Buy on Rumors - Sell on News

Markus K. Brunnermeier *
Princeton University †

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Abstract

This paper shows that a trader who receives a leaked signal prior to a public announcement can exploit this private information twice. First, when he receives his signal, and second, at the time of the public announcement. The second round advantage occurs because the early-informed trader can best infer the extent to which his information is already reflected in the current price. We also show that he speculates by building up a position in period one, which he partially unwinds 'on average' in period two. In addition, he trades very aggressively when he receives his signal. He tries to manipulate the price in order to enhance his informational advantage at the time of the public announcement. We also find that information leakage reduces the long-run information efficiency of the price process. Hence, the analysis provides strong support for SEC's Regulation FD.

JEL Classification: D82, D83, D84, G12, G13, G14

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†Princeton University, Bendheim Center for Finance, 26 Prospect Avenue, Princeton, NJ 08540-5296, Tel. (609) 258 4050, e-mail: markus@princeton.edu, http://www.princeton.edu/~markus.

1 Introduction

In a perfect world, all investors would receive information pertinent to the value of the stock immediately and simultaneously. In reality, however, some agents like corporate insiders and their favored analysts can receive signals about this information before it is disclosed to the general public. The focus of our analysis is to determine (i) the optimal trading strategy of an early-informed agent and (ii) the implications of this trading behavior for the informational efficiency of the stock market. This knowledge can facilitate the design and evaluation of trading regulations by the Securities and Exchange Commission (SEC).

Our model generates several novel insights on insider trading by enriching the information structure typically employed in the prior literature. In our analysis, a trader receives an early imprecise signal about a forthcoming news announcement - possibly in a form of a rumor. The new element is that the stock price reflects unrelated *long-run* private information held by another traders as well as the early-informed trader's *short-run* signal. Given this generalized information structure, we find that the short-run information agent's trading strategy exhibits three features: (i) he can exploit his private information twice, once before the public announcement and a second time after it; (ii) he trades for speculative reasons, that is, he intends to unwind the acquired position after the public announcement because he predicts that the market will overreact to the news; and (iii) he engages in a special form of market manipulation. We also show that information leakage reduces the informational efficiency of the price process after the public announcement.

Not only is this trading behavior interesting from a theoretical viewpoint, it also matches with events documented in the press. For example, the New York Times had this to say about the price movement of BJ Services, an oil and gas company, prior to a negative public earnings announcement in August 1993:

> *"Sell on the rumor, buy on the news.*[1] *That's Wall Street's advice for individual investors. But the pros have a different refrain: sell when company officials tell you the news, buy when they tell everyone else." ...*

The article notes that the company disclosed some information to selected analysts prior to the official announcement of weak earnings. The stock price tumbled because of their subsequent aggressive selling. After the actual earnings announcement, these analysts bought back shares, thereby stabilizing the stock price.

[1] Note that the title of the paper refers to positive rumors (news) while the quote refers to negative rumors (news).

The intuition behind the early-informed agent's trading strategy is as follows. Traders employ technical analysis after the public announcement to determine the extent to which the news is already "priced in". That is, they try to learn this information from past price movements. The early informed trader's technical analysis is more informative than the other traders' analyses since he knows the exact extent to which he has moved the past price. This provides him an additional informational advantage even after the public announcement. This is in spite of the fact that the public announcement is more precise than his original private signal. Paradoxically, it is the imprecision of the early-informed trader's signal that induces the uninformed market participants to make an error in their technical analyses, thereby giving him an informational advantage even after the public announcement.

In addition to showing that an analyst with short-run information can exploit his information twice, we demonstrate that he also trades for speculative reasons. After receiving a positive (negative) imprecise signal, the early-informed trader buys (sells) stocks that he expects to sell (buy) at the time of the public announcement. In other words, he follows the well known trading strategy: "Buy on Rumors - Sell on News." This trade reversal relies on the fact that given his information he expects that the market will overreact to the news announcement. Hence, this explanation has conceptually distinct roots from those typically discussed in the prior literature.

Our analysis also introduces a novel form of trade-based price manipulation. We define manipulative trading as active trading with the intention of moving the price such that the informational advantage is enhanced at a later time. The early-informed trader's future capital gains result from correcting the other market participants' error in technical analysis. If a short-run information trader trades very aggressively prior to the public announcement, his private signal's imprecision has a larger impact on the current price. This imprecision makes it harder for the other market participants to infer other relevant information from past prices after the public announcement. Hence, by trading more aggressively in the first trading round, the early-informed trader increases his expected future capital gains in later trading rounds. Put more bluntly, he generates a larger informational advantage by 'throwing sand in the eyes' of the other traders. The novelty of manipulative trading in our setting is that its purpose is not to keep the manipulator's own information secret but to prevent others from inferring each others information from past prices while retaining one's own ability to do so. This manipulative trading behavior is also in sharp contrast to Kyle (1985) where the insider trades less aggressively today in order to save his informational advantage for future trading rounds. In our setting, the insider trades more aggressively now in order to enhance his future informational advantage. Therefore, the optimal trading strategy could more appropriately be called "Trade 'Aggressively' on Rumors - Unwind on News".

The paper also analyzes how early selective disclosure affects the information revelation role of prices. We draw a distinction between two concepts of information revelation: "information efficiency" and "informativeness." While the former refers to the information content of the price relative to the pooled information in the economy, the latter measures how informative the price process is in an absolute sense. Our analysis shows that an information leak makes the price process less informationally efficient both before and after the general public announcement. We also find that there is a short-term gain in informativeness prior to the public announcement, but it comes at the cost of less informative prices in the long-run. The previous literature uses a less general information structure which abstracts from this long-run impact on informativeness.

Our analysis also has important policy implications. SEC recently introduced Regulation Fair Disclosure (FD) to combat selective disclosure which occurs when companies release material information to selected securities analysts or institutional investors before disclosing the information to the general public. Regulation FD forces companies to make information - which merit a public announcement - public simultaneously to all investors. While opponents argue that this regulation leads to higher volatility, proponents predict exactly the opposite and argue that selective disclosure undermines the integrity of financial markets. There are many facets to how Regulation FD affects the stock price process and its information efficiency.[2] In this paper we abstract from the more apparent incentive effects, which beg for an empirical quantification. Instead, we focus on the impact of an early-informed agent's trading on informational efficiency. We take it as given that he will receive some signal early. As pointed out above, our model predicts that selective disclosure reduces informational efficiency and hurts the long-run informativeness of the price process. Less informative prices postpone uncertainty resolution and increase future volatility. This makes it harder for firms to raise more capital. If one takes into account the fact that most information leaks occur only a few days prior to official news announcements, this long-run disadvantage could outweigh any short-run gain since capital is seldom raised a few days prior to major earnings announcements.

[2]Regulation FD affects the incentives of companies to release information as well as analysts' incentives to seek it. Opponents of Regulation FD assert that companies will release less information for fear of litigation. This so-called "chilling effect" also provides CEOs an excuse to hide information. Proponents highlight the positive incentive implications for analysts. Without Regulation FD, analysts have a desire to remain in good standing with a company in order to receive advanced private briefings. Therefore, they have an incentive to 'schmooze' rather than to conduct sound fundamental analysis about the company's prospects. They are also very reluctant to disclose negative information. This "schmooze effect" reduces the informativeness of the price process and undermines the monitoring role of analysts. Advocates of Regulation FD also argue that new communication media like the internet have reduced the information dissemination role of analysts.

In addition, we find that the early informed agent's optimal trading strategy involves buying and selling shares before and after public announcements. Thus, our analysis also provides new support for the Short Swing Rule (Rule 16b of the Securities Exchange Act (SEA)). The Short Swing Rule prohibits corporate insiders from buying and selling the same shares within a period of six months.

The empirical implications for the price process of our model are the following. First, prices follow a martingale process conditional on public information. However, from the viewpoint of an the short-run information trader, the price overshoots at the time of the news announcement. Second, as one would expect, an information leak increases the price volatility prior to public announcements and lowers the price jump at the day of the news announcement. The novelty of our analysis is that selective disclosure also increases the price volatility *after* the public announcement. Thus, our model predicts that the introduction of Regulation FD will reduce the volatility of prices after public announcements.

The remainder of the paper is organized as follows. The related literature is described in Section 2. Section 3 outlines the model. It shows that an early-informed trader still has an informational advantage at the time of the public announcement and that he trades for speculative as well as manipulative reasons. The impact of information leakage on informational efficiency is illustrated in Section 4. Section 5 extends the analysis to address mixed strategies and optimal signal precision. Conclusions and topics for future research are presented in Section 6.

2 Related Literature

Our analysis builds on the prior literature on technical analysis, speculation, manipulation and insider trading in several important ways. The prior literature on *technical analysis*, such as Brown and Jennings (1989) and Grundy and McNichols (1989), analyzes the inference of information from past prices in a competitive rational expectations model setup. Since public announcements affect all traders symmetrically in these models, no individual trader can gain an informational advantage over the other traders. In contrast, in our model the early informed trader enjoys a larger informational advantage even after the public announcement due to his superior ability to interpret the past price. Treynor and Ferguson (1985) demonstrate the usefulness of technical analysis in a setting where a trader does not know whether his information is already reflected in the current stock price. Our model provides a micro foundation for Treynor and Ferguson's reasoning and demonstrates that it only works if the price before the public announcement also reflects information other than the information related to the public announcement. Blume, Easley, and O'Hara (1994) demonstrate that traders can also infer valuable information from past volume data in a setting where the precision of traders' signals is unknown. While in our model traders do not infer information from trading volume, the analysis would not change if they could observe past net order flow in addition to past prices.

Hirshleifer, Subrahmanyam, and Titman (1994) also generate *speculative trading* wherein risk averse insiders unwind part of their risky position as soon as their private information is revealed to a larger group of traders. However, in their model speculation would not occur without risk aversion. In contrast, in our model, the insider speculates even though he is risk neutral. Therefore, our model provides a conceptually distinct explanation for speculative behavior: the insider partially unloads his position due to informational reasons and not due to risk aversion.

The prior literature on *manipulation* distinguishes between trade-based, information-based and action-based stock price manipulation (Allen and Gale 1992). Our model falls in the class of trade-based manipulation models.[3] One form of trade-based manipulation is due to differences in market liquidity. Kumar and Seppi (1992) illustrate price manipulation if futures are settled by cash rather than by physical delivery. The intuition is that 'cash settlement' acts as an infinitely liquid market in which pre-existing futures positions are closed out relative to the less liquid spot market. In Allen and Gorton (1992) trade-based manipulation is possible since buy orders are more likely to be from informed traders than sell orders. Therefore, the market is less liquid for upswings than for downturns. Unlike these papers, manipulation in our model is not driven by differences in liquidity but by the desire to generate a future informational advantage.

Allen and Gale (1992) illustrate manipulation due to informational considerations in a setting with higher order uncertainty. In their model, all traders are price takers except for one large trader, who is either an informed trader or an uninformed manipulator. His information set includes two dimensions: the actual information and knowledge that he is informed. The authors show that if the large trader is uninformed, he *still* acts as if he has received good news. This pretense helps him drive up the price. This is optimal in Allen and Gale (1992) because there is asymmetry in the timing of good and bad news announcements. Chakraborty (1997) also illustrate manipulation by a potentially informed insider in a generalized Easley and O'Hara (1987,1992) set-

[3] Information-based and action-based manipulation are more distant from the current analysis because they are not directly caused by trading activity. Information-based manipulation involves the spreading of false rumors to manipulate the price (Vila (1989), Benabou and Laroque (1992)), while action-based manipulation occurs when corporate insiders entangle corporate decisions with their private stock market activities.

ting that includes less informed followers who receive an imprecise signal of whether the insider is informed.

A related branch of literature looks at manipulative trading induced by the introduction of a mandatory disclosure rule for insider trading activities. Fishman and Hagerty (1995) initiated this line of research by showing that the mandatory disclosure of individual trading activities under Rule 16a of the SEA can lead to manipulative trading by uninformed insiders. John and Narayanan (1997) extend their analysis by showing that even an informed trader can manipulate the market if good and bad news do not occur with equal probability. More recently, Huddart, Hughes, and Levine (2001) analyze the introduction of the mandatory disclosure rule within a Kyle (1985) framework. While in their model the insider applies a mixed strategy in order to make it more difficult for the market maker to infer *his* information, in our model the early-informed trader trades more aggressively on his imprecise signal with the intention to make it harder for others to learn *somebody else's* information from the past price movements. Section 5.1 further contrasts both models and explains why mixed strategies cannot arise in our setting with multiple informed traders.

