



Competition in the stock market with asymmetric information



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ABSTRACT

We build a game theoretical model to examine how the level of information advantage of insiders and the competition between insiders and sophisticated investors affect stock price movements and traders' trading strategies and profits. We show that the competition between insiders and sophisticated investors can reduce the losses of less sophisticated investors, and thus alleviates the disadvantaged position of the less sophisticated investors. Further, traders' profits are affected by the accuracy of insiders' private information, and the number of days that insiders have obtained the information in advance. These findings show the importance of information transparency and the role of sophisticated investors in limiting insiders' trading advantages and mitigating the expropriation of investors by insiders.

1. Introduction

It has been widely acknowledged that investors are asymmetrically informed. A large body of research has examined the possibility of insiders' making profits by trading on private information in the stock market. The strong form of the efficient market hypothesis (Fama, 1970) characterizes a market where public and private information are fully reflected in prices, and no individual can earn higher expected trading profits than others. Although most of countries have enacted laws and rules deterring insiders from trading with private information (Bhattacharya and Daouk, 2002), prior studies report that insiders can circumvent such regulations by trading strategically (e.g., Noe, 1999; Ke et al., 2003; Jagolinzer, 2009), and earn profits by trading on inside information (e.g., Jaffe, 1974; Finnerty, 1976; Leland, 1992; Noe, 1999; Fried, 2000; Jagolinzer, 2009; Louis et al., 2010; Narayan et al., 2014; Westerlund and Narayan, 2015). Such findings are inconsistent with the strong form of the efficient market hypothesis.

The effect of insider trading on asset pricing has been widely debated in the literature. Critics of insider trading have made a wide array of arguments against insider trading. It is argued that allowing insiders to trade creates a perverse incentive for managers to make investment in risky projects to increase their trading profits at the expense of firm value (Carlton and Fischel, 1983). If uninformed traders know they are uninformed and believe that they would be better off not trading (Carlton and Fischel, 1983), insider trading can

give rise to adverse selection problem and thus reduce market liquidity. Insider trading may also make current stock prices more volatile, which will hurt liquidity traders (Leland, 1992; Wang, 1993). In contrast, proponents of insider trading argue that, in a world of costly monitoring and imperfect information, insider trading provides a way of communicating information to outsiders that allows new private information to be revealed and priced rapidly and thus contributes to market efficiency (Carlton and Fischel, 1983; Holden and Subrahmanyam, 1992; Aktas et al., 2008; Chau and Vayanos, 2008; Hsu and Lee, 2014). Despite continued debate on the effects of insider trading on asset pricing and market efficiency, it has been acknowledged that the potential contribution of insiders' trades to price discovery and market efficiency depends on the ability of other traders to identify insider trading (Carlton and Fischel, 1983), and that insiders' trading profits are achieved at the expense of outside investors (Leland, 1992).

In this paper, we analyze the effects of asymmetric information on insider trading through a new direction. We develop a model in which the following three roles have asymmetric information about the market: an insider, an information follower, and a price-sensitive trader. Specifically, this study explores the trading strategies used by each of these three roles, how the stock price moves after the insider obtains information about future news events, and how the competition between the insider and the information follower affects traders' trading strategies and profits. Unlike previous research, in our model,

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the insider has some inside information about a future event, but he/she is not necessarily certain that the event will occur, the information follower analyzes the actions of the insider to decide his/her trading strategies, and the price-sensitive trader follows a trading strategy in which he/she buys when prices decline and sells when prices increase.

The three roles in the model commonly exist in the real world. The empirical literature and insider trading laws and regulations generally define the management or large shareholders of listed companies as insiders (e.g., Chaney and Lewis, 1995). Sophisticated investors such as institutional investors reflect the information follower role in the model; they have the incentive and ability to collect firm-specific information and analyze insiders' trading activities (Ajinkya et al., 2005). The price-sensitive trader reflects a less sophisticated type of investor (e.g., common small investors and some nonprofit institutions) that does not have the expertise or incentives to collect and analyze information to make investment decisions, and tends to buy when prices decline and sell when prices increase. This trading strategy of buying losers and selling winners adopted by less sophisticated investors has been well documented by empirical and experimental studies on both developed and less developed markets (e.g., Shefrin and Statman, 1985; Weber and Camerer, 1998; Odean, 1999; Grinblatt and Keloharju, 2000, 2001; Oehler et al., 2003; Ng and Wu, 2007).

This paper contributes to the literature in a number of ways. First, it extends the literature on insider trading by linking insider trading profits to levels of information asymmetry and information environment in the market. Our study relates to, but is different from, prior studies that build models to analyze insiders' trading strategies and profits under information asymmetry. In a seminal article, Kyle (1985) builds a dynamic model of insider trading with sequential auctions, and shows that insiders make profits from inside information. In Kyle's model, only the monopolistic insider knows the *ex post* liquidation value of the risky asset while noise traders trade randomly, and market makers set prices efficiently. Subsequent studies introduce multiple insiders into Kyle's model to examine competition between insiders and market efficiency, and show that competing insiders generally reveal their information faster than monopolists, and that competition among insiders reduces the profitability of their trades (e.g., Holden and Subrahmanyam, 1992; Foster and Viswanathan, 1996; Back et al., 2000). Some recent studies also incorporate public disclosure into their models. Baiman and Verrecchia (1996) show that the expected profits of insider trading decrease as financial disclosure becomes more precise. Huddart et al. (2001) and Liu and Zhang (2011) find that the public disclosure of insider trading accelerates the price discovery process, increases market efficiency and lowers insider profits, while Grégoire and Huang (2012) present a trading game and show that under certain circumstances, insiders may benefit from publicly disclosing information to the market. Gong and Liu (2012) show that the public disclosure of insiders' trades and competition among insiders lead to accelerated price discovery and higher market depths.

