Rational Information Leakage

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Abstract

We present a trading model to study the incentives of an informed trader (e.g., a well informed insider) to voluntarily leak information about an asset's value to another independent trader. We show that, while leaking information dissipates the insider's information advantage about the asset's value, it enhances his information advantage about the asset's execution price relative to other informed traders. These two effects are countervailing. When the profit impact from enhanced information about the execution price dominates, the insider has incentives to leak some of his private information. We label this rational information leakage and discuss its implications for empirical research and the regulation of insider trading.

Keywords: Information leakage, insider trading, securities regulations.

JEL Classifications: G14, G18, D82.
1 Introduction

The role of information and information-based trading in capital markets has long been a topic of interest to investors, financial regulators, as well as academics. Information-based trades are often credited with contributing to the efficiency of capital markets but they are alleged also to lead to wealth transfers among investors, particularly when such trades are based on private (perhaps inside) information (e.g., Bhattacharya and Nicodano, 2001; Jeng, Metrick and Zeckhauser, 2003; De Franco, Lu and Vasvari, 2007). An important channel through which private information affects trades is through information leakage. Evidence suggests that information leakage is common. For example, evidence of abnormal changes in stock prices and trading volumes shortly before analyst recommendations or major corporate events is often attributed to leaked information (Irvine, Lipson and Puckett, 2007; Christophe, Ferri and Hsieh, 2010). Similarly, Khan and Lu (2011) suggest that leaked information can explain the increased short-sale activities of both market makers and non-market makers shortly before the sale of shares by corporate CEOs.

If information leakage is an important channel through which private information affects stock prices and trading behavior, then it is important to understand why insiders are motivated to leak their private information.\(^1\) The standard intuition holds that some informed traders, e.g., insiders or CEOs hindered from actively trading in their firms' shares, sell or reveal their private information to related parties and associates who then trade on the private information for their joint benefit. For instance, the U.S. Securities and Exchange Commission (SEC), in its ongoing campaign against insider trading, has noted the rise of so-called "expert networks" where insiders with access to private information are hired as hedge fund consultants (Zuckerman and Pulliam, 2010). In this paper, we argue that informed traders' incentives of leaking information extend beyond the above standard logic. In particular, we show that an insider who is allowed to trade actively may voluntarily reveal some of his private information to an independent (i.e., unrelated) third party and yet benefit from

\(^1\)Of course, private information can also be stolen by (or involuntarily leaked to) individuals intent on exploiting informed investors' private information. For example, in 2009, the U.S. Securities Exchange Commission (SEC) charged a major brokerage firm for illegally allowing traders from other firms to listen to confidential trading information of its institutional customers without their knowledge using "Squawk Boxes" (SEC press release #2009-54).
this leakage even in the absence of explicit payments or claims to the other party’s trading profits.

To illustrate an informed trader’s incentives to leak private information to another trader, we consider a standard Kyle model (Kyle, 1985) where a single well informed insider trades a single security in a market populated with other less well informed traders as well as liquidity traders. Using Kyle model, we assume that all traders submit market orders. As leaked information is short-lived, traders are prepared to take on price risk to achieve immediacy in trading. We characterize information leakage as the insider’s decision to provide a garbled version of his information to an unrelated informed trader whom we label as a designated trader. We find that leaking information to the designated trader (without receiving compensation in return) affects the insider’s expected trading profits in two ways. The first effect is straightforward; leaking information to another trader dissipates the insider’s information advantage concerning the fundamental value of the asset. This reduces the insider’s trading profit. The second effect reflects the fact that leaking information increases the insider’s information advantage concerning the execution price of the asset relative to other informed traders. This is because the designated trader’s reliance on the leaked information implies that the asset’s price is also sensitive to the noise or non-fundamental component of the the leaked information which is observable by the insider. This effect increases the insider’s trading profit.

The two effects of leaking information on the insider’s trading profit described above are countervailing. Clearly, when the profit impact of the first effect dominates the profit impact of the second effect, the insider has no incentive to leak information to a designated trader. Conversely, when the second effect dominates the first effect, information leakage is rational. We also show that information leakage helps the designated trader but is detrimental to other informed traders in the marketplace. This latter finding is consistent with recent empirical evidence that institutional investor trades (which are analogous to other informed traders in our model) are inversely associated with insider trades (Sias and Whidbee, 2010). Our finding also implies that other informed traders will reduce their information collection efforts as the marginal benefit of doing so declines due to information leakage. Finally, our model demonstrates that information leakage may enhance market depth and make uninformed
liquidity traders better-off by dampening the wealth transfer between liquidity and informed traders. This result complements Leland's (1992) finding that more insider trading can benefit liquidity traders by lowering the cost of capital.

The contribution of our study can be summarized as follows. First, we characterize a novel channel of information leakage and show that such leakage might indeed be rational. This is in sharp contrast to the standard intuition that an informed insider cannot benefit from such leakage without a commensurate fee or direct compensation. Second, our study provides a possible explanation to many existing empirical studies showing abnormal trading behavior before insider trading, analyst stock recommendations, or major corporate events. In this spirit, we identify the settings where information leakage is likely to occur and highlight potential empirical implications. For example, the insider is more likely to leak information when there are more informed traders, when other traders are relatively well informed, and/or when the underlying asset has more volatile cash flows.

Finally, our paper contributes to the debate on how to regulate insider trading. Information leakage has been a critical concern of capital market regulators and has attracted significant attention from academics over several decades. The wealth transfer effect from other informed traders to the designated trader and insider in our model illustrates that those who diligently collect and process information (i.e., other informed traders in our model) are not appropriately rewarded for their efforts. Thus, understanding this rational mechanism would help regulators by focusing on underlying incentives rather than simply building a Chinese Wall.

While no theory to date provides the same intuitions as we highlight in this paper, in a broad sense, our paper is related to a variety of theoretical research investigating the role of information in financial markets. The closest studies are Bommel (2003) and Brunnermeier (2005), both of which use a dynamic Kyle model to show that an informed trader can exploit his information twice; first when he receives information, and second when he expects the price to overshoot. In Bommel (2003), an informed investor with limited investment capacity spreads imprecise rumours to a group of followers whose collective trading can cause the price to overshoot. In Brunnermeier (2005), an insider receives a noisy signal about a forthcoming public announcement and the noise contained in his signal provides the insider
an information advantage about how much the price will likely overshoot after the public announcement, as he knows best the extent to which his information is already reflected in the pre-announcement price. Consistent with our paper, both these studies emphasize the importance of the noise or non-fundamental component of the leakage information as a source of information advantage for the insider.

Our study is also related to a number of studies examining the effect of selling information in financial markets; for example, Admati and Pfleiderer (1986, 1988, 1990), Benabou and Laroque (1992), Fishman and Hagerty (1995), Veldkamp (2006), Cespa (2008) and Garcia and Vanden (2009). These studies are typically in the context of analysts selling fundamental information to other traders and focus on the strategic decision of either selling the information to a finite number of traders directly or selling the information through a mutual fund. In contrast, our paper studies the information leakage decision of an insider trader and emphasizes the trade-off facing the insider between losing the information advantage about the fundamental value of the underlying asset and gaining the information advantage about future execution price. Our analysis extends this literature by showing that even in the absence of revenue from selling information, the informed trader might still want to leak information to an unrelated party.

The third strand of related literature are the studies examining the implication of disclosures using strategic Kyle-type models (e.g., Bushman and Indjejikian, 1995; Huddart, Hughes, and Levine, 2000). In particular, Bushman and Indjejikian (1995) demonstrate that disclosing information to all market participants, including the market maker, can benefit the insider trader by driving out some informed traders who would otherwise stay in the market. In contrast, in our model, only a selected trader or a group of traders (i.e., the designated trader) have access to the leaked information. Our setting reduces the trading aggressiveness of other informed traders, which benefits the insider.

The remainder of the paper is organized as follows. Section 2 describes the model setup and equilibrium. Section 3 shows the possibility of rational information leakage, outlining the conditions that must be met for the insider to leak proprietary information. Section 4 discusses the robustness of our results to some alternative settings. Section 5 concludes.

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2See Verrecchia (2001) for a survey on the disclosure literature.
2 The Model

2.1 Setup

Consider a Kyle-type model with a single risky-asset whose uncertain liquidating value is represented by

\[ \tilde{\epsilon} \sim N(\epsilon, 1/e), \text{ with } \epsilon \in \mathbb{R} \text{ and } e > 0. \]  

There are two types of risk-neutral informed traders: (1) an insider who privately observes \( \tilde{\epsilon} \); and, (2) \( N + 1 \) informed traders who observe distinct (but equally precise) signals,

\[ \tilde{y}_j = \tilde{\epsilon} + \tilde{\eta}_j, \text{ with } \tilde{\eta}_j \sim N(0, 1/h) \text{ and } h > 0, \]  

where \( j = D, 1, 2, \ldots, N \). Descriptively, the insider in our model can be thought of as a corporate CEO/executive or hedge fund manager with superior information about a firm’s prospects, while the other informed traders in our model can be thought of as institutional investors that actively engage in information acquisition but nonetheless are less well informed than corporate insiders.