In all these models, the potential manipulator is endowed with superior information, even if it is only information about whether he is informed or not. He manipulates the price in order to hide his own information or lack of information. The manipulation that arises in our model is conceptually different. In our setting, it is common knowledge that an early-informed insider has received a noisy signal about the forthcoming announcement. The novelty of our form of manipulation is that the insider can still manipulate the price in order to make it harder for others to conduct technical analysis, while maintaining his own ability to infer information from past price. Thus, he jams the signal of others as in the signalling jamming industrial organization literature (Fudenberg and Tirole 1986). Furthermore, in contrast to most of the prior models in the finance literature, manipulative trading in our model is derived without the imposition of any restriction on the traders' order size. That is, the insider's strategy space is richer than in other models rooted in the framework of Glosten and Milgrom (1985).

Other normative papers in the literature address the question of how insider trading affects the *information revelation* role of prices. Leland (1992) argues that insider trading makes prices more informative, moves forward the resolution of uncertainty, and hence reduces future volatility and makes it possible to finance more investment projects. Fishman and Hagerty (1992) endogenize the information acquisition process. In their model, trading by corporate insiders discourages analysts from collecting information, which can lead to less informative prices. In Ausubel (1990) insider trading reduces the initial ex-ante investment by the traders and can lead to a Pareto-inferior outcome. In all these models, there is only one trading round. Hence, informational efficiency after the public announcement cannot be analyzed in these models. Thus, our paper contributes to the literature by analyzing the long-run impact of insider trading on the informational efficiency of prices.

3 Analysis

3.1 Model Setup

There are two assets in the economy: a risky stock and a risk-free bond. For simplicity we normalize the interest rate of the bond to zero. Market participants include risk-neutral informed traders, liquidity traders and a market maker. The informed traders' sole motive for trading is to exploit their superior information about the fundamental value of the stock. Liquidity traders buy or sell shares for reasons exogenous to the model. Their demand typically stems from information which is not of common interest, such as from their need to hedge against endowment shocks or private investment opportunities in an incomplete market setting.[4] A single competitive risk-neutral market maker observes the aggregate order flow and sets the price. Traders submit their market orders to the market maker in two consecutive trading rounds taking into account the price impact of their orders. The market maker sets the price in each round after observing the aggregate order flow and trades the market clearing quantities. As in Kyle (1985) the market maker is assumed to set semi-strong informationally efficient prices; thus his expected profit is zero. The underlying Bertrand competition with potential rival market makers is not explicitly modelled in this analysis.[5] Analysts receive private information related and unrelated to the forthcoming public announcement before trading begins in $t = 1$. The public announcement occurs prior to trading in $t = 2$. The timeline in Figure 1 illustrates the sequence of moves.

[4] See Brunnermeier (2001) or O'Hara (1995) for a detailed discussion of the different reasons why liquidity traders trade, and for a discussion on the distinction between information of common versus private interest.

[5] Alternatively, one could also employ a setting where many competitive risk-neutral traders like scalpers, floor brokers etc. submit limit order schedules. The analysis would be formally identical and the price would be determined by market clearing. Therefore, when we speak of the information set of 'market participants' we are referring to the information set of the single market maker in our formal analysis.

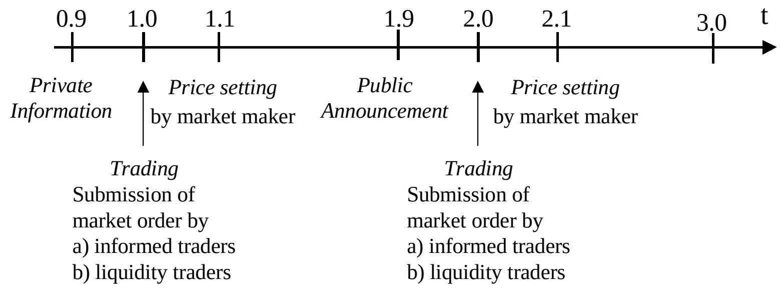

Figure 1: Timeline

Traders face a price risk submitting market orders since they do not know the price at which their trade will be executed. In contrast, limit orders allow the trader to specify a price at which the order will be executed. Traders can create demand schedules which allow them to trade conditionally on the current price by combining many limit and stop orders. Unfortunately, limit order models make the analysis less tractable without adding any significant insight. Therefore, we opt for a market order setting similar to Kyle (1985), Admati and Pfleiderer (1988) and Foster and Viswanathan (1996).

Public announcements about earnings, a major contract with a new client, a legal allegation, a new CEO, macroeconomic news etc. can have a significant impact on the market value of a stock. However, such announcements reflect only part of the relevant information pertinent to the value of the stock. In order to gain a complete picture of the long-run future prospects of a company, one has to study its business model and gather a lot of information unrelated to the announcement. The ideal role of analysts is to collect this long-run information, analyze it, and translate it into the stock market value.[6] The liquidation value of the stock in our model is the sum of two random variables $v = s + l$. The random variable s refers to the *short-run* information which will be publicly announced at $t = 2$, while l reflects the *long-run* information about the company not related to the forthcoming public announcement. In our model l is only made public at the end of the trading game at $t = 3$. This long-run information l is dispersed among many traders in the economy. In particular, we assume that each long-run information traders L_i of I traders receives a signal $\frac{1}{I}l_i$. The sum of all $\frac{1}{I}l_i$ is l. The variance of each individual l_i is set equal to I, which normalizes the variance of l to $Var\left[\frac{1}{I}\sum_{i=1}^{I} l_i\right] = 1$.

[6]Note that Regulation FD does not prevent analysts from soliciting information that does not merit a public announcement. These pieces of information are more like mosaics which allow a skilled analyst to form a more informative picture about the long-run prospects of a company's business model than a tip off prior to a forthcoming news announcement.

In addition to analyzing long-run information captured by l there is also a trader or analyst S who "schmoozes" the CEO and tries to receive an early signal about the forthcoming information in $t=2$. The company leaks a noisy signal of next period's public news $s+\varepsilon$ - possibly in the form of a rumor - to short-run information analyst S prior to trading round $t=1$. Liquidity traders do not receive any information and their aggregate trading activity is summarized by the random variables u_1 in period one and u_2 in period two.

The information structure is summarized in the following table.

Player	Period $t=1$	Period $t=2$	Period $t=3$
Market maker	X_1	s, p_1, X_2	l, p_2
Trader S	$s+\varepsilon$	s, p_1	l, p_2
Trader L_1 ... Trader L_i ... Trader L_I	$\frac{1}{I} l_i$	s, p_1	l, p_2

Table 1: Information Structure

where $X_1 = x_1^S + \sum_{i=1}^{I} x_1^{L_i} + u_1$ is the aggregate order flow in $t=1$ and $X_2 = x_2^S + \sum_{i=1}^{I} x_2^{L_i} + u_2$ is the order flow in $t=2$. All informed traders submit their market orders, x_t^i, to the market maker in each trading round. The random variables s, l, ε, u_1 and u_2 are independently normally distributed with mean zero. Let $\Sigma = Var[s]$, $\sigma_{u1}^2 = Var[u_1]$, $\sigma_{u2}^2 = Var[u_2]$ and $\sigma_\varepsilon^2 = Var[\varepsilon]$.

This information structure is common knowledge among all market participants, i.e. we assume that everybody knows that the short-run information trader S has received some noisy information about a forthcoming public announcement. However, they do not know the content of his short-run information.[7] Note also that informed traders' information sets do not stochastically dominate each other. In other words, the information sets are non-hierarchical or non-nested.

[7] This problem can also be captured in a model with higher order uncertainty, i.e. information leakage occurs only with a certain probability. In that case, the short-run information trader S receives two pieces of information. In addition to the actual signal, he knows whether some information has leaked or not. The short-run information trader's informational advantage at the time of the public announcement in $t=2$ stems from his knowledge of whether he had received an early signal or not. Such models are not pursued in this paper because they are very intractable without restricting the trading size.

In period two, each trader knows not only his signal, the price p_1 and the public information s but also his demand in $t = 1$, x_1. The risk-neutral market maker sets the execution price p_t after observing the aggregate net order flow. The price is semi-strong informationally efficient, i.e. the price is the best estimate given the market maker's information. Any different price would lead to an expected loss or an expected profit for the market maker. The latter is ruled out because the market maker faces Bertrand competition from potential rival market makers. For ease of exposition, the strategy for the market maker is exogenously specified. He has to set informationally efficient prices in equilibrium, i.e. $p_1 = E[v|X_1]$ and $p_2 = E[v|X_1, s, X_2]$ due to potential Bertrand competition.

A sequentially rational Bayesian Nash Equilibrium of this trading game is given by a strategy profile $\{x_1^S, x_2^S, \{x_1^{L_i,*}(\cdot), x_2^{L_i,*}(\cdot)\}_{i=\{1,\dots,I\}}, p_1^*(\cdot), p_2^*(\cdot)\}$ such that

(1) $x_2^{S,*} \in \arg\max_{x_2^S} E[x_2^S(v - p_2)|s + \varepsilon, x_1^S, p_1, s]$
$x_2^{L_i,*} \in \arg\max_{x_2^{L_i}} E[x_2^{L_i}(v - p_2)|\frac{1}{I}l_i, x_1^{L_i}, p_1, s] \quad \forall i \in \{1, ..., I\}$

(2) $x_1^{S,*} \in \arg\max_{x_1^S} E[x_1^S(v - p_1)|s + \varepsilon]$
$x_1^{L_i,*} \in \arg\max_{x_1^{L_i}} E[x_1^{L_i}(v - p_1)|\frac{1}{I}l_i] \quad \forall i \in \{1, ..., I\}$

(3) prices $p_1^* = E[v|X_1^*]$ and $p_2^* = E[v|X_1^*, s, X_2^*]$,

where the conditional expectations are derived using Bayes' Rule to ensure that the beliefs are consistent with the equilibrium strategy.

3.2 Characterization of Linear Equilibrium

Proposition 1 characterizes a sequentially rational Bayesian Equilibrium in linear pure strategies. It has the elegant feature that each trader's demand is the product of his trading intensity (or aggressiveness) and the difference in the trader's and market maker's expectations about the value of the stock, the trader's informational advantage. Linear strategies have the advantage that all random variables remain normally distributed. In addition, the pricing rules are linear as a consequence of the Projection Theorem. In period one the market maker's pricing rule is $p_1 = \lambda_1 X_1$ and in period two it is $p_2 = s + E[l|X_1, s] + \lambda_2 \{X_2 - E[X_2|X_1, s]\}$ in equilibrium. As in Kyle (1985) λ_t reflects the price impact of an increase in market order by one unit. This price impact restricts the trader's optimal order size. Kyle (1985) interprets the reciprocal of λ_t as market depth. If the market is very liquid, i.e. λ_t is very low, then an increase in the trader's demand only has a small impact on the stock price. The equilibrium is derived in Appendix A.1 for any number of long-run information traders. For expositional clarity, Proposition 1 and the following results focus on the equilibrium for the limiting case where I goes to infinity. That is, information about l is dispersed among infinitely many traders.

