.25) and (B.26), we have

$$\lambda_I^* = n^* a_I - n^* a_s \beta_I^* (\beta_S^*)^{-1}, \quad (B.33)$$

Combining with (B.30) and (B.33) gives

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

Plugging it into (B.24) yields $\phi_I^* = 0$. Furthermore,

$$(\alpha_X^*)^{-1}\Sigma_X(\Sigma_X + k)^{-1} = a_I - a_s\beta_I^*(\beta_S^*)^{-1} \quad (B.34)$$

Using a_s and a_I from (B.19), we have

$$(\alpha_X^*)^{-1} = -\beta_I^*(1 + \Sigma_X^{-1}k)(\beta_S^*)^{-1}, \quad \lambda_I^* = -n^*\beta_I^*(\beta_S^*)^{-1}. \quad (B.35)$$

Eq. (B.27) combined with (B.31) 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

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

Therefore, from (B.35), we have

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

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

$$0 < \lambda_O^* \Leftrightarrow n_0^* \in \left(0, \gamma\Sigma_u^{1/2}k_1^{1/2}(\Sigma_X + k)^{-1/2}\right), \quad \text{and}$$

$$0 < \alpha_X^* \Leftrightarrow \beta_I^* < 0 \Leftrightarrow k > \Sigma_X \Leftrightarrow \Sigma_z > \gamma^{-2}\rho^2(1-\rho^2)^{-2}\Sigma_f^{-1}.$$

This completes the proof of the proposition. □

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

$$F(x) \equiv x\left[\Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{-1}{2}} - \gamma^{-1}x\right] = \frac{k_1k_2^{-1}\gamma^{-1}}{x^2 + (\rho^2\Sigma_f + k)\Sigma_\delta k_2^{-1}} \equiv G(x). \quad (B.36)$$

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

$$F(0) = F\left(x^*\right) = 0, \quad \text{where} \quad x^* = \Sigma_u^{\frac{1}{2}}k_1^{\frac{1}{2}}(\rho^2\Sigma_f + k)^{\frac{-1}{2}}\gamma,$$

and its maximum F_{max} on the interval $[0, x^*]$ is

$$F_{max} = \gamma\Sigma_u k_1(\rho^2\Sigma_f + k)^{-1}/4.$$

Since the function $G(x)$ is decreasing to 0 as $x \to +\infty$, $G(x)$ must intersect with $F(x)$ in the interval $[0, x^*]$ as long as $G(0) \le F_{max}$. This gives us the condition $\Sigma_u \ge 4\gamma^{-2}\Sigma_\delta^{-1}$.

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

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

Proof of Corollary 3. From the definitions of certainty equivalents in (37)–(42), for trader $t \in \{I, S, H\}$ under his corresponding information set F_t, his wealth W_t is normally distributed and the certainty equivalent is given by

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

From Eqs. (B.4), (B.7), (B.10), (B.18), (B.21), and (B.22) in the proofs of Propositions 1 and 2, we can show that the certainty equivalents in the two economies are:

$$CE_I = \frac{-\gamma}{2}(1-\rho^2)\Sigma_f\left(\tilde{Z} - \rho\tilde{f}_a\gamma^{-1}\Sigma_f^{-1}(1-\rho^2)^{-1}\right)^2\alpha_Z n + \rho\tilde{f}_a\tilde{Z} - \frac{\gamma}{2}\Sigma_f(1-\rho^2)\tilde{Z}^2,$$

$$CE_S = \frac{1}{2}\beta_S\left(m\rho^2 + n(1-\rho^2)\right)\Sigma_f\left(\Sigma_f + \Sigma_\delta\right)^{-1}\tilde{s}_j^2,$$

$$CE_H = -\frac{1}{2}\gamma\left[\Sigma_f + \phi_H(m\rho^2\Sigma_f + n(1-\rho^2)\Sigma_f + \gamma^{-1}\lambda_\omega\phi_H)\right]\tilde{u}^2,$$