Before trade occurs, we assume that the insider leaks a garbled version of his information

\[ \tilde{y}_L = \tilde{\epsilon} + \tilde{\zeta}, \text{ with } \tilde{\zeta} \sim N(0, 1/z) \text{ and } z \geq 0, \]  

\footnote{Trader D can be interpreted as a front-runner in the sense that both of them trade on information obtained from a better informed trader.}

\footnote{The model can also accommodate a setting where the insider leaks (potentially distinct) signals to several other designated traders. However, in what follows we illustrate our intuition with a simpler model that features only one designated trader that observes the leaked information.}

to one of the other informed traders which we denote as trader D, which means a “designated trader.” In Section 3, we address the insider’s incentive to reveal \( \tilde{y}_L \) to trader D; for now, we assume \( \tilde{y}_L \) is exogenously specified so that trader D has two pieces of information \( \tilde{y}_D \) and \( \tilde{y}_L \). We note that the precision of \( \tilde{\zeta} \) dictates the extent to which the insider’s information is leaked to trader D. When \( z = 0 \), there is no information leakage because the signal \( \tilde{y}_L \) is uninformative about \( \tilde{\epsilon} \). In contrast, when \( z \to \infty \), there is full leakage in the sense that trader D is as equally well informed as the insider.
There are risk-neutral liquidity traders whose net order is represented by

\[ \tilde{u} \sim N(0, \sigma_u^2), \text{ with } \sigma_u > 0. \]  

(4)

The market-maker is risk-neutral and sets the price according to the weak efficiency rule:

\[ \tilde{p} = E(\tilde{\epsilon}|\tilde{\omega}) = \tilde{\epsilon} + \lambda \tilde{\omega}, \]  

(5)

where \( \tilde{\omega} \) is the aggregate market order flow

\[ \tilde{\omega} = \tilde{x}_I + \tilde{x}_D + \sum_{j=1}^{N} \tilde{x}_j + \tilde{u}, \]  

(6)

with \( \tilde{x}_I, \tilde{x}_D \) and \( \tilde{x}_j \) representing the orders submitted by the insider, the designated trader and the \( j \)-th other informed traders. Parameter \( \lambda \) will be endogenously determined.

### 2.2 Equilibrium

Any trader \( i \) (insider, designated trader or other informed) taking the strategies of others and the price function as given solves

\[ \max_{\tilde{x}_i} E[(\tilde{\epsilon} - \tilde{p})\tilde{x}_i|\mathcal{I}_i], \]

where \( \mathcal{I}_i \) is his information set.

The first-order condition is

\[ E\left[ \frac{\partial (\tilde{\epsilon} - \tilde{p})}{\partial \tilde{x}_i} \tilde{x}_i + (\tilde{\epsilon} - \tilde{p}) \left| \mathcal{I}_i \right. \right] = 0, \]  

(7)

which, by \( \tilde{p} = \tilde{\epsilon} + \lambda \tilde{\omega} = \tilde{\epsilon} + \lambda \left( \tilde{x}_I + \tilde{x}_D + \sum_{j=1}^{N} \tilde{x}_j + \tilde{u} \right) \), implies that the optimal order flow is

\[ \tilde{x}_i^* = \frac{1}{2\lambda} \left[ E(\tilde{\epsilon} - \tilde{\epsilon}|\mathcal{I}_i) - \lambda \sum_{k \neq i} E(\tilde{x}_k|\mathcal{I}_i) \right]. \]  

(8)

In addition, the first-order condition implies that \( E(\tilde{\epsilon} - \tilde{p}|\mathcal{I}_i) = \lambda \tilde{x}_i^* \) and thus the optimal
expected profit is
\[ \pi_i = E \{ E[(\tilde{\epsilon} - \bar{\tilde{p}}) \tilde{x}_i^* | I_i] \} = \lambda \text{Var}(\tilde{x}_i^*), \]  
where the last equality follows because, as we show shortly, the equilibrium trading strategies have a mean of zero.

Given the information structure, the optimal trading strategies of the insider, the designated trader or the \( j \)-th other informed trader take the following linear structure:

\[
\begin{align*}
\tilde{x}_I &= \alpha_I (\tilde{\epsilon} - \bar{\tilde{\epsilon}}) + \alpha_L (\tilde{y}_L - \bar{\tilde{\epsilon}}) \\
x_D &= \beta_D [E(\tilde{\epsilon}|\tilde{y}_D, \tilde{y}_L) - \bar{\tilde{\epsilon}}] + \beta_L (\tilde{y}_L - \bar{\tilde{\epsilon}}) \\
x_j &= \gamma [E(\tilde{\epsilon}|\tilde{y}_j) - \bar{\tilde{\epsilon}}]
\end{align*}
\]

where coefficients \( \alpha_I, \alpha_L, \beta_D, \beta_L \) and \( \gamma \) are endogenously determined. The coefficients \( \alpha_I \) and \( \beta_D \) respectively represent the trading aggressiveness of the insider and the designated trader when they make decisions based on their predictions regarding \( \tilde{\epsilon} \) with their own information. The coefficients \( \alpha_L \) and \( \beta_L \) capture the strategic interaction between the insider and the designated trader.

As standard in the literature, using the first-order condition (equation (8)) and the conjectured linear trading strategy structure (equation (10)), we can form a system of five unknowns \( \alpha_I, \alpha_L, \beta_D, \beta_L \) and \( \gamma \) as follows:

\[
\begin{align*}
2\alpha_I + \frac{\lambda}{e+h+z} \beta_D + \frac{N\lambda}{e+h} \gamma &= \frac{1}{\lambda} \\
2\alpha_L + \frac{\bar{\epsilon}}{e+h+z} \beta_D + \beta_L &= 0 \\
2\beta_D + \alpha_I + \frac{N\lambda}{e+h} \gamma &= \frac{1}{\lambda} \\
\alpha_L + 2\beta_L &= 0 \\
\alpha_I + \alpha_L + \frac{\lambda}{e+h+z} \beta_D + \beta_L + \left[2 + \frac{(N-1)\lambda}{e+h}\right] \gamma &= \frac{1}{\lambda}
\end{align*}
\]

Combining the above five equations with \( \lambda = \frac{\text{Cov}(\tilde{\epsilon}, \tilde{\omega})}{\text{Var}(\tilde{\omega})} \) gives a system of six equations and six unknowns (\( \lambda, \alpha_I, \alpha_L, \beta_D, \beta_L \) and \( \gamma \)). In Appendix A1, we solve this system and summarize the results in the following proposition.
Proposition 1 The equilibrium price function is

$$\hat{p} = \bar{\epsilon} + \lambda \hat{\omega},$$

and the trading strategies of the insider, designated trader, and the other informed are,

$$\bar{x}_I = \alpha_I (\bar{\epsilon} - \bar{\epsilon}) + \alpha_L (\bar{y}_L - \bar{\epsilon}),$$
$$\bar{x}_D = \frac{h}{e + h + z} \beta_D (\bar{y}_D - \bar{\epsilon}) + \left( \frac{z}{e + h + z} \beta_D + \beta_L \right) (\bar{y}_L - \bar{\epsilon}),$$
$$\bar{x}_j = \frac{h}{e + h} \gamma (\bar{y}_j - \bar{\epsilon}),$$

where $j = 1, 2, \ldots, N$, and where

$$\lambda = \frac{\Delta_1}{\sigma_u e^{1/2} \Delta_2}, \beta_D = \frac{1}{\lambda \Delta_2}, \beta_L = \frac{1}{3} \frac{z}{e + h + z} \beta_D,$$
$$\alpha_I = \left( 1 + \frac{e + z}{e + h + z} \right) \beta_D, \alpha_L = \frac{2}{3} \frac{z}{e + h + z} \beta_D,$$
$$\gamma = \frac{1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z}}{1 + \frac{e}{e + h}} \beta_D,$$

with

$$\Delta_1 = \left[ 2 + \frac{e}{e + h + z} \left( 1 + \frac{e + z}{e + h + z} \right) + \frac{2}{3} \frac{z}{e + h + z} \left( 2 + \frac{1}{3} \frac{e + z}{e + h + z} \right) \right]^{1/2} + \frac{Nh}{e + h} \left( \frac{1}{1 + \frac{e}{e + h}} \right)^{1/2},$$
$$\Delta_2 = 2 \left( 1 + \frac{e + z}{e + h + z} \right) + \frac{h}{e + h + z} + \frac{Nh}{e + h} \left( 1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z} \right),$$

Proof. See Appendix A1. □

Three notable observations emerge from Proposition 1. First, we note that the insider's trading strategy depends explicitly on the leaked information $\bar{y}_L = \bar{\epsilon} + \check{\zeta}$ (i.e., $\alpha_L \neq 0$) despite the fact that the insider observes $\bar{\epsilon}$, and $\bar{y}_L$ is simply a garbled version of $\bar{\epsilon}$. This means that price is sensitive to the $\bar{y}_L$-based trades of both the insider and trader D whose joint $\bar{y}_L$-based order flow equals $\alpha_L + \left( \frac{\bar{\epsilon}}{e + h + z} \beta_D + \beta_L \right) = \frac{2}{3} \frac{\bar{\epsilon}}{e + h + z} \beta_D$.

Second, we note that the insider's $\bar{y}_L$-based trading strategy (i.e., $\alpha_L$) is negative while
trader D’s \( \tilde{y}_L \)-based trading strategy, \( \frac{e + \tilde{z}}{e + h + z} \beta_D + \beta_L \), is positive which means that the insider trades in the opposite direction to trader D with respect to the leaked information. This reflects the insider’s desire to dampen the market order flow by (partially) offsetting orders submitted by trader D that are sensitive to \( \tilde{y}_L \) in order to secure favorable price terms from the market maker.