Proposition 1 *A sequentially rational Bayesian Nash Equilibrium in which all pure trading strategies are of the* ***linear*** *form*

$$x_1^S = \beta_1^S (s+\varepsilon) \qquad x_1^L = \beta_1^L \left(\tfrac{1}{I} l_i\right)$$

$$x_2^S = \alpha^S T + \beta_2^S \left(l + \tfrac{1}{\beta_1^L} u_1\right) \qquad x_2^L = \alpha^L T + \beta_2^L \left(\tfrac{1}{I} l_i\right)$$

and the market maker's pricing rule is of the linear form

$$p_1 = E[v|X_1] = \lambda_1 X_1,$$

$$p_2 = E[v|X_1, s, X_2] = s + \frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2} T + \lambda_2 \left\{X_2 - E\left[X_2|X_1, s\right]\right\},$$

with $T = \frac{X_1 - \beta_1^S s}{\beta_1^L}$,

is determined by the following system of equations

$$\beta_1^S = \frac{1}{2\lambda_1} \frac{\Sigma}{\Sigma + \sigma_\varepsilon^2} \left[1 - \frac{\lambda_2}{\lambda_1} \left(\frac{\alpha^S}{\beta_1^L}\right)^2 \frac{\sigma_\varepsilon^2}{\Sigma + \sigma_\varepsilon^2}\right]^{-1} \qquad \beta_1^L = \left[2\lambda_1 + \frac{1}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2} \beta_2^L\right]^{-1}$$

$$\alpha^S = -\frac{1}{2\lambda_2} \frac{1}{2C} \frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2} \qquad \alpha^L \to 0$$

$$\beta_2^S = \frac{1}{2\lambda_2} \frac{1}{2C} \frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \sigma_{u1}^2} \qquad \beta_2^L = \frac{1}{2\lambda_2} \frac{2C-1}{C}$$

$$\lambda_1 = \frac{\beta_1^L + \beta_1^S \Sigma}{\left(\beta_1^S\right)^2 (\Sigma + \sigma_\varepsilon^2) + \left(\beta_1^L\right)^2 + \sigma_{u1}^2}$$

$$\lambda_2 = \frac{\left(\beta_2^L + \beta_2^S\right) Var[l|T]}{\left(\beta_2^L + \beta_2^S\right)^2 Var[l|T] + \left(\frac{\beta_2^S}{\beta_1^L}\right)^2 Var[u_1|T] + \sigma_{u2}^2}$$

$$C = \frac{\frac{3}{4}\left(\beta_1^L\right)^2 + \sigma_{u1}^2}{\left(\beta_1^L\right)^2 + \sigma_{u1}^2} + \frac{1}{4} \frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2}$$

if the second order conditions $\lambda_1 \geq \lambda_2 \left(\frac{\alpha^S}{\beta_1^L}\right)^2$, $\lambda_1 \geq \frac{1}{4\lambda_2} \frac{\left(\beta_1^L\right)^2}{\left[\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2\right]^2}$ *and* $\lambda_2 \geq 0$ *are satisfied.*

The interested reader is referred to the Appendix for a complete proof of the proposition. The proof makes use of backward induction. In order to solve the continuation game in $t = 2$, the information structure prior to trading in $t = 2$ has to be derived. For this purpose, let us propose an arbitrary action rule profile, $\{\beta_1^S, \{\beta_1^{L_i}\}_{i \in \{1,\ldots,I\}}, p_1(X_1)\}$ for $t = 1$, which is mutual knowledge and is considered to be an equilibrium profile by all agents. In $t = 2$ all market participants can derive the aggregate order flow $X_1 = \beta_1^S (s + \varepsilon) + \beta_1^L l + u_1$ from price p_1. After knowing s, the price signal, the information which can be inferred from the past price by using technical analysis, is $T = l + \frac{\beta_1^S}{\beta_1^L} \varepsilon + \frac{1}{\beta_1^L} u_1$. Even if a trader deviates in $t = 1$, other market participants still assume that he has played his equilibrium strategy. This is because the liquidity traders order size u_1 is normally distributed and thus any aggregate order flow from $(-\infty, +\infty)$ can arise in equilibrium. This makes it unnecessary to specify off-equilibrium beliefs as the market maker and the other traders do not see an order flow that could not be observed in equilibrium. In $t = 2$ traders face a generalized static Kyle-trading-game with the usual trade-off. On the one hand, a risk-neutral trader wants to trade very aggressively in order to exploit the gap between his estimate of the fundamental value of the stock and the price of the stock. On the other hand, very aggressive trading moves the price at which his order will be executed towards his estimate of the asset's value since it allows the market maker to infer more of the trader's information from the aggregate order flow. This latter price impact reduces the value-price gap from which the trader can profit and restrains the traders from trading very aggressively.

Using backward induction one has to check whether a single player wants to deviate in $t = 1$ from the proposed action rule profile, $\{\beta_1^S, \{\beta_1^{L_i}\}_{i\in\{1,\dots,I\}}, p_1(X_1)\}$. Trading in $t = 1$ affects not only the capital gains in $t = 1$ but also the future prospects for trading in $t = 2$. Any deviation in $t = 1$ alters the price p_1. Since other market participants infer wrong information from p_1, their trading and price setting in $t = 2$ is also affected. An equilibrium is reached if no trader wants to deviate from the proposed action rule profile in $t = 1$. In other words, the sequentially rational Bayesian Nash Equilibrium is given by the fixed point described in Proposition 1.

Proposition 1 also presents two inequality conditions. They result from the second order conditions in the traders' maximization problems. They guarantee that the quadratic objective functions for each period have a maximum rather than a minimum. In economic terms, they require that the market is sufficiently liquid/deep in trading round one relative to trading round two. These inequality restrictions rule out the case where it is optimal to trade an unbounded amount in $t = 1$, move the price, and make an infinitely large capital gain in $t = 2$.

3.3 Exploiting Information Twice due to Technical Analysis

Information about the fundamental value of the stock as well as information about other traders' demand affects the traders' optimal order size. In period two, traders can infer some information from the past price, p_1. Brown and Jennings (1989) call this inference 'technical analysis'. If a trader's prediction of the stock's liquidation value is more precise than the market maker's prediction, then the trader has an informational advantage. Proposition 2 shows that the short-run information trader still has an informational advantage in period two over the market maker as well as over all long-run information traders. The short-run information trader can, therefore, exploit his private information twice. First, when he receives his signal, and second, at the time of the public announcement. This is surprising since one might think that the public announcement s is a sufficient statistic for the short-run information trader's private information $s + \varepsilon$.

Lemma 1 *The short-run information trader retains an informational advantage in period two in spite of the public announcement in period two. Technical analysis is more informative about the value of the stock for the short-run information trader than for any other market participant.*

Since all traders trade conditional on their signal in period one, the price p_1 reflects not only the signal about l but also the signal about $s + \varepsilon$. In period two all market participants try to infer information in $t = 2$ from the past price p_1. However, only the short-run information trader knows the exact extent to which the past price, p_1, already reflects the new public information, s. That is, while the other market participants can only separate the impact of s on p_1, the short-run information trader can also deduce the impact of the ε error term on p_1.

In general, technical analysis serves two purposes. First, traders try to infer more about the fundamental value of the stock, $v = s + l$, from the past price. After s is announced the remaining uncertainty about the fundamental value concerns only the long-run information l. Second, they use the past price to forecast the forecasts of others. Knowing others' estimates is useful for predicting their market orders in $t = 2$. This in turn allows traders to estimate the execution price p_2 more precisely.

When conducting technical analysis, the market maker and all long-run information traders are aware that price p_1 is affected by the error term ε. The price, $p_1 = \lambda_1 X_1$ depends on the individual demand of short-run information trader S, x_1^S, and thus on the signal $s + \varepsilon$. The short-run information trader's informational advantage in $t = 2$ is his knowledge of the error ε. He can infer ε from the difference between his signal in $t = 1$ and the public announcement in $t = 2$. If the short-run information trader would have abstained from trading in $t = 1$, the public announcement s would be a sufficient statistic for short-run information trader's private information, $s + \varepsilon$. However, since he traded in $t = 1$, all long-run information traders and the market maker would like to know the extent to which his trading activities changed price, p_1. Knowledge not only of s but also of ε would allow them to infer even more information from the price, p_1. Hence, the public announcement in $t = 2$ is not a sufficient statistic of $s + \varepsilon$ for interpreting the past price, p_1.

The short-run information trader applies technical analysis in order to infer more information about the fundamental value of the stock, more specifically about l. This information is also valuable for predicting the aggregate net demand of all long-run information traders in $t = 2$. The additional information about the value of the stock provided by technical analysis is higher for the short-run information trader than for the market maker and for long-run information traders. Since the short-run information trader knows his own demand, he can infer $\frac{1}{\beta_1^L}(\frac{p_1}{\lambda_1} - x_1^S) = l + \frac{1}{\beta_1^L}u_1$. All long-run information traders conduct technical analysis in order to infer each others l-signal from p_1. They - as well as the market maker - can only infer $(l + \frac{1}{\beta_1^L}u_1) + \frac{\beta_1^S}{\beta_1^L}\varepsilon$. This is the short-run information trader's price signal perturbed by the additional error term, ε. Therefore, the short-run information trader's informational advantage is due to the term, $\frac{\beta_1^S}{\beta_1^L}\varepsilon$, which increases with his trading intensity, β_1^S, and decreases with the trading intensity of long-run information traders, β_1^L. Intuitively, if the short-run information trader trades more aggressively in $t = 1$ his signal's imprecision has a higher impact on the price, p_1.

3.4 Speculative and Manipulative Trading

In general, trading occurs for risk sharing purposes or for informational reasons. Since all traders are risk-neutral in this setting, their only motive to trade is to exploit their informational advantage. As illustrated in Lemma 1, current trading affects future informational advantages. In Kyle (1985), the single insider reduces his trading intensity in order to save information for future trading rounds. The single insider faces a trade-off. Taking on a larger position in period one can result in higher profits today but also leads to worse prices for current and future trading rounds. Thus in a Kyle (1985), setting the insider restrains his trading activity with the objective of not trading his informational advantage away.

In contrast to the literature based on Kyle (1985), the short-run information trader in our model trades more aggressively in period one. He makes short-term non-optimal excessive trades in period one, but he more than recuperates the reduction of period one profits by making additional profit in period two. Trading more aggressively in period one changes the price in such a way that his informational advantage in the next trading round is enhanced. We define trading with the sole intention of increasing one's informational advantage in the next period as *manipulative trading* and trading with the expectation to unwind one's position in the next period as *speculative trading.*

Proposition 2 shows that the short-run information trader trades for speculative reasons since he expects to unwind part of his acquired position in period two. Furthermore, he trades excessively with the objective of manipulating the price.

Proposition 2 *In period one, part of the short-run information trader's trades* $\beta_1^S(s+\varepsilon)$ *is due to speculative and manipulative trading.*

Speculative trading is given by $-\alpha^S \frac{\beta_1^S}{\beta_1^L} \frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2} (s+\varepsilon)$.

Manipulative trading is given by $\left[\frac{\lambda_1}{\lambda_2}\left(\frac{\beta_1^L}{\alpha^S}\right)^2 \frac{\Sigma+\sigma_\varepsilon^2}{\sigma_\varepsilon^2} - 1\right]^{-1} (s+\varepsilon)$,
where the coefficients in front of $(s+\varepsilon)$ *are strictly positive.*

The proof in the appendix shows that if the short-run information trader receives a positive signal, all trading objectives induce the trader to take a long position in the stock. Similarly, if the short-run information trader receives a negative signal he sells the stock. He does not apply a contrarian trading strategy.

Proposition 2 introduces a novel form of stock price manipulation. The underlying purpose of the short-run information trader's manipulative trading is to extend the informational gap in the second trading round. In contrast to the previous literature, trader S does not trade in order to hide his own information or lack of information. The novelty of this form of manipulation is that the short-run information trader's aggressive trading worsens the other market participants' ability to infer each others' information from the past price in period two, while he retains his full ability to conduct technical analysis. More specifically, by trading excessively in $t = 1$, the short-run information trader confounds the other market participants' price signal T in $t = 2$. The reason is that the imprecision of the short-run information trader's signal ε has a larger impact on p_1 if he trades more aggressively. Consequently, the larger is β_1^S, the less the price signal $T = l + \frac{\beta_1^S}{\beta_1^L}\varepsilon + \frac{1}{\beta_1^L}u_1$ reveals about the value l. This increases trader S's informational advantage in $t = 2$ with respect to the market maker and long-run information traders. In addition, it also makes each long-run information trader's forecast about the short-run information trader's forecast of l worse. Recall that all traders also conduct technical analysis to forecast the others' market orders in order to better predict the execution price p_2. The short-run information trader's market order in $t = 2$ is based on his information, $l + \frac{1}{\beta_1^L}u_1$ and T. Long-run information traders also do not know $\frac{1}{\beta_1^L}u_1$, the short-run information trader's error in predicting the fundamental value l. The usefulness of the price signal T in predicting $\frac{1}{\beta_1^L}u_1$ also decreases as β_1^S increases. In short, if the short-run information trader trades more aggressively in period one, he makes it not only more difficult for others to infer information about the value l, but also worsens others' forecasts about his forecast. Hence, more aggressive trading in period one increases the short-run information trader's expected future capital gains. The proof in the appendix shows that in equilibrium the trading intensity of the short-run information trader is higher if he takes the impact on future expected capital gains into account, given the strategies of all other players. It is the expected knowledge of the ε-term in $t = 2$ which induces manipulative trading.