$$CE_I^* = \frac{-\gamma}{2}(1-\rho^2)\Sigma_f\left(\tilde{Z} - \rho\tilde{f}_a\gamma^{-1}\Sigma_f^{-1}(1-\rho^2)^{-1}\right)^2\alpha_Z^* n^* + \rho\tilde{f}_a\tilde{Z} - \frac{\gamma}{2}\Sigma_f(1-\rho^2)\tilde{Z}^2,$$

$$CE_S^* = \frac{1}{2}n^*\beta_S^*k_1k_2^{-1}\cdot\left(\tilde{s}_j - (1 + \rho^{-2}\Sigma_f^{-1}k)^{-1}(\rho\tilde{f}_a - \tilde{Z}\gamma(1-\rho^2)\Sigma_f)\right)^2,$$

$$CE_H^* = \frac{1}{2}\gamma k_1(\rho^2\Sigma_f + k)^{-1}\left((\phi_H^*)^2(n^*)^2 - 1\right)\tilde{u}^2 + \tilde{u}\left(1 + \Sigma_X^{-1}k\right)^{-1}(\tilde{X} - \gamma\Sigma_Y\tilde{Z}).$$

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

Proof of Corollary 4. Under the 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 the disclosure regime, we have

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

After some tedious computations, we can derive

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

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

Proof of Corollary 5. Since the market maker sets the price via $\tilde{p}^* = \mathbb{E}[\tilde{f}|\tilde{\omega}^*, D_I^*]$, we have

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

This proves this corollary. □

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

Part (3): From Corollary 4 and Proposition C.1, we can show that when Σ_z is sufficiently large, we have

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

Part (4): When Σ_z is sufficiently large, Proposition C.1 in Appendix C shows

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

Here, n_0^* is the positive root of Eq. (C.1). When $|\rho| \le 1/\sqrt{2}$, we have $\lambda_I^* < \lambda_\omega$. □

Appendix 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 C.1 characterizes the approximation equilibrium. Corollary C.1 characterizes investors' profits. Proposition C.2 characterizes the investors' profits and welfare in the first-order approximation equilibria. Proposition C.3 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 C.1. *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 equilibrium parameters under the non-disclosure regime are given by*

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

$n - m \approx \gamma^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1} q_5 \Sigma_z^{-1}.$

Here, the constants $q_1, q_2, \dots, q_5$ *are*

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

The equilibrium parameters under the disclosure regime 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 $q_1^*, q_2^*, \dots, q_7^*$ *are*

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

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

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

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

Non-disclosure regime. Since the two constants m and n in Eqs. (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:

$$\Sigma_X = \rho^2\Sigma_f, \quad \Sigma_Y = (1-\rho^2)\Sigma_f, \quad k = \gamma^2\Sigma_Y^2\Sigma_z, \quad \text{(C.2)}$$
$$\alpha_X = \rho^{-1}\alpha_f, \quad n = 1-\lambda_\omega\beta_S, \quad m = 1-\lambda_\omega(\alpha_X+\beta_S). \quad \text{(C.3)}$$

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 (B.14) in the proof of Proposition 1 since α_Z goes to a non-zero constant. From the definition in (C.3), this also implies the two constants m and n both go to one when Σ_z goes to infinity. Then, from (B.11) and (B.12), we obtain 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 Eq. (B.14), we compute that the first-order approximation of λ_ω is

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

For the insider's demand, from Eqs. (B.11) and (C.3), we have

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

For speculator j's demand, from Eq. (B.12), we derive

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

For the hedger's demand, from Eq. (B.13), we have

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

Disclosure regime. Recall that

$$k = \gamma^2(1-\rho^2)^2\Sigma_f^2\Sigma_z, \; k_1 = k\Sigma_f + \rho^2(1-\rho^2)\Sigma_f^2, \; k_2 = k_1 + (k+\Sigma_X)\Sigma_\delta. \quad \text{(C.4)}$$

When Σ_z goes to infinity, the positive root n_0^* of quartic function (36) in Proposition 2 reduces to the positive root in (C.1).