Third, we note that when \( z = 0 \), \( \tilde{x}_D = \tilde{x}_j \); otherwise, when \( z > 0 \), trader D trades more than the other \( N \) informed traders in the sense that \( \text{Var}(\tilde{x}_D) > \text{Var}(\tilde{x}_j) \), which can be shown by direct computation (see also Proposition 2 below).

3 Rational Information Leakage

In this section, we address the insider’s rationale for leaking information based on the equilibrium results in Proposition 1. We begin by first characterizing the ex ante profits of the designated trader and other \( N \) informed traders. Substituting the trading strategies \( \tilde{x}_D \) and \( \tilde{x}_j \) described in Proposition 1 into the traders’ respective profit expressions, we have:

\[
\pi_D (z, e, h, N) = \sigma_u \left[ \frac{1}{e + h + z} + \frac{4}{3(e + h + z)} \right]^2 + \frac{\left( \frac{h}{e + h + z} \right)^2}{h} + \frac{\left( \frac{3}{3(e + h + z)} \right)^2}{z} \]
\[
= \pi_j (z, e, h, N) + \frac{8 z \sigma_u e^{1/2} 8 e^2 + 14 h e + 8 z e + 6 h z + 5 h^2}{9 \Delta_1 \Delta_2} \frac{(h + 2 e)^2 (h + z + e)^2}{(h + 2 e)^2 (h + z + e)^2}, \tag{12}
\]

\[
\pi_j (z, e, h, N) = \frac{\sigma_u}{e^{1/2} \Delta_1 \Delta_2} \frac{h}{e + h} \left( \frac{1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z}}{1 + \frac{e}{e + h}} \right)^2, \tag{13}
\]

where \( j = 1, 2, \ldots, N \). We note that the profit expressions in (12) and (13) are characterized as functions of the four exogenous parameters of interest: \( z \), the precision of leaked information \( \tilde{y}_L \); \( e \), the precision of the cash flow of the underlying asset \( \tilde{z} \); \( h \), the precision of the other informed traders’ private signal \( \tilde{y}_j \); and \( N \), the number of the other informed traders.

As expected, expressions (12) and (13) suggest that \( \pi_D \geq \pi_j \) so that the leaked information makes the designated trader (weakly) better off. This is because the leaked information provides the designated trader with additional information about the asset payoff unavailable to the other traders. Moreover, we can show that as the leaked information becomes increa-
ingly more precise (i.e., as $z$ increases), the other $N$ traders become less active and trade less aggressively. As a consequence, the profits of the other $N$ traders decrease while the profit of the designated trader increases. We summarize these observations in the following proposition.

**Proposition 2** The expected profit of the designated trader is increasing in the precision of the leaked information. The expected profits of the other $N$ informed traders are decreasing in the precision of leaked information. That is, $\pi_D \geq \pi_j$ with $\frac{\partial \pi_D(z,e,h,N)}{\partial z} \geq 0$ and $\frac{\partial \pi_j(z,e,h,N)}{\partial z} \leq 0$.

**Proof.** See Appendix A2. ■

Whereas the profit impact of leaking information on the designated trader and other $N$ traders is clear, the impact on the insider is more subtle. In particular, we find that an increase in $z$, the precision of leaked information, can increase or decrease the insider’s expected profit. Intuitively, leaked information can decrease the insider’s profit because it renders a competing trader (i.e., the designated trader) better informed. At the same time, leaked information can increase the insider’s profit because it makes other competing traders (i.e., the other $N$ traders) less active or aggressive. This means that, if we interpret $z$ as the insider’s choice variable, then there are settings where the insider will choose to leak information as well as settings where he will refrain from doing so. Hence, we write,

$$z^* = \max \left\{ 0, \arg \max_z \pi_I(z,e,h,N) \right\}$$

where $z^*$ represents the insider’s optimal choice of $z$ and $\pi_I(z,e,h,N)$ represents the expected profit of the insider. Clearly, if $\arg \max_z \pi_I(z,e,h,N) > 0$, i.e. $z^* > 0$, information leakage is “rational”.

To characterize conditions under which information leakage is “rational,” we rewrite the insider’s trading strategy (from Proposition 1) as follows:

$$\tilde{x}_I^* = \alpha_I (\tilde{e} - \bar{e}) + \alpha_L (\tilde{y}_L - \tilde{e})$$

$$= (\alpha_I + \alpha_L) (\tilde{e} - \bar{e}) + \alpha_L \zeta,$$  \hfill (14)

where the second equality follows from $\tilde{y}_L = \tilde{e} + \zeta$. Substituting the above trading strategy
into the profit expression (equation (9)), we can decompose the insider’s ex ante profit as follows:

$$
\pi_I (z, e, h, N) = \lambda \text{Var} (\hat{\varepsilon}^*_I) = \frac{\lambda}{2} (\alpha_I + \alpha_L)^2 e^{-1} + \lambda \alpha_L^2 z^{-1}.
$$

(15)

The first term in (15), labeled “fundamental-based profit,” is based on the first component of the insider’s order in equation (14) which depends on his information \( \hat{\varepsilon} \). Information leakage lowers the insider’s fundamental-based profit, i.e., \( \frac{\partial [\lambda (\alpha_I + \alpha_L)^2 e^{-1}]}{\partial z} < 0 \), because as \( z \) increases the designated trader becomes more informed about the asset’s fundamental value and captures some of the insider’s information advantage. In the extreme, when \( z \rightarrow \infty \), the insider’s fundamental-based profit is minimized because leaking perfect information is equivalent to making trader D just another insider.

The second term in (15), labeled “noise-based profit,” is based on the second component of the insider’s order in equation (14) which depends on the insider’s observation of \( \bar{z} \). Recall that because price is sensitive to \( \bar{y}_L \)-based trades, the insider enjoys an information advantage over the execution price, \( \bar{p} \). Of course, when there is no information leakage (i.e., \( z = 0 \)), the insider’s noise-based profit is zero. In the other extreme, when \( z \rightarrow \infty \), the insider’s noise-based profit is also zero because with perfect leakage trader D perfectly observes \( \bar{e} \) and hence price is no longer sensitive to \( \bar{z} \). This means that the insider’s noise-based profit, i.e., \( \lambda \alpha_L^2 z^{-1} \), increases for lower values of \( z \) and decreases for higher values of \( z \). Moreover, we can show that \( \lambda \alpha_L^2 z^{-1} \) is a single-peaked function of \( z \) and hence, some information leakage always increases the insider’s noise-based profit.

In sum, the decomposition in (15) suggests that information leakage weakens the insider’s information advantage about the fundamental value \( \hat{\varepsilon} \) but at the same time strengthens the insider’s information advantage about the execution price. Therefore, the rationality of information leakage by the insider (i.e., the choice of a nonzero \( z \)) depends on the relative importance of these two effects. Because the complexity of the expression for \( \pi_I (z, e, h, N) \) precludes a full characterization, we describe a sufficient condition for rational information leakage, namely, a characterization for when the function \( \pi_I (z, e, h, N) \) is strictly increasing at \( z = 0 \). We have:

**Proposition 3** [Rational Information Leakage] Information leakage is rational when
\[
\frac{\partial \pi_i(z, e, h, N)}{\partial z} \bigg|_{z=0} > 0, \text{ a condition which is satisfied if and only if the number } N \text{ of other informed traders exceeds a threshold } \hat{N} \text{ (defined in equation (48) in Appendix A3) where } \hat{N} \text{ is a decreasing function of other traders' signal-to-noise ratio } h/e.
\]

**Proof.** See Appendix A3. ■

Figure 1 plots the function \( \hat{N} \left( \frac{h}{e} \right) \) with a solid curve in the plane of \( \left( \frac{h}{e}, N \right) \). We label this solid curve separating leakage vs. non-leakage regions as "information leakage frontier". Information leakage is likely to occur in the region above the frontier (with "+" marks), i.e., when \( N \) is greater than \( \hat{N} \left( \frac{h}{e} \right) \).

**INSERT FIGURE 1 HERE**

Proposition 3 (and Figure 1) suggest that information leakage is more likely when (i) there are more informed traders in the market (\( N \) is large) and/or (ii) other informed traders' are relatively well informed about the underlying asset (\( h/e \) is large). The intuition is as follows: The insider’s benefit of leaking information comes from the reduced trading of the other informed traders; if there are many such traders (\( N \) is large) and/or if these traders trade aggressively due to their precise signals (\( \frac{h}{e} \) is large), the benefit of leaking information to the insider is large and it is potentially rational for him to leak the information to a designated trader. Figure 2 illustrates two settings, one where information leakage is optimal and one where it is not. Specifically, in Panel (a), \( N = 10 \), while in Panel (b), \( N = 50 \). The common parameter values for the two economies are \( e = h = \sigma_u = 1 \). In Panel (a), the optimal \( z^* \) is 0, suggesting no information leakage, while in Panel (b), the optimal \( z^* \) is 0.55, suggesting the existence of rational information leakage. This is consistent with Proposition 3: For the two economies, we have \( \hat{N} \left( \frac{h}{e} \right) = \hat{N}(1) = 27.4 \); in Panel (a), \( N = 10 < \hat{N}(1) \), so that \( z^* = 0 \), while in Panel (b), \( N = 50 > \hat{N}(1) \), so that \( z^* > 0 \).