Speculation in this model is driven purely by trading for informational reasons. A positive (negative) signal for trader S has two implications. First, he buys (sells) shares in the first trading round and second, he expects that ε is positive (negative), that is $E[\varepsilon|s+\varepsilon] = Var[\varepsilon](Var[s]+Var[\varepsilon])^{-1}(s+\varepsilon) > (<)0$. Other market participants' technical analysis in $t=2$ is based on $T = l + \frac{\beta_1^S}{\beta_1^L}\varepsilon + \frac{1}{\beta_1^L}u_1$. That is, if ε is positive (negative), the market maker and the long-run information traders overestimate (underestimate) the long-run value l in period two. Since the short-run information trader can infer ε in period two, he expects to make money by correcting the market maker's overoptimism (pessimism). In short, he expects to sell (buy) shares in period two. Therefore, the short-run information trader expects to trade in the opposite direction in period two. 'On average', he partially unwinds his position in period two. This is solely due to informational reasons since the short-run information trader expects the price to overshoot in $t=2$. Given, however, the information of the market maker or of any other outsider who only observes the past prices and the public announcement, the price follows a Martingale process, i.e. it neither overshoots nor undershoots.

Speculative trading is also caused by the imprecision of the short-run information trader's signal, ε. Consequently, an increase in trading intensity in period one due to manipulative behavior also leads to more speculation. The short-run information trader expects to unwind a larger position in $t=2$. The imprecision ε of the short-run information trader's early signal plays a crucial role in this analysis.[8]

The following figures illustrate the short-run information trader's trading behavior as we vary the precision of his signal from $\sigma_\varepsilon^2 = 0$ to $\sigma_\varepsilon^2 = 10$. All other variance terms are set equal to one. The solid line in Figure 2 shows how speculative trading as a fraction of the short-run information trader's total trading increase with σ_ε^2. The x-marked line illustrates the fraction which is due to manipulative trading.

Obviously, for $\sigma_\varepsilon^2 = 0$ neither manipulative trading nor speculative trading occurs. As the imprecision of the short-run information trader's signal increases, so does the fraction of speculative trading and the fraction which is due to manipulative trading. For $\sigma_\varepsilon^2 = 10$ more than 25 % of the short-run information trader's trade can be classified as speculative trading while between 5 % and 10 % are due to manipulation.

Figure 3 plots the coefficients in front of $(s+\varepsilon)$ for speculative trading (solid line) and manipulative trading (x-marked line) derived in Proposition 2 for different values of σ_ε^2. The coefficient times the signal realization $(s+\varepsilon)$ represents the amount of speculative trading and manipulative trading, respectively. It shows that speculative

[8] Note that if s and l could be traded separately neither speculative nor manipulative trading would arise. Questions such as whether the short-run information trader has an incentive to generate some additional noise of his own or how his expected profit varies as $Var[\varepsilon]$ varies are relegated to Section 5.1 and 5.2.

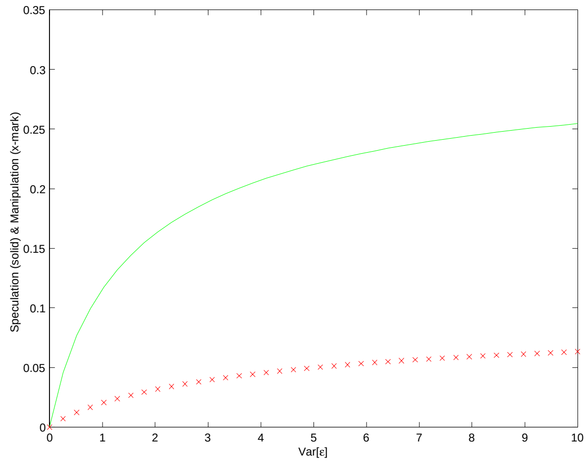

Figure 2: Fraction of speculative and manipulative trading for different σ_ε^2.

trading peaks at a σ_ε^2-value between 1 and 2, while the peak for manipulative trading only occurs for a σ_ε^2-value larger than 2. The hump shape confirms the theoretical results which show that there is neither manipulative nor speculative trading for $\sigma_\varepsilon^2 = 0$ and $\sigma_\varepsilon^2 = \infty$.

Further numerical analysis shows that the amount of speculative trading and manipulative trading increases as the variance of noise trading in $t = 2$, σ_{u2}^2, increases. Note that Figure 2 and 3 provide very conservative estimates of the amount of manipulative and speculative trading since the amount of noise trading is typically larger after public announcements than prior to it.

While in our setting speculative trading is purely driven by strategic reasons, Hirshleifer, Subrahmanyam, and Titman (1994) appeal to traders' risk-aversion and thus provide a very distinct explanation for speculative behavior. In their setting early-informed risk averse traders are willing to take on a riskier position in order to profit from their superior private information. After a larger group of traders receives the same information one period later, they partially unwind their position to reduce their risk exposure. In their model, no speculation would occur without risk aversion, while in our setting the short-run information trader speculates even though he is risk neutral. His speculation is driven by informational reasons. It is easy to visualize a generalized setting with risk averse traders where these traders speculate due to risk aversion and informational reasons. In that setting, the amount of speculative trading would be larger than that derived in the simulations presented above.

Note also that the size of manipulative trading is also sensitive to possible extensions

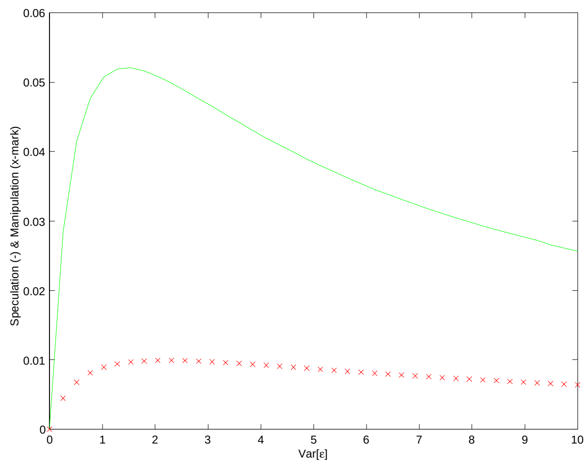

Figure 3: Coefficient on $(a+\varepsilon)$ for speculative and manipulative trading for different σ_ε^2.

of the model. If the public announcement about s occurs only with a certain probability, then manipulation only pays off if the announcement actually occurs. Hence, the short-run information trader's incentive to manipulate the price p_1 is reduced. Another extension of the model is to allow for multiple trading rounds after the public announcement. In this case, manipulative trading would provide a higher profit for many trading rounds and hence manipulative trading would be enhanced.

4 Impact of Information Leakage on Informational Efficiency - An Argument in Favor of Regulation FD

The information structure analyzed above also provides new insights on how information leakage affects market efficiency. Information leakage leads to insider trading which in general reduces liquidity trading and the amount of risk sharing. It might even lead to market breakdowns. Therefore, information leakage typically reduces allocative efficiency. The argument follows a similar line of reasoning as in Akerlof's (1970) "market for lemons." On the other hand, if there is some information leakage prices might adjust faster to be in line with the true asset value. This section focuses solely on the implication of information leakage on informational efficiency and, therefore, the amount of liquidity trading is assumed to be exogenously fixed. More specifically, this section illustrates how the noisy information leakage of $s+\varepsilon$ to a short-run information trader prior to the official public announcement of s in $t=2$ affects the informational content revealed by prices. Often this information is given away to some preferred analyst who then forwards it first to his clients. The benchmark is the setting where trader S receives no signal prior to the public announcement. A dynamic trade-off is illustrated: while information leakage can make prices more informative in the very short-run, it reduces informational efficiency in the long-run.

Before diving into the analysis, we first define two different measures of the degree of information revelation by prices. A market is (strong-form) *informationally efficient* if the price is a sufficient statistic for all the information dispersed among all market participants. In this case, the market mechanism perfectly aggregates all information available in the economy, and the price reveals it to everybody. In general, if traders trade for informational as well as non-informational reasons, the price is not informationally efficient. This is also the case in our setting where some traders try to exploit their superior information and others trade for liquidity reasons. Nevertheless, one can distinguish between more and less informationally efficient markets. A measure of informational efficiency should reflect the degree to which information dispersed among many traders can be inferred from the price (process) together with other public information. Consider the forecast of the fundamental value of the stock v, given the pool of all available information in the economy at a certain point in time. If the price (process) is informationally efficient then the price(s) and other public information up to this time yields the same forecast. Consequently, the variance of this forecast conditional on prices and other public information is zero. This conditional variance increases as the market becomes less informationally efficient. Therefore, we choose the reciprocal of this conditional variance, i.e. the precision, as a measure of the degree of informational efficiency. Note that the degree of informational efficiency depends crucially on the pool of information in the economy. To illustrate this, consider a world without asymmetric information. In that setting, any price process is informationally efficient even though it is uninformative. While informational efficiency is relative to the information dispersed in the market, *informativeness* of a price process is absolute. The conditional variance of the stock value itself captures how informative the price (process) and the other public information are.[9] This variance term, therefore, also measures the risk a liquidity trader faces when trading this stock. This conditional variance is zero if all public information, including the price process, allows one to perfectly predict the liquidation value of the stock. In this case everybody knows the true stock value. The following definitions define both measures more formally. Let us denote $\mathcal{I}_t^{\text{public}}$ set of all public information which is known to all market participants and $\mathcal{I}_t^{\text{pooled}}$ the information set which pools all public and private information up to time t.

[9] Note that all public information at the beginning of the trading game is incorporated in the common priors.

Definition 1 (Informational Efficiency) *The reciprocal of the variance $Var[E[v|\mathcal{I}_t^{pooled}]|\mathcal{I}_t^{public}]$ conditional on the public information, $\mathcal{I}_t^{public}$, and the pool of private information up to time t measures the degree of informational efficiency at time t.*

Definition 2 (Informativeness) *The reciprocal of the conditional variance $Var[v|\mathcal{I}_t^{public}]$ measures how informative the price (process) and the public information are at time t.*

Equipped with these measures, we can now analyze how the information leakage of $s + \varepsilon$ to a potential short-run information trader affects informational efficiency and informativeness of the price (process). In addition, these measures also allow us to address the role of the imprecision of the rumor.

Since these definitions are time dependent, let us analyze informational efficiency and informativeness at the time after the first trading round, after the public announcement of s, and after the second trading round. We assume in this section that long-run information traders submit myopically optimal market orders. This assumption simplifies the analysis a great deal without affecting the main insights.

Proposition 3 *In $t = 1$, information leakage makes the price p_1 more informative but less informationally efficient. However, after the public announcement in $t = 2$, the price p_1 and price process $\{p_1, p_2\}$ is less informative and less informationally efficient.*

Leakage of information about a forthcoming announcement to an analyst makes the price p_1 in $t = 1$ more informative. The short-run information trader trades on his information $s + \varepsilon$ and thus price p_1 reveals information about not only l but also about s. The short-run information trader's market activity increases informed trading relative to liquidity trading. This allows the market maker as well as the public to infer more information from the aggregate order flow X_1.

On the other hand, information leakage makes the market less informationally efficient in $t = 1$. In this case, the information dispersed in the economy is not only l but also $s + \varepsilon$. If there is no leakage, p_1 reveals more about l than p_1 reveals about $E[v|l, s + \varepsilon] = l + \Sigma\left(\Sigma + \sigma_\varepsilon^2\right)^{-1}(s + \varepsilon)$ in the case of a leakage. The reason is that information leakage leads to a higher λ_1 which reduces the trading intensity of long-run information traders, β_1^L. Therefore, less information can be inferred about l. In addition, $s + \varepsilon$ can only be partly inferred from the price p_1. Both effects together result in a lower informational efficiency for p_1 in the case of a leakage.