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

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

Since

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

from Eq. (34), we derive that

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

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

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

Since $k_1k_2^{-1} \approx (1+\Sigma_\delta\Sigma_f^{-1})^{-1} - \rho^4\Sigma_f^2\Sigma_\delta(\Sigma_f+\Sigma_\delta)^{-2}k^{-1}$, for speculator j's demand, from Eqs. (30) and (31), we have

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

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 Eq. (32), we have

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

$$\approx -(n^*)^{-1}\left[1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2}\right] + \frac{1}{2}\gamma^{-3}\Sigma_f^{-3/2}\rho^4(1-\rho^2)^{-2}(n^*)^{-1}n_0^*\Sigma_u^{-1/2}\Sigma_z^{-1}.$$

This completes the proof. □

The following corollary presents expected trading profits without the first order approximation.

Corollary C.1. *Investors' expected trading profits are given by*

$$\pi_I = m\rho\Sigma_f\alpha_f - \lambda_\omega\alpha_Z^2\Sigma_z,\quad \pi_S = \beta_S(m\rho^2 + n(1-\rho^2))\Sigma_f,\quad \pi_H = -\lambda_\omega\phi_H^2\Sigma_u, \tag{C.5}$$

$$\pi_I^* = 0,\quad \pi_S^* = k_1(\rho^2\Sigma_f + k)^{-1}n^*\beta_S^*,\quad \pi_H^* = -\pi_S^*. \tag{C.6}$$

Proof. Non-disclosure regime: The insider's trading profit is

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

Speculator j's trading profit is

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

The hedger's trading profit is

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

Disclosure regime: The insider's trading profit $\pi_I^* = 0$ is given in Corollary 5. Speculator j's trading profit is

$$\begin{aligned}\pi_S^* &= \mathbb{E}\left[D_{S,j}^*(\tilde{f} - \tilde{p}^*)\right] = \mathbb{E}\left[D_{S,j}^*\,\mathbb{E}\left[\tilde{f} - \tilde{p}^*|\tilde{s}_j, D_I^*\right]\right]\\ &= \mathbb{E}\left[(D_{S,j}^*)^2\,Var(\tilde{f} - \tilde{p}^*\big|\tilde{s}_j, D_I^*)\right] = k_1(\rho^2\Sigma_f + k)^{-1}n^*\beta_S^*.\end{aligned}$$

Since it is a zero-sum game, we know $\pi_H^* = -\pi_S^*$. This completes the proof. □

Proposition C.2. *In the first-order approximation equilibria, the ex ante expectations of the certainty equivalents under the non-disclosure and disclosure regimes are given by*

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

In the first-order approximation equilibria, investors' trading profits are

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

Proof. It follows directly by plugging the first order approximation equilibrium parameters of Proposition C.1 into expected certainty equivalents of Corollary 3, and trading profits of Corollary C.1. We omitted the details. □

Proposition C.3. *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 (C.7).*
(b) *if $\Sigma_z > \bar{\Sigma}_2$, disclosure increases the insider's expected trading profit but decreases outside investors' expected trading profits: $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$, where $\bar{\Sigma}_2$ is given by (C.8).*

Proof. (a) From Proposition C.2, in the first-order approximation equilibria, we could get the estimations of lower boundaries such that disclosure is worse off for the insider, speculators and the hedger. That is, $\mathbb{E}[CE_t] > \mathbb{E}[CE_t^*]$ when $\Sigma_z > \Sigma_{z,1}^t$, $t \in \{I, S, H\}$, where