**INSERT FIGURE 2 HERE**

Propositions 2 and 3 suggest that rational information leakage is consistent with the designated trader and the insider benefiting at the expense of other informed traders. In our
final result in this section, we also examine the impact of information leakage on the aggregate expected profit of all informed traders given by $\lambda \sigma_u^2$. Note that $\lambda \sigma_u^2$ is also a measure of wealth transfer, because trading is a zero-sum game, that is, the profits of informed traders come at the expense of liquidity traders and thus $\lambda \sigma_u^2$ is equivalent to the expected cost of trading borne by liquidity traders. Hence, given $\lambda \sigma_u^2 = \pi_L + \pi_D + N \pi_j = \frac{\sigma H}{e^{1/2} \Delta_2}$ (where $\Delta_1$ and $\Delta_2$ are defined in Proposition 1), we can show that

$$\frac{\partial \lambda(z, e, h, N)}{\partial z} \bigg|_{z=0} < 0 \text{ if and only if } N > 9 - 4 \frac{(h/e)^{-1}}{e}.$$  \hspace{1cm} (16)

Gennette and Leland (1990) suggest that informed trader's signal-to-noise ratio is 0.2. If we assume that 0.2 is an empirically relevant value for $h/e$, then the above condition suggests that information leakage typically reduces the aggregate profit of informed traders and enhances market liquidity or depth. More importantly, because the threshold level $\hat{N}$ that renders information leakage rational in Proposition 3 exceeds $9 - 4 \frac{(h/e)^{-1}}{e}$, rational information leakage also implies more liquid markets. We have:

**Proposition 4** If information leakage is rational, then information leakage increases market liquidity. That is, if $N > \hat{N}$, then $\frac{\partial \lambda(z, e, h, N)}{\partial z} \bigg|_{z=0} < 0$.

**Proof.** See Appendix A4. \quad \blacksquare

Proposition 4 suggests that, compared with the case without information leakage, liquidity traders lose less money when there is information leakage. However, all other informed traders make less money, which may affect the incentive of collecting and processing information.

4. **Model Extensions**

In this section, we discuss the robustness of our results to some alternative modeling assumptions.
4.1 Sale of Information to the Designated Trader

Our model assumes that the insider leaks information to the designated trader for free. As a practical matter, the insider can also demand an explicit payment or fee as compensation for the leaked information. Incorporating such a feature in our model is relatively straightforward. Intuitively, by charging a fee, the insider recoups some of the profit earned by the designated trader, and thus has a stronger incentive to leak information than in our baseline model. More generally, however, selling information may not be optimal for the parties concerned because such a sale/purchase transaction has the potential for legal ramifications.

4.2 Endogenous Number of Other Informed Traders

Our model assumes that there are \(N\) other informed traders in the market, where \(N\) is exogenously fixed. To assess how information leakage might affect \(N\) if \(N\) were endogenous, we assume that the other informed traders enter the market by acquiring the signal \(\hat{g}_j\) at a fixed cost \(C > 0\). Hence, the endogenous number \(N^*\) of other informed traders is determined by \(\pi_j(z, e, h, N^*) = C\). Briefly, we find that information leakage reduces \(\pi_j\) (Proposition 2), and by virtue of \(\pi_j(z, e, h, N^*) = C\), drives out some informed traders from the market (i.e., \(N^*\) decreases).\(^5\) Hence, we show that the insider is more likely to leak information when \(N\) is endogenous than otherwise.

4.3 Mixed Trading Strategy of the Insider

In our model, the insider’s information advantage about execution price arises because the designated trader submits orders based on the leaked information. Given that the insider is responsible for leaking the information in the first place, an important question that arises is whether the insider can produce a similar information advantage about execution price on his own; for example, by simply adding or subtracting some noise to/from his optimal trading strategy. We argue that this is not feasible because this is akin to the insider employing a mixed strategy to introduce a privately known noise into the price function. As Brunnermeier

\(^5\)The notion that information leakage can drive out other informed traders is consistent with recent evidence that finds a strong inverse relation between insider trading and institutional trades (Sias and Whidbee, 2010).
(2005) shows, such a mixed strategy is not supported in equilibrium because the insider's problem is concave and admits a unique optimal solution.

To be more precise, the insider in our model gains an information advantage about execution price because the noise contained in the leaked information affects order flow and hence price. This requires that the designated trader have a credibly different objective function than the insider. Otherwise, market participants will treat both traders as one. For example, if the insider leaks information to a relative or an affiliated trader, then the leaked information is not credible in the sense that both the market maker and the other informed traders will consider the insider and the designated trader to have a common objective function. In such a setting, leaking information is not valuable because the noise in the leaked information does not affect price. In this sense, leaking information to an unrelated designated trader and the profit that the insider forgoes in doing so can be viewed as the insider’s commitment cost.

4.4 Information Stealing

In this subsection, we consider “information stealing” as opposed to “information leakage” as a means of informing a designated trader. In contrast to information leakage, we assume that the information that is stolen is not observed by the insider (but the fact that it is stolen is common knowledge). This distinction is important because stolen information has been long considered another important channel of how prices reflect private information. For example, in 2009, the SEC charged a major brokerage firm for illegally allowing traders from other firms to listen to confidential trading information of its institutional customers without their knowledge using “Squawk Boxes” (SEC press release #2009-54). Thus, this channel per se deserves serious examination.

The distinction between information leakage and information stealing is also important because, unlike information leakage, stolen information does not convey an information advantage to the insider over execution price. In the context of our model, this means that stolen information makes the designated trader better off but renders the insider unambiguously worse off.
5 Summary and Discussion

In this paper we examine an insider’s incentives to voluntarily leak information about an asset’s value to an unrelated third party to whom we refer to as a designated trader. Using a stylized Kyle model, we show that, while leaking information dissipates the insider’s information advantage about the asset’s value, it enhances his information advantage about the asset’s execution price relative to other informed traders. These two effects are countervailing. When the profit impact from enhanced information about the execution price dominates, the insider has incentives to leak some of his private information.

Although admittedly stylized, our model highlights a number of issues and implications for capital markets, particularly those that pertain to insider trading regulations designed to enhance public confidence in capital markets. The Securities and Exchange Act of 1934 and the subsequent amendments state that it is illegal to use or pass on to others material, non-public information or enter into transactions while in possession of such information. The regulations give the enforcement power to the SEC which can bring civil charges against any violators and refer cases to the Justice Department for criminal prosecution.

In the context of our model, if we interpret the insider as a corporate CEO, officer, or director, then rational information leakage in our model can be characterized potentially as illegal insider trading behavior by the SEC. On the other hand, if we interpret the insider in our model as a brokerage firm whose analysts inform (or tip-off) their clients about some of the information they collect and process, then the impropriety of information leakage is less obvious. In these latter types of settings, the SEC usually evaluates potential insider trading violations on a case by case basis because the SEC regulations do not explicitly address such tipping-off practices by security analysts. In a similar vein, although the financial industry’s professional code of conduct explicitly prohibits trading by a brokerage firm before the public release of its own analysts’ reports, it does not preclude the brokerage firm’s clients from trading before the reports become public.²

Notwithstanding the legalities of insider trading and the SEC’s enforcement efforts, there is a plethora of evidence to suggest that information leakage and insider trading is prevalent.

²For instance, see National Association of Securities Dealers (formerly NASD now FINRA) professional code of conduct Rule 2110 “Standards of Commercial Honor and Principles of Trades”.

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For example, Seyhun (1992) shows that both the profitability and the volume of insider trading increased significantly (by a factor of 4 to 6) during the 1980s despite increased SEC enforcement efforts. Similarly, Irvine et al. (2007) provide evidence that institutional traders are unusually active ahead of analyst buy recommendations, and Christope et al. (2010) find that short sellers tend to short more shares ahead of analyst sell recommendations. Taken together, these findings are consistent with the perception that difficulties in investigating and proving insider trading cases renders the likelihood of being caught and prosecuted for leaking information very low (see also SEC's insider trading website). The chance of detection and prosecution is likely to be even lower if the insider leaks information to an unrelated third party (interpreted as the designated trader in our model) who can disavow a duty of trust. Finally, in the event of prosecution, the designated trader (at least as captured in our model) can mount an affirmative defense that the leaked information was not a factor in his decision to trade and that his trades are based on other private sources of information.

Our model also identifies settings where information leakage is likely to be observed as well as settings where current SEC regulations are most likely to be effective. For example, our model shows that the insider is more likely to leak information when more informed traders actively trade in the security, when other traders are better informed about the underlying asset value, and when the underlying asset has more volatile cash flows, suggesting the leakage problem might be more severe in the trading of growth firms. Similarly, our analysis suggests that Reg FD (issued by the SEC in 2000 mandating that all publicly traded companies disclose material information to all investors at the same time) is most effective in reducing insider trading for those firms above the information leakage frontier described by our model.
References


Appendix: Proofs

A1 Proof of Proposition 1

A1.1 Form the System of Coefficients

We first use equations (8), (10) and the equation \( \lambda = \frac{\text{Cov}(\bar{e}, \bar{e})}{\text{Var}(\bar{e})} \) to form the system of the unknown coefficients \( \alpha_I, \alpha_L, \beta_D, \beta_L, \gamma \) and \( \lambda \).