After the public announcement in $t = 2$, s is commonly known and the pooled information of all long-run information traders include l, (i.e. the best forecast of v

given the pooled information is v). Consequently, the measures of informational efficiency and informativeness coincide from that moment onwards. Since s is common knowledge, the conditional variance stems solely from the uncertainty about l. The proof in the appendix shows that information leakage leads to a less liquid market, i.e. to a higher λ_1. This reduces β_1^L and thus makes the price signal about l less precise. In addition, the price signal $T = l + \frac{\beta_1^S}{\beta_1^L}\varepsilon + \frac{1}{\beta_1^L}u_1$ is perturbed by the ε-error term. Therefore, information leakage makes the price p_1 after the public announcement less informative and less informationally efficient. The same is true after the second trading round for the price process $\{p_1, p_2\}$.

In summary, information leakage prior to public announcements to an analysts reduces informational efficiency at each point in time. It makes the price process more informative in the very short run prior to the public announcement and less informative afterwards in the long-run.

5 Extensions

The propositions in Section 3 demonstrated that the short-run information trader's informational advantage as well as his speculative and manipulative trading result from the imprecision of the rumor. The noise term ε is crucial for these results. Some interesting extensions come to mind: (i) is it possible for the short-run information trader to generate the imprecision himself in equilibrium by trading above or below his optimal level in period one; (ii) what is the optimal level of imprecision for the short-run information trader? These questions are addressed in the following subsections.

5.1 Mixed Strategy Equilibria

Before addressing the question about which signal precision the short-run information trader prefers, let us analyze the case where he adds some noisy component $\tilde{\beta}_1^S\xi$ to his optimal order size. For simplicity we assume in this subsection that trader S receives a perfect signal s. His order size is then of the form $x_1^S = \tilde{\alpha}_1^S s + \tilde{\beta}_1^S\xi$ and he follows a mixed (or behavioral) strategy.[10] In order to preserve normality for all random variables, assume $\xi \sim \mathcal{N}(0,1)$.

[10] Pagano and Röell (1993) conjecture a mixed strategy equilibrium in a model which analyzes front-running by brokers. Investors submit their orders to the broker who forwards it to the market maker. Prior to trading the broker observes the aggregate order flows for the next two trading rounds. Hence he has more information than the market maker in the first trading period. In the first trading round he front-runs by adding his own (possibly random) orders.

The addition of a random demand $\tilde{\beta}_1^S \xi$ in trading round one makes the market more liquid in $t = 1$, but less liquid in $t = 2$. This occurs because the short-run information trader trades in $t = 2$ on information generated by $\tilde{\beta}_1^S \xi$. The changes in the liquidity measure, λ_t, also alters the trading intensities, $\tilde{\beta}_t^S$ and $\tilde{\beta}_t^L$. All this affects the new price signal $T = l + \frac{\tilde{\beta}_1^S}{\tilde{\beta}_1^L}\xi + \frac{1}{\tilde{\beta}_1^L}u_1$, with the additional error term $\frac{\tilde{\beta}_1^S}{\tilde{\beta}_1^L}\xi$. This additional term is known to the short-run information trader, but not to the other market participants. Trader S's knowledge of $\frac{\tilde{\beta}_1^S}{\tilde{\beta}_1^L}\xi$ is his informational advantage in $t = 2$. The analysis of the continuation game in $t = 2$ is analogous to the one in Proposition 1.

Note that this error term differs from the ε-error term in the previous sections in two respects. First, the short-run information trader knows ξ already in $t = 1$, whereas he learns the precise value of ε only at the time of the public announcement. Second, if the short-run information trader wants to increase the importance of the ε error term in the previous sections, he had to trade more aggressively on $s + \varepsilon$, thereby revealing more of his signal. In contrast, by trading on a unrelated random noise term ξ, he reveals less about his signal s. Overall, the trade-off is that while he acts like a noise trader in $t = 1$ incurring trading costs on the one hand, he also increases his informational advantage in $t = 2$ on the other hand.

For a mixed strategy to sustain in equilibrium, the short-run information trader has to be indifferent between any realized pure strategy, i.e. between any realization of ξ. Since the random variable ξ can lead to any demand with positive probability, he has to be indifferent between any $\tilde{x}_1^S$ in equilibrium. This requires that the marginal trading costs in $t = 1$ exactly offset the expected marginal gains in $t = 2$. More formally, the short-run information trader's objective function consists of two parts: the expected capital gains in $t = 1$, $\left(E[v|s] - \tilde{\lambda}_1 \tilde{x}_1^{dS}\right)\tilde{x}_1^{dS}$ and the expected value function for capital gains in $t = 2$, $\tilde{\lambda}_2(\tilde{x}_2^{dS})^2$. The sum of both quadratic functions have to reduce to a constant in equilibrium to ensure that trader S is indifferent between all realizations of ξ. This is only the case if the short-run information trader's second order condition binds, that is $\tilde{\lambda}_1 = \tilde{\lambda}_2 \left(\tilde{\alpha}^S / \tilde{\beta}_1^L\right)^2$. This necessary condition together with the second order condition of the long-run information traders allows us to rule out mixed strategy equilibria.

Proposition 4 *There does not exist a linear mixed strategy equilibrium.*

The non-existence of a mixed strategy equilibrium is in sharp contrast to Huddart, Hughes, and Levine (2001). The *single* insider in Huddart, Hughes, and Levine (2001) employs a mixed strategy since his order size is made public after his order is executed. Similar to our setting without the ε-error term, the insider forgoes all future profit opportunities if he employs a pure trading strategy. In Huddart, Hughes, and Levine (2001) the incentive for the single insider to deviate from any pure strategy is extremely high since the market would be infinitely deep in $t = 2$, that is $\lambda_2 = 0$. That is, any tiny deviation in $t = 1$ would yield an infinite profit in the future trading rounds. Therefore only a mixed strategy equilibrium exists in Huddart, Hughes, and Levine (2001). In contrast, in our model the market is not infinitely deep in $t = 2$ since there are *multiple* informed traders. The trading activities of long-run information traders destroy the incentive to apply a mixed strategy in $t = 1$.

5.2 Optimal $Var[\varepsilon]$ - Sale of Information

In the last subsection we used the fact that the short-run information trader is only believed to follow a mixed strategy if he is indifferent between any realization of ξ. The fact that the the short-run information trader cannot commit to use a certain mixed strategy eliminates the possibility that he adds more noise to his signal in equilibrium. In contrast to the noise term ξ, this commitment problem does not arise if the short-run information trader just observes a less precise signal. That is, the variance of the error term ε is higher. Increasing σ_ε^2, increases the capital gains after the public announcement. However, it also lowers the expected capital gains in the trading round prior to the public announcements. The purpose of this subsection is to analyze how trader S's overall profit changes as σ_ε^2 varies.

Let us first examine the two extreme cases $\sigma_\varepsilon^2 = 0$ and $\sigma_\varepsilon^2 = \infty$. For $\sigma_\varepsilon^2 = 0$, the short-run information trader knows s perfectly already in $t = 1$ and will have no informational advantage in the second trading round. Consequently, no manipulative trading or speculative trading will occur in this case. In the other limiting case of $\sigma_\varepsilon^2 = \infty$, the short-run information trader's signal is totally uninformative. This case served as a benchmark case in Section 4 and the short-run information trader will not engage in any trading activity. In both cases the expected capital gains in trading round $t = 2$ is zero. In order to conduct the comparative static exercise for any possible $\sigma_\varepsilon^2 \in (0, \infty)$, it is necessary to explicitly derive the expected profit function of the short-run information trader. Unfortunately, a closed-form expression of the expected profit function can not be obtained due to the complexity of the information structure. Any further analysis is therefore limited to numerical simulations. Figure 4 shows the short-run information trader's ex-ante overall expected capital gains is monotonically decreasing in σ_ε^2 if we set all other variance terms equal to one. This finding is also robust for other parameter values.

This finding is also of interest for someone who knows s in $t = 1$ and considers selling his news to a single trader. Given our numerical analysis, the short-run infor-

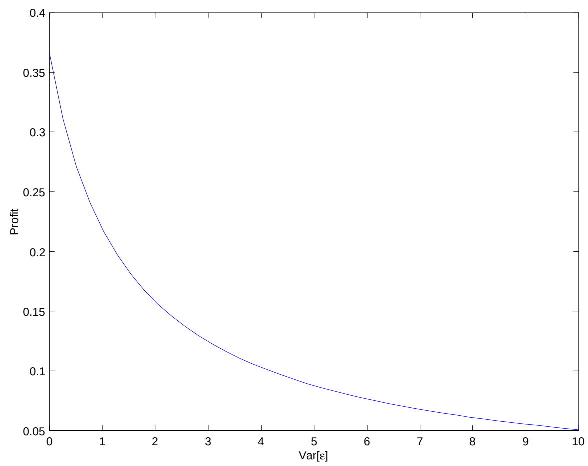

Figure 4: Trader A's profit for different σ_ε^2.

mation trader's profit is highest for $\sigma_\varepsilon^2 = 0$. Even though his capital gains in $t = 2$ are zero, the additional profit he is able to achieve with a more precise signal in $t = 1$ more than outweighs this. Hence, the seller of information would not prefer to sell a noisy version of his signal instead of his precise information s. In Admati and Pfleiderer (1986), the information monopolist prefers to sell personalized noisy signals. Using a static rational expectations setting, they show that more traders acquire personalized signals if the information monopolist adds an idiosyncratic personalized noise term to his information. This increases the seller's revenue. In contrast to their model setup, we employ a strategic setting with a single S trader, but two trading rounds. The noise ε of the short-run information trader's acquired information provides him an additional informational advantage in the second trading round. In a generalized setting with endogenous information acquisition and potentially many short-run information traders, it might also be the case that the number of traders interested in acquiring a signal about s increases if the information monopolist sells personalized signals.

6 Conclusion

An understanding of trading patterns is essential for detecting insider trading and effectively enforcing regulatory measures. This analysis uncovers three novel features of insider trading by applying a more realistic information structure. We demonstrate that (i) insiders have an informational advantage even after the public announcement; (ii) they trade very aggressively prior to the public announcement in order to manipulate the others' price signal; and (iii) they partially unwind their position after the public announcement.

It is well understood that insider trading typically reduces risk sharing and allocative efficiency. One of the main messages of this paper is that insider trading also reduces informational efficiency of prices in the long run. Therefore, it provides strong support for the new Regulation FD. By introducing multiple trading rounds and a more realistic signal structure, we generate conclusions that are in sharp contrast to the previous literature on insider trading with exogenous information acquisition. However, the paper does not make any normative welfare statements. In order to conduct a welfare analysis, one has to endogenize the trading activities of the liquidity traders. For example, one could consider risk-averse uninformed investors who are engaged in a private investment project. If the returns of these private investment projects are correlated with the value of stock, they trade for hedging reasons even though they face trading costs. A thorough welfare analysis would allow us to evaluate insider trading laws more explicitly.

If the early-informed trader happens to be a corporate insider, our analysis offers additional support for the Short Swing Rule (Rule 16 b of the SEA). This rule prohibits corporate insiders to profit from buying and selling the same security within a period of six months and thus deprives corporate insiders their theoretically optimal trading strategy.

Some further extensions of this analysis come to mind. It is intuitive that in a setting in which many traders receive the early signal, $s + \varepsilon$, manipulative trading and speculation still occur, but to a lesser degree. As the number of short-run information traders converges to infinity, short-run information traders still speculate whereas manipulative trading vanishes. The reason is that all short-run information traders try to free ride on the manipulative activity of the other manipulators. Manipulation is costly but benefits all other short-run information traders in the second trading round. Furthermore, a larger number of short-run information traders also enhances the competition in the second trading round. This lowers the expected capital gains in $t = 2$ and hence the incentive to manipulate in $t = 1$. In summary, this discussion suggests that a rumor leads to more speculation as well as to more manipulative trading. The latter, however, only occurs as long as the rumor is not widely spread among many traders. Additional insights could be obtained by endogenizing the information acquisition process. It would also be interesting to determine when it is more profitable to buy imprecise information about a forthcoming announcement and when it is more lucrative to acquire long-lived information. But these are all tasks left for future research.

A Appendix

A.1 Proof of Proposition 1

Propose an arbitrary linear action rule profile for $t = 1$, $\{\beta_1^S, \{\beta_1^{L_i}\}_{i\in\{1,\ldots,I\}}, p_1(X_1)\}$.

Equilibrium in continuation game in $t = 2$.

Information structure in $t = 2$.

After s is publicly announced, l is the only uncertain component of the stock's value.