$$\begin{aligned}\Sigma_{z,1}^I &= \gamma^{-2}\left[\rho^2\left((1-\rho^2)^{-1} - n^*(1-\rho^2)(1-n^*\rho^2)^{-2}\right) + 2\gamma^{-1}\Sigma_\delta^{-1}\Sigma_f\right]\\ &\quad(1-n^*\rho^2)(1-\rho^2)^{-1}(1-n^*)^{-1}\Sigma_f^{-1},\\ \Sigma_{z,1}^S &= \Sigma_f^{-1}(1-n^*)^{-1}(1+\Sigma_\delta^{-1}\Sigma_f)^{-1}\left\{(1+\Sigma_f\Sigma_\delta^{-1})(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})q_5^2\right.\\ &\quad\left.+ n^*\gamma\Sigma_\delta\left[\Sigma_f(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})p_3 - \rho^4\gamma^{-3}(1-\rho^2)^{-2}\Sigma_\delta^{-1}\right]\right\},\\ \Sigma_{z,1}^H &= \left\{\Sigma_u q_5\left[\Sigma_f\Sigma_\delta^{-1} + 1 + (1-\rho^2)^{-1}\right] - \right.\\ &\quad\gamma\left[\left[(1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2 - 1\right]\rho^4(1-\rho^2)^{-2}\gamma^{-2}\right.\\ &\quad\left.\left.- 2\Sigma_f n^*q_5^*(1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})\right]\right\}\\ &\quad\gamma^{-1}\Sigma_f^{-1}\left[(1 - n_0^*\Sigma_u^{-1/2}\gamma^{-1}\Sigma_f^{-1/2})^2 - 1\right]^{-1}.\end{aligned}$$

Define

$$\bar{\Sigma}_1 \equiv \max\left(\Sigma_{z,1}^I, \Sigma_{z,1}^H, \Sigma_{z,1}^S\right). \tag{C.7}$$

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

(b) Again, from Proposition C.2, in the first-order approximation equilibria, we can obtain lower boundaries of Σ_z such that disclosure increase the insider's expected trading profit but decrease these of outside investors. That is, $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$, when $\Sigma_z > \Sigma_{z,2}^t$, $t \in \{I, S, H\}$, where

$$\begin{aligned}\Sigma_{z,2}^I &= \Sigma_\delta\gamma\Sigma_f^{-1}\left[\rho q_1 - \rho^2\gamma^{-2}\Sigma_\delta^{-1}(1-\rho^2)^{-1}\Sigma_f^{-1}q_5 - \gamma^{-2}(1-\rho^2)^{-2}\Sigma_f^{-2}\rho^2q_5\right.\\ &\quad\left.- 2\gamma(1-\rho^2)\rho^{-1}q_1q_5\right],\\ \Sigma_{z,2}^S &= \left[n^*\left[q_3^*\Sigma_f - \frac{\rho^4(1-\rho^2)^2\gamma^{-3}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\right] + \gamma^{-1}\Sigma_\delta^{-1}(1-\Sigma_f\Sigma_\delta^{-1})q_5^2\right]\\ &\quad\Sigma_\delta\gamma(1+(1-n^*)\Sigma_f\Sigma_\delta^{-1})\Sigma_f^{-1}(1-n^*)^{-1}(1+\Sigma_f\Sigma_\delta^{-1})^{-1},\\ \Sigma_{z,2}^H &= \left[q_5\Sigma_u - n^*\left(q_3^*\Sigma_f - \frac{\rho^4(1-\rho^2)^2\gamma^{-3}\Sigma_\delta^{-1}}{1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f}\right)\right]\\ &\quad\times(1+(1-n^*)\Sigma_\delta^{-1}\Sigma_f)\gamma\Sigma_\delta(n^*)^{-1}\Sigma_f^{-1}\end{aligned}$$

Define

$$\bar{\Sigma}_2 \equiv \max\left(\Sigma_{z,2}^I, \Sigma_{z,2}^H, \Sigma_{z,2}^S\right). \tag{C.8}$$

So, when $\Sigma_z > \bar{\Sigma}_2$, we have $\pi_I^* > \pi_I$, $\pi_S^* < \pi_S$, and $\pi_H^* < \pi_H$. □

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