Insider. The insider has an information set of \( \mathcal{I}_I = \{\bar{e}, \bar{y}_L\} \). Thus, his forecast for the fundamental value is

\[ E(\bar{e} - \bar{e}|\mathcal{I}_I) = \bar{e} - \bar{e}, \]

and his forecasts of the order-flows of the designated trader and other \( N \) informed traders are:

\[
\bar{x}_D = \beta_D \left[ E(\bar{e}|\bar{y}_D, \bar{y}_L) - \bar{e} \right] + \beta_L \left( \bar{y}_L - \bar{e} \right)
\]

and

\[
E(\bar{x}_D|\mathcal{I}_I) = \beta_D \left( \frac{h}{e + h + z} (\bar{y}_D - \bar{e}) + \left( \beta_D \frac{z}{e + h + z} + \beta_L \right) (\bar{y}_L - \bar{e}) \right)
\]

\[
\bar{x}_j = \gamma \left[ E(\bar{e}|\bar{y}_j) - \bar{e} \right] = \gamma \left( \frac{h}{e + h} (\bar{y}_j - \bar{e}) \right)
\]

\[
E(\bar{x}_j|\mathcal{I}_I) = \gamma \left( \frac{h}{e + h} (\bar{y}_j - \bar{e}) \right)
\]

Plugging the expressions of \( E(\bar{e} - \bar{e}|\mathcal{I}_I) \), \( E(\bar{x}_D|\mathcal{I}_I) \) and \( E(\bar{x}_j|\mathcal{I}_I) \) into the optimal trading strategy of the insider (equation (8)):

\[
\bar{x}_I = \frac{E(\bar{e} - \bar{e}|\mathcal{I}_I) - \lambda \sum_{k \neq I} E(\bar{x}_k|\mathcal{I}_I)}{2\lambda} = \frac{1 - \lambda \frac{h}{e + h + z} \beta_D - \lambda \frac{N h}{e + h} \gamma}{2\lambda} (\bar{e} - \bar{e}) - \lambda \left( \frac{e + h}{e + h + z} \beta_D + \beta_L \right) (\bar{y}_L - \bar{e})
\]

Comparing the above expression with the conjectured trading strategy of the insider (i.e., \( \bar{x}_I = \alpha_I (\bar{e} - \bar{e}) + \alpha_L (\bar{y}_L - \bar{e}) \)), we have the following two equations of \( \alpha_I \) and \( \alpha_L \):

\[
\alpha_I = \frac{1 - \lambda \frac{h}{e + h + z} \beta_D - \lambda \frac{N h}{e + h} \gamma}{2\lambda},
\]

\[
\alpha_L = -\frac{\frac{e + h}{e + h + z} \beta_D + \beta_L}{2},
\]

which implies

\[
2\alpha_I + \frac{h}{e + h + z} \beta_D + N \frac{h}{e + h} \gamma = \frac{1}{\lambda}, \quad (17)
\]

\[
2\alpha_L + \frac{z}{e + h + z} \beta_D + \beta_L = 0. \quad (18)
\]

Trade D. The information set of the designated trader is \( \mathcal{I}_D = \{\bar{y}_D, \bar{y}_L\} \). Thus, his forecast for the fundamental value of the underlying asset is \( E(\bar{e} - \bar{e}|\mathcal{I}_D) = E(\bar{e} - \bar{e}|\bar{y}_D, \bar{y}_L) \). His forecasts of the order flows of the insider and other informed traders are

\[
\bar{x}_I = \alpha_I (\bar{e} - \bar{e}) + \alpha_L (\bar{y}_L - \bar{e}) \Rightarrow
\]

\[
E(\bar{x}_I|\bar{y}_D, \bar{y}_L) = \alpha_I E(\bar{e} - \bar{e}|\bar{y}_D, \bar{y}_L) + \alpha_L (\bar{y}_L - \bar{e}),
\]

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and

\[ \tilde{x}_j = \gamma [E(\tilde{\varepsilon}|\tilde{y}_j) - \tilde{\varepsilon}] = \frac{h(\tilde{y}_j - \tilde{\varepsilon})}{e + h} \Rightarrow \]

\[ E(\tilde{x}_j|\tilde{y}_D, \tilde{y}_L) = \frac{h}{e + h} \gamma E(\tilde{\varepsilon} - \tilde{\varepsilon}|\tilde{y}_D, \tilde{y}_L). \]

Thus, plugging those expressions in equation (8) delivers

\[ \tilde{x}_D = \frac{E(\tilde{\varepsilon} - \tilde{\varepsilon}|I_D) - \lambda \sum_{k \neq j} E(\tilde{x}_k|I_D)}{2\lambda} \]

\[ = \frac{1 - \lambda \alpha_I - \lambda \frac{Nh}{e + h} \gamma}{2\lambda} E(\tilde{\varepsilon} - \tilde{\varepsilon}|\tilde{y}_D, \tilde{y}_L) - \lambda \alpha_L (\tilde{y}_L - \tilde{\varepsilon}). \]

Comparing with the conjectured trading strategy of the designated trader, we have

\[ \beta_D = \frac{1 - \lambda \alpha_I - \lambda \frac{Nh}{e + h} \gamma}{2\lambda}, \]

\[ \beta_L = \frac{-\alpha_L}{2}. \]

Further simplifying, we have two additional equations:

\[ 2\beta_D + \alpha_I + N \frac{h}{e + h} \gamma = \frac{1}{\lambda}, \quad \text{(19)} \]

\[ \alpha_L + 2\beta_L = 0. \quad \text{(20)} \]

**Informed Trader j.** The information set of trader \( j \) is \( I_j = \{ \tilde{y}_j \} \). His forecast of the fundamental value of the underlying asset is \( E(\tilde{\varepsilon} - \tilde{\varepsilon}|I_j) \). His forecasts of the submitted order flows of the insider, the designated trader and other informed traders are

\[ \tilde{x}_I = \alpha_I (\tilde{\varepsilon} - \tilde{\varepsilon}) + \alpha_L (\tilde{y}_L - \tilde{\varepsilon}) \Rightarrow \]

\[ E(\tilde{x}_I|\tilde{y}_j) = (\alpha_I + \alpha_L) E(\tilde{\varepsilon} - \tilde{\varepsilon}|\tilde{y}_j), \]

\[ \tilde{x}_D = \beta_D \frac{h}{e + h + z} (\tilde{y}_D - \tilde{\varepsilon}) + \left( \beta_D \frac{h + z}{e + h + z} + \beta_L \right) (\tilde{y}_L - \tilde{\varepsilon}) \Rightarrow \]

\[ E(\tilde{x}_D|\tilde{y}_j) = \left( \frac{h + z}{e + h + z} \beta_D + \beta_L \right) E(\tilde{\varepsilon} - \tilde{\varepsilon}|\tilde{y}_j), \]

and

\[ x_{j'} = \gamma [E(\tilde{\varepsilon}|\tilde{y}_{j'}) - \tilde{\varepsilon}] = \gamma \frac{h}{e + h} (\tilde{y}_{j'} - \tilde{\varepsilon}) \Rightarrow \]

\[ E(\tilde{x}_{j'}|\tilde{y}_j) = \frac{h}{e + h} \gamma [E(\tilde{\varepsilon}|\tilde{y}_j) - \tilde{\varepsilon}]. \]

Plugging those expressions into equation (8), we have

\[ \tilde{x}_j = \frac{E(\tilde{\varepsilon} - \tilde{\varepsilon}|I_j) - \lambda \sum_{k \neq j} E(\tilde{x}_k|I_j)}{2\lambda} \]

\[ = \frac{1 - \lambda (\alpha_I + \alpha_L) - \lambda \left( \frac{h + z}{e + h + z} \beta_D + \beta_L \right) - \lambda (N - 1) \frac{h}{e + h} \gamma}{2\lambda} E(\tilde{\varepsilon} - \tilde{\varepsilon}|\tilde{y}_j). \]

Comparing with the conjectured trading strategy of the informed traders, we have:

\[ \gamma = \frac{1 - \lambda (\alpha_I + \alpha_L) - \lambda \left( \frac{h + z}{e + h + z} \beta_D + \beta_L \right) - \lambda (N - 1) \frac{h}{e + h} \gamma}{2\lambda}, \]

\[ \text{21} \]
which implies:

\[(\alpha_I + \alpha_L) + \left(\frac{h + z}{e + h + z} \beta_D + \beta_L\right) + \left[2 + (N - 1) \frac{h}{e + h}\right] \gamma = \frac{1}{\lambda}.
\] (21)

Equations (17)-(21) form the system specified by equation (11) in the main text. Then combining this system with equation \(\lambda = \frac{\text{Cov}(\varepsilon, \omega)}{\text{Var}(\omega)}\), we have a system of the underlying six unknowns \(\alpha_I, \alpha_L, \beta_D, \beta_L, \gamma\) and \(\lambda\).

**A1.2 Solve the System**

We solve the system in two steps. First, we use equations (17)-(21) to express \(\alpha_I, \alpha_L, \beta_D, \beta_L\) and \(\gamma\) in terms of \(\lambda\). Second, we use \(\lambda = \frac{\text{Cov}(\varepsilon, \omega)}{\text{Var}(\omega)}\) to solve \(\lambda\).