Proof of Lemma 1

The *market maker* knows the aggregate order flow in $t = 1$, $X_1 = \beta_1^S(s+\varepsilon) + \beta_1^L(l) + u_1$ in addition to s. His price signal T (aggregate order flow signal, X_1) can be written as $T = \frac{X_1 - \beta_1^S s}{\beta_1^L} = l + \frac{\beta_1^S}{\beta_1^L}\varepsilon + \frac{1}{\beta_1^L}u_1$. Since all market participants can invert the pricing function $p_1 = \lambda_1 X_1$ in $t = 2$, they all know T. *Trader* S can also infer ε in $t = 2$ and thus his price signal is $l + \frac{1}{\beta_1^L}u_1$. Each *trader* L_i*'s* information consists of T and his original signal $\frac{1}{I}l_i$. ■

The conjectured trading rules for $t = 2$ are $x_2^S = \alpha^S T + \beta_2^S\left(l + \frac{1}{\beta_1^L}u_1\right)$ for trader S and $x_2^{L_i} = \alpha^L T + \beta_2^L \frac{1}{I}l_i$ for all trader L_i. Each market participants tries to forecast each other's forecasts or more specifically the others' market order. Trader S expectation of the aggregate order flow of all L traders is $E\left[\sum_j x_2^{L_j} | l + \frac{1}{\beta_1^L}u_1, T\right] = I\alpha^L T + \beta_2^L E\left[l | l + \frac{1}{\beta_1^L}u_1\right]$. Trader L_i's expects an order of size $E\left[x_2^S | \frac{1}{I}l_i, T\right] = \beta_2^S E\left[l + k_u u_1 | \frac{1}{I}l_i, T\right] + \alpha^S T$ from trader S and of size $E\left[\sum_{j\neq i} x_2^{Bj} | \frac{1}{I}l_i, T\right] =$
$\beta_2^L E\left[\left(l - \frac{1}{I}l_i\right) | \frac{1}{I}l_i, T\right] + (I-1)\alpha^L T$ from all other L traders. It proves useful to denote the regression coefficients by ϕ's. Let the market maker's expectations $E[l|T] = \phi_{mm}^l T$, that is $\phi_{mm}^l = \frac{1}{1 + \frac{(\beta_1^S)^2}{(\beta_1^L)^2}\sigma_\varepsilon^2 + \frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}$. Trader S's expectations $E\left[l | l + \frac{1}{\beta_1^L}u\right] = \phi_S^l\left(l + \frac{1}{\beta_1^L}u\right)$, that is $\phi_S^l = \frac{1}{1 + \frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}$; and for any trader L_i, $E\left[l - \frac{1}{I}l_i | T - \frac{1}{I}l_i\right] = \phi_L^l\left(T - \frac{1}{I}l_i\right)$, that is $\phi_L^l = \frac{\frac{I-1}{I}}{\frac{I-1}{I} + \frac{(\beta_1^S)^2}{(\beta_1^L)^2}\sigma_\varepsilon^2 + \frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}$. For the conditional expectations of $\frac{1}{\beta_1^L}u_1$: $E\left[\frac{1}{\beta_1^L}u_1 | T\right] = \phi_{mm}^u T$ and $E\left[\frac{1}{\beta_1^L}u_1 | T - \frac{1}{I}l_i\right] = \phi_L^u\left(T - \frac{1}{I}l_i\right)$. In other words, $\phi_{mm}^u = \frac{\frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}{1 + \frac{(\beta_1^S)^2}{(\beta_1^L)^2}\sigma_\varepsilon^2 + \frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}$ and $\phi_L^u = \frac{\frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}{\frac{I-1}{I} + \frac{(\beta_1^S)^2}{(\beta_1^L)^2}\sigma_\varepsilon^2 + \frac{1}{(\beta_1^L)^2}\sigma_{u1}^2}$.

Action (trading) rules in $t = 2$.

Due to potential Bertrand competition the risk-neutral *market maker* sets the price $p_2 = E[v|X_1, X_2] = s + E[l|T] + \lambda_2 [X_2 - E[X_2|T]]$. Note that $\lambda_2 = \frac{Cov[l,X_2|T]}{Var[X_2|T]}$.

Trader S's optimization problem in $t = 2$ is $\max_{x_2^S} x_2^S E[s + l - p_2|l + \frac{1}{\beta_1^L}u_1, T]$. The first order condition of $\max_{x_2^S} x_2^S E[w - \lambda_2 \left(x_2^S + \beta_2^L l + u_2\right) |l + \frac{1}{\beta_1^L}u_1, T]$ leads to $x_2^{S,*} = \alpha^S T + \beta_2^S \left(l + \frac{1}{\beta_1^L}u_1\right)$, where $\alpha^S = -\frac{1}{\lambda_2}\phi_{mm}^l + \left(\beta_2^S + \beta_2^L\right)\phi_{mm}^l + \beta_2^S \phi_{mm}^u$ and $\beta_2^S = \left(\frac{1}{2\lambda_2} - \frac{1}{2}\beta_2^L\right)\phi_S^l$.

Trader L_i's optimization problem is $\max_{x_2^{L_i}} x_2^{L_i} E[s + l - p_2|\frac{1}{I}l_i, T]$. The first order condition translates into $x_2^{L_i,*} = \alpha^L T + \beta_2^L \frac{1}{I}l_i$, where $\alpha^L = \left[\frac{1}{\lambda_2} - \left(\beta_2^S + \beta_2^L\right)\right]\left(\phi_L^l - \phi_{mm}^l\right) - \beta_2^S\left(\phi_L^u - \phi_{mm}^u\right)$ and $\beta_2^L = \frac{1}{2\lambda_2}\left(1 - \phi_L^l\right) + \frac{1}{2}\beta_2^L\phi_L^l - \frac{1}{2}\beta_2^S\left[\left(1 - \phi_L^l\right) - \phi_L^u\right]$. The second order condition for all traders' maximization problem is $\lambda_2 > 0$.

The *equilibrium strategies for* $t = 2$ for a given action (trading) rule profile in $t = 1$ is given by

$$
\begin{aligned}
\alpha^S &= \frac{1}{\lambda_2 4C}\left\{-\left[2 - \phi_S^l\right]\phi_{mm}^l + \phi_S^l\phi_{mm}^u\right\} \\
I\alpha^L &= \frac{1}{\lambda_2 4C}\left\{\left[2 - \phi_S^l\right] I\left(\phi_L^l - \phi_{mm}^l\right) - \phi_S^l I\left(\phi_L^u - \phi_{mm}^u\right)\right\} \\
\beta_2^S &= \frac{1}{2\lambda_2}\frac{1}{2C}\phi_S^l \\
\beta_2^L &= \frac{1}{2\lambda_2}\frac{2C-1}{C} \\
\lambda_2 &= \sqrt{\frac{\left(1 - \frac{2-\phi_S^l}{4C}\right)\frac{2-\phi_S^l}{4C}Var[l|T] - \left(\frac{\phi_S^l}{4C\beta_1^L}\right)^2\sigma_{u1}^2}{\sigma_{u2}^2}}
\end{aligned}
$$

where $C = 1 - \frac{1}{2}\phi_L^l - \frac{1}{4}\phi_S^l + \frac{1}{4}\phi_S^l\phi_L^l + \frac{1}{4}\phi_S^l\phi_L^u$ and

where $Var[l|T] = 1 - \phi_{mm}^l$ and $Var[u_1|T] = \frac{\sigma_{u1}^2\left[1 + \frac{\left(\beta_1^S\right)^2}{\left(\beta_1^L\right)^2}\sigma_\varepsilon^2\right]}{1 + \frac{\left(\beta_1^S\right)^2}{\left(\beta_1^L\right)^2}\sigma_\varepsilon^2 + \frac{1}{\left(\beta_1^L\right)^2}\sigma_{u1}^2}$.

Equilibrium in $t = 1$.

The proposed arbitrary action rule profile is an equilibrium if no player wants to deviate given the strategies of the others.

The *market maker*'s pricing rule in $t = 1$ is always given by $p_1 = E[v|X_1] = \lambda_1 X_1$ with $\lambda_1 = \frac{Cov[v,X_1]}{Var[X_1]}$.

Trader S's best response.

Deviation of trader S from $x_1^S(s+\varepsilon) = \beta_1^S(s+\varepsilon)$ to x_1^{dS} will not alter the subsequent trading intensities of the other market participants, i.e. $\lambda_1, \beta_2^L, \lambda_2$. They still believe that trader S plays his equilibrium strategy since they cannot detect his deviation. Nor does his deviation change his own price signals since he knows the distortion his deviation causes.

Other market participants' misperception in $t = 2$.

Trader S's deviation, however, distorts the other players price signal, T to T^{dS}. This occurs because the other market participants attribute the difference in the aggregate order flow in $t = 1$ not to trader S's deviation, but to a different signal realization or different noise trading. Deviation to $x_1^{dS}(\cdot)$ distorts the price signal by $T^{dS} = T + \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)$. Trader S expects that the aggregate order of all L traders is $\beta_2^L\phi_S^l(s+\varepsilon) + I\alpha^L\left[T + \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right]$. Price p_2 is also distorted. The market maker's best estimate of v prior to trading in $t = 2$ is $s + \phi_{mm}^l\left(T^{dS} - T\right)$ and after observing X_2^{dS}, $E\left[p_2^{dS}|S_2^S, T, T^{dS}\right] =$

$$
\begin{aligned}
= \; & \phi_{mm}^l\left(T + \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right) \\
& + \lambda_2\left\{x_2^{dS} + \beta_2^L\phi_S^l\left(l + \frac{1}{\beta_1^L}u_1\right) + I\alpha^L\left[T + \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right] - E_{mm}^{dS}\left[X_2|T\right]\right\}.
\end{aligned}
$$

where $E_{mm}^{dS}\left[X_2|T\right]$ denotes the market makers expectations of X_2 thinking that trader S did not deviate. Using the above derived coefficients, Trader S's expected execution price in $t = 2$ is

$$
\lambda_2 x_2^{dS} + \frac{2C-1}{2C}\phi_S^l\left(l + \frac{1}{\beta_1^L}u_1\right) - \left[\left(\frac{\phi_S^l - 2}{2C}\right)\phi_{mm}^l + \frac{1}{2C}\phi_S^l\phi_{mm}^u\right]\left(T + \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right)
$$

Trader S's optimal trading rule in $t = 2$ after deviation in $t = 1$ results from the adjusted maximization problem $\max_{x_2^{dS}} E[x_2^{dS}\left(s + l - p_2^{dS}\right)|l + \frac{1}{\beta_1^L}u_1, T, T^{dS}]$. It is given by $x_2^{dS,*} = x_2^S + \alpha^S\frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)$, if the second order condition $\lambda_2 > 0$ is satisfied.