**Step 1. Express \(\alpha_I, \alpha_L, \beta_D, \beta_L\) and \(\gamma\) in terms of \(\lambda\).**

We first express \(\alpha_I, \alpha_L, \beta_L\) and \(\gamma\) in terms of \(\beta_D\) and then solve \(\beta_D\) in terms of \(\lambda\). By equations (18) and (20), we can express the two coefficients related to the leaked information, \(\alpha_L\) and \(\beta_L\), as follows:

\[\beta_L = \frac{1}{3} \frac{z}{e + h + z} \beta_D;\] (22)

\[\alpha_L = \frac{2}{3} \frac{z}{e + h + z} \beta_D.\] (23)

By equations (17) and (19), we have

\[\alpha_I = \left(1 + \frac{e + z}{e + h + z}\right) \beta_D.\] (24)

Equations (19) and (21) combine to produce

\[\gamma = \frac{1 + \frac{e}{e + h} + \frac{1}{3} \frac{e}{e + h + z}}{1 + \frac{e}{e + h}} \beta_D.\] (25)

Then, plugging the expressions of \(\alpha_I\) and \(\gamma\) in equations (24) and (25) into (19), we have

\[\beta_D = \frac{1}{\lambda} \left(3 + \frac{e + z}{e + h + z} + N \frac{h}{e + h} \frac{1 + \frac{e}{e + h} + \frac{1}{3} \frac{e}{e + h + z}}{1 + \frac{e}{e + h}}\right)^{-1}.\] (26)

Define the following coefficients:

\[
\begin{bmatrix}
    c_{\beta_L} &=& \frac{1}{3} \frac{e}{e + h + z}, & c_{\alpha_L} &=& -\frac{2}{3} \frac{e}{e + h + z}, & c_{\alpha_I} &=& 1 + \frac{e + z}{e + h + z}, & c_{\gamma} &=& \frac{1 + \frac{e}{e + h} + \frac{1}{3} \frac{e}{e + h + z}}{1 + \frac{e}{e + h}} \\
    C_0 &=& \left(3 + \frac{e + z}{e + h + z} + N \frac{h}{e + h} \frac{1 + \frac{e}{e + h} + \frac{1}{3} \frac{e}{e + h + z}}{1 + \frac{e}{e + h}}\right)^{-1}
\end{bmatrix}
\] (27)

So, equations (22)-(26) imply

\[\beta_L = c_{\beta_L} \beta_D, \alpha_L = c_{\alpha_L} \beta_D, \alpha_I = c_{\alpha_I} \beta_D, \gamma = c_{\gamma} \beta_D, \beta_D = C_0 / \lambda.\] (28)
Step 2. Solve $\lambda$.

By the definition of the total order flow:

$$\tilde{\omega} = \tilde{x}_I + \tilde{x}_D + \sum_{j=1}^{N} \tilde{x}_j + \tilde{u}$$

$$= \alpha_I (\tilde{\epsilon} - \tilde{\epsilon}) + \alpha_L (\tilde{y}_L - \tilde{\epsilon}) + \beta_D [E (\tilde{\epsilon}|\tilde{y}_D, \tilde{y}_L) - \tilde{\epsilon}] + \beta_L (\tilde{y}_L - \tilde{\epsilon})$$

$$+ \sum_{j=1}^{N} \gamma [E (\tilde{\epsilon}|\tilde{y}_j) - \tilde{\epsilon}] + \tilde{u}$$

$$= \alpha_I (\tilde{\epsilon} - \tilde{\epsilon}) + \alpha_L (\tilde{y}_L - \tilde{\epsilon}) + \beta_D \frac{h (\tilde{y}_D - \tilde{\epsilon}) + z (\tilde{y}_L - \tilde{\epsilon})}{e + h + z} + \beta_L (\tilde{y}_L - \tilde{\epsilon})$$

$$+ \sum_{j=1}^{N} \gamma \frac{h}{e + h} (\tilde{y}_j - \tilde{\epsilon}) + \tilde{u}.$$  

By equation (28),

$$\tilde{\omega} = \left( c_{\alpha_I} + c_{\alpha_L} \frac{z}{e + h + z} + c_{\beta_L} + \frac{h}{e + h + z} + N c_{\gamma} \frac{h}{e + h} \right) \beta_D (\tilde{\epsilon} - \tilde{\epsilon})$$

$$+ \left( c_{\alpha_L} + \frac{z}{e + h + z} + c_{\beta_L} \right) \beta_D \tilde{\zeta}$$

$$+ \frac{h}{e + h + z} \beta_D \tilde{\eta}_D + c_{\gamma} \frac{h}{e + h} \beta_D \sum_{j=1}^{N} \tilde{\eta}_j + \tilde{u}.$$  

Define

$$\begin{bmatrix}
A_\epsilon &=& c_{\alpha_I} + c_{\alpha_L} + \frac{z}{e + h + z} + c_{\beta_L} + \frac{h}{e + h + z} + N c_{\gamma} \frac{h}{e + h}, \\
A_\zeta &=& c_{\alpha_L} + \frac{z}{e + h + z} + c_{\beta_L}, \quad A_D = \frac{h}{e + h + z}, \quad A_\gamma = c_{\gamma} \frac{h}{e + h}. 
\end{bmatrix}$$  

(29)

Thus,

$$\tilde{\omega} = A_\epsilon \beta_D (\tilde{\epsilon} - \tilde{\epsilon}) + A_\zeta \beta_D \tilde{\zeta} + A_D \beta_D \tilde{\eta}_D + A_\gamma \beta_D \sum_{j=1}^{N} \tilde{\eta}_j + \tilde{u}.$$  

As a result,

$$\lambda = \frac{Cov(\tilde{\omega}, \tilde{\omega})}{Var(\tilde{\omega})} = \frac{A_\epsilon \beta_D}{e} \Rightarrow \lambda = A_\epsilon \beta_D.$$  

Thus,

$$\sigma_u^2 \lambda^2 = A_\epsilon/e C_0 - (A_\epsilon^2/e + A_\zeta^2/z + A_D^2/h + A_\gamma^2 N/h) C_0^2 \Rightarrow$$

$$\lambda = \sigma_u^{-1} e^{-1/2} C_0 \sqrt{A_\epsilon/C_0 - \left( A_\epsilon^2 + A_\zeta^2/z + A_D^2/h + A_\gamma^2 N/h \right)} \Rightarrow$$

$$\lambda = \sigma_u^{-1} e^{-1/2} \Delta_1 \Delta_2^{-1}.$$  

(30)

where

$$\Delta_1 = \sqrt{A_\epsilon A_\zeta - \left( A_\epsilon^2 + A_\zeta^2/z + A_D^2/h + A_\gamma^2 N/h \right)},$$  

$$\Delta_2 = 2 \left( 1 + \frac{e + z}{e + h + z} + \frac{h}{e + h + z} + \frac{Nh}{e + h} \right) \frac{1 + \frac{\tilde{\epsilon}}{e + h + z}}{1 + \frac{\tilde{\epsilon}}{e + h}}.$$  

(31)

(32)

where $\Delta_2$ is essentially $C_0^{-1}$.

By the definitions of $C_0$ in equation (27) and the definitions of $A'$s in equation (29), we can
further show that

$$
\Delta_1 = \left[ 2 + \frac{e}{e+h+z} \left( 1 + \frac{e+h+z}{e+h+z} \right) + \frac{\frac{z}{e+h+z}}{2} \left( 2 + \frac{\frac{e+h+z}{e+h+z}}{2} \right) \right]^{1/2} + \frac{NH}{e+h} \left( \frac{1}{1 + e+h} \right). \tag{33}
$$

By equations (27), (28), (30) and (32), we have

$$
\beta_D = C_0/\lambda = \sigma_u e^{1/2} \Delta_1^{-1}. \tag{34}
$$

Then equations (27) and (28) give the expressions of $\beta_L$, $\alpha_L$, $\alpha_I$ and $\gamma$ and equations (33) and (32) give the expressions of $\Delta_1$ and $\Delta_2$ in Proposition 1.

A2 Proof of Proposition 2

A2.1 Expressions of the Profit Functions of Trader D and Other Informed Traders

Trader D's Profit. By the expression of $\tilde{x}_D^*$ in Proposition 1:

$$
\text{Var} (\tilde{x}_D^*) = \left( \frac{\beta_D (h+z)}{e+h+z} + \beta_L \right)^2 /e + \left( \frac{\beta_D h}{e+h+z} \right)^2 /h + \left( \frac{\beta_D z}{e+h+z} + \beta_L \right)^2 /z.
$$

Then by the expressions of $\beta_L$ and $\beta_D$ in equations (22) and (34), we have

$$
\text{Var} (\tilde{x}_D^*) = \sigma_u^2 \Delta_1 \left[ \left( \frac{h}{e+h+z} + \frac{4}{3} \frac{z}{e+h+z} \right)^2 + \left( \frac{h}{e+h+z} \right)^2 e/h + \left( \frac{4}{3} \frac{z}{e+h+z} \right)^2 e/z \right].
$$

Thus, by equation (9), the expected profit of trader D is:

$$
\pi_D (z, e, h, N) = \lambda \text{Var} (\tilde{x}_D^*) = \frac{\sigma_u S_D}{e^{1/2} \Delta_1 \Delta_2}, \tag{35}
$$

where

$$
S_D = \left( \frac{h}{e+h+z} + \frac{4}{3} \frac{z}{e+h+z} \right)^2 + \left( \frac{h}{e+h+z} \right)^2 e/h + \left( \frac{4}{3} \frac{z}{e+h+z} \right)^2 e/z. \tag{36}
$$

Other Informed's Profit. By the expression of $\tilde{x}_j^*$ in Proposition 1, we have

$$
\text{Var} (\tilde{x}_j^*) = \left( \frac{h}{e+h} \right)^2 (1/e + 1/h).
$$

By the expressions of $\gamma$ and $\beta_D$ in equations (25) and (34), we have

$$
\text{Var} (\tilde{x}_j^*) = \sigma_u^2 \Delta_1 \frac{h}{e+h} \left( \frac{1 + \frac{e}{e+h+z} + \frac{1}{3} \frac{e}{e+h+z}}{1 + \frac{e}{e+h}} \right)^2.
$$

Thus,

$$
\pi_j (z, e, h, N) = \lambda \text{Var} (\tilde{x}_j^*) = \frac{\sigma_u S_O}{e^{1/2} \Delta_1 \Delta_2}, \tag{37}
$$

where

$$
S_O = \frac{h}{e+h} \left( \frac{1 + \frac{e}{e+h+z} + \frac{1}{3} \frac{e}{e+h+z}}{1 + \frac{e}{e+h}} \right)^2. \tag{38}
$$
A2.2 Impact of Information Leakage

Impact on Trader $D$. By equation (35), taking derivative of $\log (\pi_D)$ with respect to $z$ (note that $S_D$, $\Delta_1$ and $\Delta_2$ are functions of $z$ by equations (36), (33) and (32)) yields:

$$\frac{\partial \log (\pi_D)}{\partial z} = \frac{\partial}{\partial z} \left[ \log \left( \sigma_w e^{-1/2} \right) + \log (S_D) - \log (\Delta_1) - \log (\Delta_2) \right]$$

$$= \frac{1}{S_D} \frac{\partial S_D}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z}.$$ 

Direct computations show

$$\frac{\partial S_D}{\partial z} = \left[ 2 \left( \frac{h}{e+h+z} + \frac{4}{3} \frac{z}{e+h+z} \right) \left( -\frac{h}{e+h+z} + \frac{4}{3} \frac{e+h}{e+h+z} \right) + 2 \left( \frac{e+h}{e+h+z} \right) \frac{e}{h} \left( -\frac{h}{e+h+z} \right)^2 \right]$$

$$\overset{\text{(39)}}{} + 2 \left( \frac{4}{3} \frac{z}{e+h+z} \right) \left( \frac{4}{3} \frac{e+h}{e+h+z} \right) \frac{e}{h} \left( -\frac{h}{e+h+z} \right)^2 - \frac{e}{z},$$

$$\frac{\partial \Delta_1}{\partial z} = \left[ -\frac{e}{(e+h+z)} \left( 1 + \frac{z}{e+h+z} \right) + \frac{e}{e+h+z} \left( \frac{h}{e+h+z} \right) \left( 2 + \frac{1}{3} \frac{e+h}{e+h+z} \right) \right]$$

$$\overset{\text{(40)}}{} + \frac{2}{3} \frac{e}{(e+h+z)} \left( \frac{e}{(e+h+z)} \right) \left( \frac{h}{e+h+z} \right) \left( -\frac{e}{(e+h+z)} \right)^2 + \frac{1}{3} \left( \frac{e}{e+h+z} \right) \left( -\frac{e}{(e+h+z)} \right)^2,$$

and

$$\frac{\partial \Delta_2}{\partial z} = \left[ \frac{h}{(e+h+z)^2} + \frac{N h}{e+h} \left( \frac{e}{(e+h+z)^2} + \frac{1}{3} \frac{e+h}{(e+h+z)^2} \right) \right].$$

Plugging the above derivative expressions and equations (36), (33) and (32) into the term of

$$\left[ \frac{1}{S_D} \frac{\partial S_D}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} \right],$$

we can show that

$$\frac{1}{S_D} \frac{\partial S_D}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z}$$

$$\overset{\text{(41)}}{} = \left[ \begin{array}{c}
108000 h^5 + 16659 h^5 e + 81408 z e^6 + 2079 N h^6 + 6372 h^5 z + 172515 h^2 e^4 \\
+ 144396 h^3 e^3 + 67446 h^4 e^2 + 79872 z e^6 + 26112 z^3 e^3 + 540 N h^6 e^4 \\
+ 3264 h^3 z^3 + 7920 h^5 z^2 + 27648 z^3 + 1701 h^6 + 1728 N h^5 z^2 + 5616 N h^5 e^3 \\
+ 6480 N h^3 e^3 + 154944 h^3 z^2 e^2 + 1124 N h^3 z^2 + 2496 N h^2 z^2 e + 13824 N h e^5 \\
+ 15741 N h e^6 + 252000 z e^6 + 54468 h^4 z e^3 + 774 N h^5 z + 49464 N h^2 z^2 e^4 \\
+ 68796 h^3 z^3 e + 46926 h^5 z^2 e + 3132 N h z^3 e^3 + 8316 N h z^2 e^3 + 39169 z^2 e^3 \\
+ 8316 N h^3 z^3 e + 3132 N h^3 z^3 e^3 + 8316 N h z^2 e^3 + 39169 z^2 e^3 \\
+ 9552 N h^3 z^3 + 2016 N h^3 z^3 e^3 + 4608 N h^3 z^3 e^2 + 1024 N h^3 z^3 e^2 \\
+ 10944 N h^3 z^3 e^2 + 6336 N h^3 z^3 e^2 + 38784 N h z^3 e^4 + 47652 N h z^3 e^2 \\
+ 8340 N h^3 z^3 e^2 + 35968 N h z^3 e^2 + 11008 N h z^3 e^2 + 106416 N h z^3 e^2 \\
+ 131312 N h^3 z^3 e^2 + 107856 N h^3 z^3 e^2 + 45472 N h^3 z^3 e^2 + 8352 N h^3 z^3 e^2 \\
\end{array} \right]$$

$$2 e$$

$$= \left[ \begin{array}{c}
(9 h e + 16 e + 24 h z + 9 h^2 + 16 z^2) \times \\
(3 N h^2 + 30 h e + 24 e + 12 h z + 24 h^2 e + 9 h^2 + 6 N h e + 4 N h z) \times \\
32 h^3 e^3 + 117 h^3 e^3 + 272 z e^3 + 9 N h^4 + 48 h^3 z + 288 h^2 e^2 + 128 z e^2 \\
+ 32 h^2 e^2 + 144 e^4 + 36 N h^3 e + 45 N h^3 e + 464 h^2 z e + 128 z e^2 \\
+ 260 h^2 z e + 24 N h^3 z + 72 N h^2 z^2 + 16 h^2 z^2 + 48 N h z^2 + 16 N h z^2 + 72 N h^2 z e \\
\end{array} \right]$$

which is positive. Thus, we have

$$\frac{\partial \pi_D (z,e,h,N)}{\partial z} > 0.$$
**Impact on the Other Informed Trader j.** By equation (37),
\[
\frac{\partial \log (\pi_j)}{\partial z} = \frac{\partial}{\partial z} \left[ \log \left( \sigma_u e^{-1/2} \right) + \log (S_O) - \log (\Delta_1) - \log (\Delta_2) \right] = \frac{1}{S_O} \frac{\partial S_O}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z}.
\]
Take derivative of \( S_O \) with respect to \( z \), we have
\[
\frac{\partial S_O}{\partial z} = 2 \left( 1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z} \right) \left( -\frac{e}{(e + h + z)^2} + \frac{1}{3} \frac{e + h}{(e + h + z)^2} \right) \frac{h}{e + h} \left( 1 + \frac{e}{e + h} \right)^{-2}.
\]
Plugging equations (40), (41), (42), (33) and (32) into \( \left[ \frac{1}{S_O} \frac{\partial S_O}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} \right] \), we have
\[
\frac{1}{S_O} \frac{\partial S_O}{\partial z} - \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} = \frac{2e (h + 2e)}{(3h + 4e + 6e)} \times \left( \begin{array}{c}
7992he^3 + 3258he^3 + 6048ze^3 + 207Nh^4 + 1224h^4z \\
+7668he^3 + 2880ze^3 + 720h^2z^2 + 3168e^4 + 513h^4 \\
+792Nh^4 + 1026Nh^4 + 10944hze^2 + 2880hz^2e \\
+6408h^2ze + 504Nh^2z^2 + 1620Nh^2e^2 + 304Nh^2z^2 \\
+1152Nhze^2 + 416Nh^2ze + 1584Nh^2ze
\end{array} \right)
\]
which is negative. Thus,
\[
\frac{\partial \pi_j (z, e, h, N)}{\partial z} < 0,
\]
for \( j = 1, ..., N \).