Trader S's value function $V^S(x_1^{dS}) = x_2^{dS,*}E[s + l - p_2^{dS}|l + \frac{1}{\beta_1^L}u_1, T, T^{dS}]$, which can be rewritten as $x_2^{dS,*}\left\{E[s+l|\cdot] - \lambda_2 E\left[\sum_i x_2^{L_i}|\cdot\right]\right\} - \lambda_2\left\{x_2^{dS,*}\right\}^2$. Note that the first order condition in $t = 2$ implies that $2\lambda_2 x_2^{dS,*} = \left\{E[s+l|\cdot] - \lambda_2 E\left[\sum_i x_2^{L_i}|\cdot\right]\right\}$ and, hence

$$
V^S(x_1^{dS}) = \lambda_2\left[x_2^{dS}\right]^2 = \lambda_2\left[x_2^S + \alpha^S\frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right]^2.
$$

Trader S's optimization problem in $t = 1$ is thus $\max_{x_1^{ds}} E[x_1^{dS}\left(v - p_1^{dS}\right) + V^S(x_1^{dS})|s + \varepsilon]$, where $p_1^{dS} = \lambda_1 X_1^{dS} = \lambda_1\left(x_1^{dS} + \beta_1^L l + u_1\right)$. Since $s+\varepsilon$ is orthogonal to l the first order condition is

$$2\lambda_1 x_1^{dS} = \frac{\Sigma_s}{\Sigma_s + \sigma_\varepsilon^2}(s+\varepsilon) + \frac{\partial E\left[V|s+\varepsilon\right]}{\partial x_1^{S,dS}}.$$

Note that

$$\begin{aligned}\frac{\partial E\left[V|s+\varepsilon\right]}{\partial x_1^{S,dS}} &= \lambda_2 E\left[2\gamma^S \frac{1}{\beta_1^L}\left[x_2^S + \alpha^S \frac{1}{\beta_1^L}\left(x_1^{dS} - x_1^S\right)\right]|s+\varepsilon\right] \\ &= \lambda_2 2\gamma^S \frac{1}{\beta_1^L} E\left[x_2^S|s+\varepsilon\right] + 2\lambda_2\left(\alpha^S \frac{1}{\beta_1^L}\right)^2\left(x_1^{dS} - x_1^S\right)\end{aligned}$$

Since $E\left[x_2^S|s+\varepsilon\right] = \alpha^S E\left[T|s+\varepsilon\right] = \alpha^S \frac{\frac{\beta_1^S}{\beta_1^L}\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \Sigma_s}(s+\varepsilon)$, the first order condition is

$$2\lambda_1 x_1^{dS} = \frac{\Sigma_s}{\Sigma_s + \sigma_\varepsilon^2}(s+\varepsilon) + 2\lambda_2\left(\alpha^S\right)^2 \frac{1}{\beta_1^L}\frac{\frac{\beta_1^S}{\beta_1^L}\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \Sigma_s}(s+\varepsilon) + 2\lambda_2\left(\alpha^S \frac{1}{\beta_1^L}\right)^2\left(x_1^{dS} - x_1^S\right).$$

Note that in equilibrium $x_1^{dS} = x_1^S$ and hence

$$\beta_1^S = \frac{1}{2\lambda_1}\frac{\Sigma_s}{\Sigma_s + \sigma_\varepsilon^2}\left[1 - \frac{\lambda_2}{\lambda_1}\left(\frac{\alpha^S}{\beta_1^L}\right)^2 \frac{\sigma_\varepsilon^2}{\Sigma_s + \sigma_\varepsilon^2}\right]^{-1}$$

The second order condition is $\lambda_1 \geq \lambda_2\left(\frac{\alpha^S}{\beta_1^L}\right)^2$. We consider only parameter values which satisfy the second order condition.

Trader L_i's best response.

Other market participants' misperception in $t = 2$.

Deviation from $x_1^{L_i}(\frac{1}{I}l_i)$ to $x_1^{dL_i}$ distorts the price signal by $T^{dL_i} = T + \frac{1}{\beta_1^L}\left(x_1^{L,dL} - x_1^L\right)$. Hence, trader L_i's expectations of trader S's order size at $t = 2$ is

$$\left[\beta_2^S\left(1 - \phi_L^l\right) - \beta_2^S \phi_L^u\right]\frac{1}{I}l + \left[\beta_2^S \phi_L^l + \beta_2^S \phi_L^u + \alpha^S\right]\left(T + \frac{1}{\beta_1^L}\left(x_1^{dL_i} - x_1^{L_i}\right)\right)_i$$

and of all other L_j's order is $-\beta_2^L \phi_L^l \frac{1}{I} l_i + \left[\beta_2^L \phi_L^l + (I-1)\alpha^L\right]\left(T + \frac{1}{\beta_1^L}\left(x_1^{dL_i} - x_1^{L_i}\right)\right)$. Price p_2 is also distorted. The market maker's best estimate of v prior to trading in $t = 2$ is $s + \phi_{mm}^l\left(T^{dL_i}\right)$ and after observing $X_2^{dL_i}$,

$$= \lambda_2 x_2^{dL_i} + \left[\frac{1}{4C}\phi_S^l - \frac{\phi_S^l + 4C - 2}{4C}\phi_L^l - \frac{1}{4C}\phi_S^l \phi_L^u \right] \frac{1}{I} l_i + DT^{dL_i}$$

where $D = \left\{ \phi_{mm}^l + \left(\frac{\phi_S^l + 2C - 2}{2C} \right) \left(\phi_L^l - \phi_{mm}^l \right) + 2 \frac{1}{4C} \phi_S^l \left(\phi_L^u - \phi_{mm}^u \right) \right\}$.

Trader L_i's optimal trading rule in $t = 2$ after deviation in $t = 1$ is the result of $\max_{x_2^{dL_i}} E[x_2^{dL_i} (s + l - p_2) | \frac{1}{I} l_i, T^{dL_i}, T]$. Deriving the FOC and replacing the coefficients shows that the optimal order at $t = 2$ after a deviation at $t = 1$ is

$$x_2^{dL_i,*} = x_2^{L_i} - D \frac{1}{2\lambda_2} \frac{1}{\beta_1^L} \left(x_1^{dL_i} - x_1^{L_i} \right).$$

if the second order condition $\lambda_2 > 0$ is satisfied.

Trader L_i's value function $V^{L_i}(x_1^{dL_i}) = x_2^{dL_i,*} E[s + l - p_2 | \frac{1}{I} l_i, T^{dL_i}, T]$. Following the same steps as for trader S, it is easy to show that $V^{L_i}(x_1^{dL_i}) = \lambda_2 \left[x_2^{dL_i} \right]^2 = \lambda_2 \left[x_2^{L_i} - D \frac{1}{2\lambda_2} \frac{1}{\beta_1^L} \left(x_1^{dL_i} - x_1^{L_i} \right) \right]^2$.

Trader L_i's optimization problem in $t = 1$ is thus $\max_{x_1^{dL_i}} E[x_1^{dL_i} \left(v - p_1^{dL} \right) + V_2^L(x_1^{dL_i}) | \frac{1}{I} l_i]$, where $E \left[v | \frac{1}{I} l_i \right] = \frac{1}{I} l_i$ and $E \left[p_1^{dL} | \frac{1}{I} l_i \right] = \lambda_1 x_1^{dL_i}$. The first order condition is $2\lambda_1 x_1^{dL_i} = \frac{1}{I} l_i + \frac{\partial E \left[V^L | \frac{1}{I} l_i \right]}{\partial x_1^{L_i,dL_i}}$. Note that

$$\begin{aligned} \frac{\partial E \left[V^L | \frac{1}{I} l_i \right]}{\partial x_1^{L_i,dL_i}} &= -D \frac{1}{\beta_1^L} E \left[x_2^{L_i} - D \frac{1}{2\lambda_2} \frac{1}{\beta_1^L} \left(x_1^{dL_i} - x_1^{L_i} \right) | \frac{1}{I} l_i \right] \\ &= -D \frac{1}{\beta_1^L} \left(\beta_2^L + \alpha^L \right) \left(\frac{1}{I} l_i \right) + (D)^2 \frac{1}{2\lambda_2} \left(\frac{1}{\beta_1^L} \right)^2 \left(x_1^{dL_i} - x_1^{L_i} \right) \end{aligned}$$

since $E \left[x_2^{L_i} | \frac{1}{I} l_i \right] = \beta_2^L \left(\frac{1}{I} l_i \right) + \alpha^L E \left[T | \frac{1}{I} l_i \right] = \left(\beta_2^L + \alpha^L \right) \left(\frac{1}{I} l_i \right)$. In equilibrium $x_1^{dL_i} = x_1^{L_i}$ and hence

$$\beta_1^L = \frac{1}{2\lambda_1} \left[1 - \frac{D}{\beta_1^L} \left(\beta_2^L + \alpha^L \right) \right].$$

The second order condition is given by $-2\lambda_1 + (D)^2 \frac{1}{2\lambda_2} \left(\frac{1}{\beta_1^L} \right)^2 < 0$.

Note that $\lambda_1 = \frac{Cov[s, X_1] + Cov[l, X_1]}{Var[X_1]} = \frac{Cov[s, X_1]}{Var[X_1]} + \frac{Cov[l, X_1]}{Var[X_1]} = \frac{\beta_1^S \Sigma_s + \beta_1^L}{\left(\beta_1^S \right)^2 (\Sigma + \sigma_\varepsilon^2) + \left(\beta_1^L \right)^2 + \sigma_{u1}^2}$.

This fully describes the sequentially rational **Bayesian Nash Equilibrium** for any number of L_i-traders. For tractability reasons we primarily consider the limiting case $I \to \infty$.

Limiting case $I \to \infty$.

Note that $\left(\phi_L^l - \phi_{mm}^l\right) \to 0$, $(\phi_L^u - \phi_{mm}^u) \to 0$, $D - \phi_{mm}^l \to 0$ as $I \to \infty$. Furthermore, the term $\lim_{I\to\infty} I\alpha^L = \frac{1}{\lambda_2 4D\phi_S^l}\left(\phi_{mm}^l\right)^2\left[\phi_S^l\left(\frac{\beta_1^S}{\beta_1^L}\right)^2\sigma_\varepsilon^2 - 2\left[\left(\frac{\beta_1^S}{\beta_1^L}\right)^2\sigma_\varepsilon^2 + \left(\frac{1}{\beta_1^L}\right)^2\sigma_{u1}^2\right]\right]$ drops out of the system of equations. By slightly abusing the notation we consider from now on all parameters for the limiting case.

After replacing the ϕ-terms, the sequentially rational Perfect Bayesian Nash Equilibrium is given by the following system of equations.

$$
\begin{aligned}
\beta_1^S &= \frac{1}{2\lambda_1}\frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}\left[1 - \frac{\lambda_2}{\lambda_1}\left(\frac{\alpha^S}{\beta_1^L}\right)^2\frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2}\right]^{-1} \\
\beta_1^L &= \left[2\lambda_1 + \frac{1}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2}\beta_2^L\right]^{-1} \\
\lambda_1 &= \frac{\beta_1^L + \beta_1^S\Sigma}{\left(\beta_1^S\right)^2(\Sigma+\sigma_\varepsilon^2) + \left(\beta_1^L\right)^2 + \sigma_{u1}^2} \\
\alpha^S &= -\frac{1}{2\lambda_2}\frac{1}{2C}\frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2} \\
\beta_2^S &= \frac{1}{2\lambda_2}\frac{1}{2C}\frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \sigma_{u1}^2} \\
\beta_2^L &= \frac{1}{2\lambda_2}\frac{2C-1}{C} \\
(\lambda_2)^2 &= \frac{\left(1 - \frac{\left(\beta_1^L\right)^2 + 2\sigma_{u1}^2}{4C\left[\left(\beta_1^L\right)^2 + \sigma_{u1}^2\right]}\right)\frac{\left(\beta_1^L\right)^2 + 2\sigma_{u1}^2}{4C\left[\left(\beta_1^L\right)^2 + \sigma_{u1}^2\right]}\left[\left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2\right]}{\sigma_{u2}^2\left[\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2\right]} \\
&\quad - \frac{\left(\frac{\beta_1^L}{4C\left[\left(\beta_1^L\right)^2 + \sigma_{u1}^2\right]}\right)^2\left[\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2\right]\sigma_{u1}^2}{\sigma_{u2}^2\left[\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2\right]} \\
C &= \frac{\frac{3}{4}\left(\beta_1^L\right)^2 + \sigma_{u1}^2}{\left(\beta_1^L\right)^2 + \sigma_{u1}^2} + \frac{1}{4}\frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2\sigma_\varepsilon^2 + \sigma_{u1}^2}
\end{aligned}
$$

■

A.2 Proof of Proposition 2

Speculative Trading

Trader S expects to trade $E[\alpha^S T + \beta_L^2 \left(l + \frac{1}{\beta_1^L} u_1 \right) |s+\varepsilon]$ in $t = 2$. Note that $E[T|s+\varepsilon] = \frac{\beta_1^S}{\beta_1^L} \frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2}(s+\varepsilon)$. Since $\alpha^S < 0$ and all other terms are positive, trader S expects to sell (buy) $\alpha^S \frac{\beta_1^S}{\beta_1^L} \frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2}(s+\varepsilon)$ stocks in $t = 2$ if he buys (sells) stocks in $t = 1$.

Manipulative Trading

Trader S trades excessively for manipulative reasons since $\beta_1^S > \beta_1^{S,\text{myopic}}$ (given the strategies of the other market participants).

$\beta_1^S = \frac{1}{2\lambda_1} \frac{\Sigma}{\Sigma+\sigma_\varepsilon^2} \left[1 - \frac{\lambda_2}{\lambda_1} \left(\frac{\alpha^S}{\beta_1^L} \right)^2 \frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2} \right]^{-1}$ whereas $\beta_1^{S,\text{myopic}} = \frac{1}{2\lambda_1} \frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}$. Thus manipulative trading is given by $\left[\frac{\lambda_1}{\lambda_2} \left(\frac{\beta_1^L}{\alpha^S} \right)^2 \frac{\Sigma+\sigma_\varepsilon^2}{\sigma_\varepsilon^2} - 1 \right]^{-1} (s+\varepsilon)$. The coefficient $\left[\frac{\lambda_1}{\lambda_2} \left(\frac{\beta_1^L}{\alpha^S} \right)^2 \frac{\Sigma+\sigma_\varepsilon^2}{\sigma_\varepsilon^2} - 1 \right]^{-1} > 0$ since the second order condition requires that $\lambda_1 \geq \lambda_2 \left(\frac{\alpha^S}{\beta_1^L} \right)^2$.

Note that for $\sigma_\varepsilon \to 0$, the coefficient goes to zero and hence, neither speculative nor manipulative trading will occur. ■

A.3 Proof of Proposition 3

This proposition compares two different equilibria: one with information leakage and one without. Let us denote all variables of the former equilibrium with upper bars and the equilibrium without information leakage with hat.

Lemma 2 *$\bar{\lambda}_1 > \hat{\lambda}_1$ for myopic background traders L.*

Proof of Lemma

Recall $\beta_1^S = \frac{1}{2\lambda_1} \frac{\Sigma}{\Sigma+\sigma_\varepsilon^2} [1+M]$, where $M = \left[\frac{\lambda_1}{\lambda_2} \left(\frac{\beta_1^L}{\alpha^S} \right)^2 \frac{\Sigma+\sigma_\varepsilon^2}{\sigma_\varepsilon^2} - 1 \right]^{-1}$ and $\beta_1^L = \frac{1}{2\lambda_1}[1-K]$, where $K = \frac{\frac{1}{2\lambda_1} \frac{1}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2} \beta_2^L}{1 + \frac{1}{2\lambda_1} \frac{1}{\left(\beta_1^L\right)^2 + \left(\beta_1^S\right)^2 \sigma_\varepsilon^2 + \sigma_{u1}^2} \beta_2^L}$.

$$\lambda_1 = \frac{\frac{1}{2\lambda_1} \frac{\Sigma^2}{\Sigma+\sigma_\varepsilon^2} [1+M] + \frac{1}{2\lambda_1}[1-K]}{\frac{1}{4(\lambda_1)^2} [1+M]^2 \left(\frac{\Sigma}{\Sigma+\sigma_\varepsilon^2} \right)^2 (\Sigma + \sigma_\varepsilon^2) + \frac{1}{4(\lambda_1)^2} [1-K]^2 + \sigma_{u1}^2}.$$

Collecting all λ_1-terms yields,

$$\begin{aligned} (\lambda_1)^2 \sigma_{u1}^2 &= \left\{ \frac{1}{2}[1+M] - \frac{1}{4}[1+M]^2 \right\} \frac{\Sigma^2}{\Sigma+\sigma_\varepsilon^2} + \left\{ \frac{1}{2}[1-K] - \frac{1}{4}[1-K]^2 \right\} \\ (\lambda_1)^2 &= \frac{1}{\sigma_{u1}^2} \left\{ \frac{1}{4} \left(1 - M^2\right) \frac{\Sigma^2}{\Sigma+\sigma_\varepsilon^2} + \frac{1}{4} \left(1 - K^2\right) \right\} \end{aligned}$$

For myopic background traders $K = 0$. Note that in the case without information leakage the first term is zero. Hence $\bar{\lambda}_1 > \hat{\lambda}_1$. Furthermore, the myopic trading intensities for the background traders L_i are $\bar{\beta}_1^L = \frac{1}{2\bar{\lambda}_1} < \frac{1}{2\hat{\lambda}_1} = \hat{\beta}_1^L$. ∎

Prior to public announcement

Informativeness

$\bar{p}_1$ is more informative than $\hat{p}_1$, i.e. $Var\left[s + l|\bar{X}_1\right] < Var\left[s + l|\hat{X}_1\right]$.

$Var\left[s + l|\bar{X}_1\right] = \Sigma + 1 - \bar{\lambda}_1 Cov\left[s + l, \bar{X}_1\right] = \Sigma + 1 - \lambda_1 \bar{\beta}_1^S \Sigma - \lambda_1 \bar{\beta}_1^L = \left(1 - \lambda_1 \bar{\beta}_1^S\right)\Sigma + \frac{1}{2}$.

In contrast, $Var\left[s + l|\hat{X}_1\right] = \Sigma + 1 - \bar{\lambda}_1 Cov\left[l, \hat{X}_1\right] = \Sigma + 1 - \tilde{\lambda}_1 \hat{\beta}_1^L = \Sigma + \frac{1}{2}$.

Informational Efficiency

$\bar{p}_1$ is less informationally efficient than $\tilde{p}_1$, i.e. $Var[E\left[s|s + \varepsilon\right] + l|\bar{X}_1] > Var[l|\hat{\beta}_1^L l + u_1]$.

$Var[E\left[s|s + \varepsilon\right] + l|X_1] = Var[\frac{\Sigma}{\Sigma + \sigma_\varepsilon^2}\left(s + \varepsilon\right) + l|\bar{\beta}_1^S\left(s + \varepsilon\right) + \bar{\beta}_1^L l + u_1] =$

$= Var\left[\frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}\left(s + \varepsilon\right) + l\right] - \frac{\left[\frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}\bar{\beta}_1^S\left(\Sigma+\sigma_\varepsilon^2\right)+\bar{\beta}_1^L\right]^2}{\left(\bar{\beta}_1^S\right)^2(\Sigma+\sigma_\varepsilon^2)+\left(\bar{\beta}_1^L\right)^2+\sigma_{u1}^2} = \frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}\left(\Sigma + \sigma_\varepsilon^2\right) + 1 - \frac{\left[\Sigma\beta_1^S+\beta_1^L\right]^2}{\left(\beta_1^S\right)^2(\Sigma+\sigma_\varepsilon^2)+\left(\beta_1^L\right)^2+\sigma_{u1}^2} =$

$= \Sigma + 1 - \bar{\lambda}_1\left(\Sigma\bar{\beta}_1^S + \bar{\beta}_1^L\right) = \Sigma + \frac{1}{2} - \bar{\lambda}_1\Sigma\bar{\beta}_1^S = \frac{1}{2} + \left(1 - \bar{\lambda}_1\bar{\beta}_1^S\right)\Sigma.$

Note that $\bar{\lambda}_1\bar{\beta}_1^S = \frac{1}{2}\frac{\Sigma}{\Sigma+\sigma_\varepsilon^2}\left[1 - \frac{\lambda_2}{\lambda_1}\left(\frac{\alpha^S}{\bar{\beta}_1^L}\right)^2\frac{\sigma_\varepsilon^2}{\Sigma+\sigma_\varepsilon^2}\right]^{-1} = \frac{\frac{1}{2}\Sigma}{\Sigma+\left[1-\frac{\lambda_2}{\lambda_1}\left(\frac{\alpha^S}{\bar{\beta}_1^L}\right)^2\right]\sigma_\varepsilon^2} < 1$ since by the SOC, $1 - \frac{\lambda_2}{\lambda_1}\left(\frac{\alpha^S}{\bar{\beta}_1^L}\right)^2 > 0$.

In contrast, $Var[l|\hat{\beta}_1^L l + u_1] = 1 - \frac{\left[\hat{\beta}_1^L\right]^2}{\left(\hat{\beta}_1^L\right)^2+\sigma_{u1}^2} = 1 - \tilde{\lambda}_1\hat{\beta}_1^{L,\text{myopic}} = 1 - \frac{1}{2} = \frac{1}{2}$

Prior to trading in $t = 2$

Since $\bar{\beta}_1^L < \hat{\beta}_1^L$, then $\hat{T} = l + \frac{1}{\hat{\beta}_1^L}u_1$ is more informative than $\bar{T} = l + \frac{\bar{\beta}_1^S}{\bar{\beta}_1^L}\varepsilon + \frac{1}{\bar{\beta}_1^L}u_1$, even if $Var[\varepsilon] = 0$.

After trading in $t = 2$

The continuation game in $t = 2$ corresponds to a static Kyle (1985) model with multiple insiders. Note that public price signal, $\hat{T}$ in the case without information leakage is more informative than the private signal of trader S, $l + \frac{\bar{\beta}_1^S}{\bar{\beta}_1^L}\varepsilon + \frac{1}{\bar{\beta}_1^L}u_1$ in the case of information leakage. From this follows immediately that the prices are more informationally efficient and more informative in the case without information leakage from $t = 2$ onwards. ∎

A.4 Proof of Proposition 4

Note that $\tilde{\alpha}_1^S = \frac{1}{2\tilde{\lambda}_1}$ and the rest of the analysis is analogous to the one in Proposition 1. Therefore, we only add a tilde to all the coefficients. In any mixed strategy equilibrium, trader S has to be indifferent between any x_1^S, i.e. $\tilde{\lambda}_1 = \tilde{\lambda}_2 \left(\tilde{\alpha}^S/\tilde{\beta}_1^L\right)^2$. In addition, the second order condition of long-run information traders must hold

$$\begin{aligned} \tilde{\lambda}_1 &\geq \frac{1}{4\tilde{\lambda}_2}\tilde{D}^2\left(\frac{1}{\tilde{\beta}_1^L}\right)^2, \\ \tilde{\lambda}_2\left(\tilde{\alpha}^S/\tilde{\beta}_1^L\right)^2 &\geq \frac{1}{4\tilde{\lambda}_2}\tilde{D}^2\left(\frac{1}{\tilde{\beta}_1^L}\right)^2 \end{aligned}$$

Note that $\alpha^S = \frac{1}{4C\tilde{\lambda}_2}\frac{\left(\tilde{\beta}_1^L\right)^2}{\left(\tilde{\beta}_1^L\right)^2+\left(\tilde{\beta}_1^S\right)^2\sigma_\varepsilon^2+\sigma_{u1}^2}$ and recall $\tilde{D} = \frac{\left(\tilde{\beta}_1^L\right)^2}{\left(\tilde{\beta}_1^L\right)^2+\left(\tilde{\beta}_1^S\right)^2\sigma_\varepsilon^2+\sigma_{u1}^2}$ for $I \to \infty$. Hence, both necessary conditions are only satisfied if $\frac{1}{4C^2} > 1$. Since $C = \frac{\frac{3}{4}\left(\beta_1^L\right)^2+\sigma_{u1}^2}{\left(\beta_1^L\right)^2+\sigma_{u1}^2} + \frac{1}{4}\frac{\left(\beta_1^L\right)^2}{\left(\beta_1^L\right)^2+\left(\beta_1^S\right)^2\sigma_\varepsilon^2+\sigma_{u1}^2} > \frac{1}{2}$, this is never satisfied. ■

A.5 Expected Profit of Short-run Information Trader

Trader S's expected profit is $E\left[x_1^S\left(\frac{\Sigma_s}{\Sigma_s+\sigma_\varepsilon^2}(s+\varepsilon)-\lambda_1 x_1^S\right)\right]+\lambda_2 E\left[\left(x_2^S\right)^2\right]$. That is,
$E\left[\beta_1^S(s+\varepsilon)\left(\frac{\Sigma_s}{\Sigma_s+\sigma_\varepsilon^2}(s+\varepsilon)-\lambda_1\beta_1^S(s+\varepsilon)\right)\right]+\lambda_2 E\left[\left(\beta_2^S\left(l+\frac{1}{\beta_1^L}u_1\right)+\alpha^S\left(l+\frac{\beta_1^S}{\beta_1^L}\varepsilon_1+\frac{1}{\beta_1^L}u_1\right)\right)^2\right]$.
Taking expectations yields $\beta_1^S\left(\Sigma-\lambda_1\beta_1^S\left[\Sigma+\sigma_\varepsilon^2\right]\right)+\lambda_2\left[\beta_2^S+\alpha^S\right]^2\left[1+\left(\frac{1}{\beta_1^L}\right)^2\sigma_1\right]+\lambda_2\left(\alpha^S\right)^2\left[\left(\frac{\beta_1^S}{\beta_1^L}\right)^2\sigma_\varepsilon^2\right]$.

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