**A3 Proof of Proposition 3**

Plugging in the expressions of \( \alpha_L \) and \( \alpha_I \) in equations (23) and (24) and the expression of \( \beta_D \) in equation (34), we have
\[
\text{Var}(\bar{x}_I^*) = (\alpha_I + \alpha_L)^2/e + \alpha_L^2/z
\]
\[
= \frac{\sigma_u^2}{\Delta_1^2} \left[ \left( 1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z} \right)^2 + \left( \frac{2}{3} \frac{z}{e + h + z} \right)^2 \frac{e}{z} \right].
\]
Thus, by equation (30),
\[
\pi_I (z, e, h, N) = \lambda \text{Var}(\bar{x}_I^*) = \frac{\sigma_u S_I}{e^{1/2} \Delta_1 \Delta_2},
\]
where
\[
S_I = \left( 1 + \frac{e}{e + h + z} + \frac{1}{3} \frac{z}{e + h + z} \right)^2 + \left( \frac{2}{3} \frac{z}{e + h + z} \right)^2 \frac{e}{z}.
\]
Therefore,
\[
\frac{\partial \log (\pi_I)}{\partial z} = \frac{1}{S_I} \frac{\partial S_I}{\partial z} - \frac{\partial \Delta_1}{\Delta_1} - \frac{\partial \Delta_2}{\Delta_2}.
\]

Direct computation shows that
\[
\frac{\partial S_I}{\partial z} = \left[ 2 \left( 1 + \frac{e}{e+h+z} + \frac{1}{3(e+h+z)^2} \left( \frac{e}{e+h+z} + \frac{1}{3(e+h+z)^2} \right) \right) + 2 \left( \frac{2}{3(e+h+z)} \right) \left( \frac{2}{3(e+h+z)^2} \right) \frac{h}{z} + \left( \frac{2}{3(e+h+z)^2} \right) \left( -\frac{h}{z} \right) \right] \right].
\]

So, evaluating \( S_I, \Delta_1, \Delta_2, \frac{\partial S_I}{\partial z}, \frac{\partial \Delta_1}{\partial z} \) and \( \frac{\partial \Delta_2}{\partial z} \) at \( z = 0 \) in equations (44), (33), (32), (45), (40) and (41), and then plugging them into \( \left[ \frac{1}{S_I} \frac{\partial S_I}{\partial z} - \frac{\partial \Delta_1}{\Delta_1} - \frac{\partial \Delta_2}{\Delta_2} \right] \), we have
\[
\left[ \frac{1}{S_I} \frac{\partial S_I}{\partial z} - \frac{\partial \Delta_1}{\Delta_1} - \frac{\partial \Delta_2}{\Delta_2} \right] \bigg|_{z=0} = \frac{2 \left( \frac{h}{e} \right)^3 + N^2 \left( \frac{h}{e} \right)^2}{N^2 - \left[ 13 \left( \frac{h}{e} \right)^3 + 44 \left( \frac{h}{e} \right)^2 + 28 \frac{h}{e} \right] N - \left[ 45 \left( \frac{h}{e} \right)^3 + 202 \left( \frac{h}{e} \right)^2 + 292 \frac{h}{e} + 144 \right]} \frac{(9/2) e^{-4(h+2e)^2}(3h+4e+Nh)(Nh^2+5he+4e^2+1+2h^2+Nhe)}{(9/2) e^{-4(h+2e)^2}(3h+4e+Nh)(Nh^2+5he+4e^2+1+2h^2+Nhe)}
\]

The denominator of the above equation is positive, but the sign of the numerator is ambiguous. Define the numerator as
\[
F(N, \frac{h}{e}) \triangleq 2 \left( \frac{h}{e} \right)^3 + N^2 \left( \frac{h}{e} \right)^2 - \left[ 13 \left( \frac{h}{e} \right)^3 + 44 \left( \frac{h}{e} \right)^2 + 28 \frac{h}{e} \right] N - \left[ 45 \left( \frac{h}{e} \right)^3 + 202 \left( \frac{h}{e} \right)^2 + 292 \frac{h}{e} + 144 \right] .
\]

If we treat \( \frac{h}{e} \) as a parameter, then \( F(N, \frac{h}{e}) \) is a quadratic function of \( N \). In order to determine the sign of \( F(N, \frac{h}{e}) \), we need to calculate the root of \( N \) in the equation of \( F(N, \frac{h}{e}) = 0 \).

Setting \( F(N, \frac{h}{e}) = 0 \), we find that the unique positive root of \( N \) as a function of \( \frac{h}{e} \) is:
\[
\tilde{N} \left( \frac{h}{e} \right) \triangleq \frac{\left[ 13 \left( \frac{h}{e} \right)^3 + 44 \left( \frac{h}{e} \right)^2 + 28 \frac{h}{e} \right] + \sqrt{4 \left[ 2 \left( \frac{h}{e} \right)^3 + 2 \left( \frac{h}{e} \right)^2 \right] \left[ 13 \left( \frac{h}{e} \right)^3 + 44 \left( \frac{h}{e} \right)^2 + 28 \frac{h}{e} \right]^2 + 2 \left[ 2 \left( \frac{h}{e} \right)^3 + 2 \left( \frac{h}{e} \right)^2 \right] \left[ 529 \left( \frac{h}{e} \right)^6 + 2004 \left( \frac{h}{e} \right)^5 + 484 \right]}}{2 \left[ 2 \left( \frac{h}{e} \right)^3 + 2 \left( \frac{h}{e} \right)^2 \right]}. \]

By factoring the term under the square root, we can further simplify \( \tilde{N} \left( \frac{h}{e} \right) \) as:
\[
\tilde{N} \left( \frac{h}{e} \right) = \frac{13 \left( \frac{h}{e} \right)^2 + 44 \left( \frac{h}{e} \right) + 28}{4 \left( \frac{h}{e} \right)^3 + 4 \left( \frac{h}{e} \right)^2 + 1004 \left( \frac{h}{e} \right) + 529}. \]

Thus, \( F(N, \frac{h}{e}) > 0 \) if and only if \( N > \tilde{N} \left( \frac{h}{e} \right) \); that is, \( \left. \frac{\partial \pi_I(z,e,h,N)}{\partial z} \right|_{z=0} > 0 \) if and only if \( N > \tilde{N} \left( \frac{h}{e} \right) \).

In addition, we can show that the function \( \tilde{N} \left( \frac{h}{e} \right) \) is decreasing in \( \left( \frac{h}{e} \right) \), because direct computation shows that the first order derivative of the function \( \tilde{N} \left( z \right) = \frac{13z^2+44z+28}{4z^3+4z^2+1004z+529} \)
\[ \hat{N} (x) = \frac{\left( (26x + 44) + \sqrt{529x^2 + 1004x + 484} + (x + 2) \frac{2x \sqrt{529x^2 + 1004x + 484} + 1004}{2 \sqrt{529x^2 + 1004x + 484}} \right) 4x (x + 1)}{\left( (13x^2 + 44x + 28) + (x + 2) \sqrt{529x^2 + 1004x + 484} \right) 4 (2x + 1)} \]

\[ = \frac{1}{4} \left[ \frac{2940x + 56x \sqrt{1004x + 529x^2 + 484} + 31x^2 \sqrt{1004x + 529x^2 + 484} + 28 \sqrt{1004x + 529x^2 + 484} + 2994x^2 + 1031x^3 + 968}{x^2 (x + 1)^2 \sqrt{1004x + 529x^2 + 484}} \right] < 0. \]

**A4 Proof of Proposition 4**

By equation (30), \( \lambda = \frac{\Delta_1}{\sigma w^{1/3} \Delta_2} \). Thus,

\[ \frac{\partial \log (\lambda)}{\partial z} = \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z}. \]

Evaluating \( \Delta_1, \Delta_2, \frac{\partial \Delta_1}{\partial z} \) and \( \frac{\partial \Delta_2}{\partial z} \) at \( z = 0 \) in equations (33), (32), (40) and (41), respectively, and then plugging those values into the expression of \( \left[ \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} \right] \), we have

\[ \left[ \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} \right]_{z=0} = \frac{2}{9 N^2 h^3 + 9 N^2 h^2 + 5 N h^3 + 12 e N h^2 + 8 e^2 N h + 6 h^3 + 23 e h^2 + 32 e^2 h + 16 e^3} \cdot (N h - 9 h + 4 e) \]

Thus, \( \frac{\partial \lambda}{\partial z} \bigg|_{z=0} < 0 \) (i.e., \( \frac{\partial \log(\lambda)}{\partial z} \bigg|_{z=0} = \left[ \frac{1}{\Delta_1} \frac{\partial \Delta_1}{\partial z} - \frac{1}{\Delta_2} \frac{\partial \Delta_2}{\partial z} \right]_{z=0} < 0 \)) if and only if

\[ N h - 9 h + 4 e < 0 \iff N > 9 - 4 (h/e)^{-1}. \] (49)

By equation (48):

\[ \hat{N} \left( \frac{h}{e} \right) = \frac{\left[ 13 (h/e)^2 + 44 (h/e) + 28 \right] + (h/e + 2) \sqrt{529 (h/e)^2 + 1004 (h/e) + 484}}{4 (h/e) (h/e + 1)} \]

\[ > \frac{13 (h/e) (h/e + 1) + \sqrt{529 (h/e) (h/e + 1)}}{4 (h/e) (h/e + 1)} = 9 > 9 - 4 (h/e)^{-1}. \]

So, if \( N > \hat{N} \), then \( \frac{\partial \lambda}{\partial z} \bigg|_{z=0} < 0. \)
Figure 1 The Region of Rational Information Leakage

This figure uses "+" to indicate the region for which the number of other informed traders $N$ exceeds the threshold value $\tilde{N}(h/e)$, which is a function of the other informed trader's signal-to-noise ratio $(h/e)$. The solid curve is identified as "information leakage frontier".
Figure 2 Insider's Profit v.s. Information Leakage

(a) \( N=10 \)

(b) \( N=50 \)

This figure shows the implications of information leakage for the insider's profit when the number of the other informed traders takes a value of 10 (Panel (a)) or 50 (Panel (b)). The other parameter values are \( e = h = \sigma_u = 1 \).