However, the models proposed by prior studies do not fully capture the characteristics of inside information and the information environment. In real world financial markets, the level of information asymmetry between insiders and outsiders is likely to vary depending on insiders' information advantages in specific circumstances such as the nature of the news, the level of the insiders' privileged access to the private information, and the characteristics of the firms. For example, managers' inside information about earnings to be announced in their firms' financial reports is likely to be more accurate than their inside information about potential merger deals, as the latter is likely to be affected by factors beyond the managers' control such as the other parties' bargaining power and market conditions. Similarly, previous studies (e.g., Seyhun, 1986; Lakonishok and Lee, 2001) show that insiders have better information advantages in small firms than in large firms. Further, some insiders such as the chairperson of a board of directors are more knowledgeable with the overall affairs of a firm, and thus have a greater predictive ability of future stock price movements

(e.g., Seyhun, 1986). Additionally, if aware of information asymmetry, some uninformed traders may gather information to reduce their information disadvantage (Admati and Pfleiderer, 1988; Barth et al., 2001). Conversely, other uninformed traders may not have the expertise, or incentives to collect and analyze information to make investment decisions. Thus, it is reasonable to expect that information asymmetry varies among uninformed traders.

The novelty of the model proposed in this study is that it seeks to capture the level of information advantage of insiders by using the level of accuracy of the inside information and the length of the timing advantage of the inside information. In addition, it accounts for varying levels of investor sophistication among outsiders by distinguishing between more sophisticated investors (the information follower in our model) and less sophisticated investors (the price-sensitive trader in our model). The model allows us to better approximate information asymmetry problems in real world financial markets, and to provide insight into how varying levels of insiders' information advantages and competition between insiders and sophisticated investors determine traders' trading profits and stock price movements.

The second contribution of the paper is that it adds to the literature on stock price movements by reconciling the conflicting evidence on the effects that news events have on stock price movements. Some studies (e.g., Cutler et al., 1989; Mitchell and Mulherin, 1994) find that news events play a minor role in stock price movements; however, other studies show that price jumps are related to unexpected extreme news (Asgharian et al., 2011), or associated with pre-scheduled earnings announcements and other company-specific news events (Lee and Mykland, 2008). Our model reconciles this conflict by showing that price jumps are related not only to the effects of news events, but also to the accuracy of insiders' private information.

The findings of this study also have practical and policy implications that will be of interest to policy makers and market participants concerned with insiders' strategic trades and interested in limiting insiders' trading advantages. Previous studies (e.g., Leland, 1992) show that insider trading profits are earned at the expense of outside investors. However, our model shows that competition between the insider and the information follower can alleviate the disadvantaged position of the price-sensitive trader. The findings emphasize the important role of sophisticated investors in limiting the ability of insiders to earn profits using private information and mitigating the expropriation of outsiders by insiders. These findings are consistent with the findings of Frankel and Li (2004), who find that increased analyst following is associated with the reduced profitability of insider trades.

The remainder of the paper is organized as follows. Section 2 discusses the assumptions of the proposed model. Section 3 analyzes the strategies of the insider and the information follower and how stock price moves. Next, a Monte Carlo simulation is designed to understand the premiums of different roles and stock price movements. The last section concludes the paper.

2. Assumptions

The model assumes that there is only one stock and three roles in the stock market: (i) an insider; (ii) an information follower; and (iii) a price-sensitive trader.

2.1. Assumption 1: economic state

In our model, we define a variable that only reflects news events that have occurred. We call this new variable 'economic state' or e . We assume that:

- (1) the economic state can only be changed by the occurrence of a news event;
- (2) each role in the stock market cannot precisely know the previous

- economic state, the current economic state, or the future economic state; and
- (3) the price of the stock is affected by the current economic state; that is, the opening price of the stock on day $i + 1$ ($p_{o(i+1)}$) is determined by the closing price of the stock on the previous trading day (p_{ci}) and the current economic state:

$$p_{o(i+1)} = \alpha p_{ci} + (1-\alpha)e_{i+1} + \varepsilon_{i+1} \quad (1)$$

where e_{i+1} is the current economic state; ε_{i+1} is a disturbance term, $E(\varepsilon_{i+1})=0$; $0 < \alpha < 1$.

2.2. Assumption 2: news events

A news event is defined as information that can change the economic state; that is, when a news event occurs, the economic state changes from e to $e + \Delta e$, where Δe represents the effect of the news event, $\Delta e > 0$ refers to a positive news event, and $\Delta e < 0$ refers to a bad news event.

We assume that there are two types of news events. First, a news event scheduled to occur on a specified day (e.g., an earnings announcement of a company to be released to the stock market on a pre-scheduled date). Second, a news event that occurs during a period (e.g., significant corporate events such as mergers, acquisitions, and changes in corporate control that need to pass various hurdles before completion, including negotiations with deal parties, and gaining the approval of shareholders and regulators, which are not fully under the control of insiders or a particular party). In relation to the second type of news events, while it is possible for some traders to estimate the timeframe for the completion of the transactions during the proposal stage due to their informational advantage, a precise date for the completion of the transaction cannot be known before the deal proposals pass all the necessary hurdles.

Significant news events are normally announced after trading hours, or during trading halts. Thus, we assume (without a loss of generality) that no news events occur during trading hours (i.e., that all news events occur after the stock market has closed). We also assume that a maximum of one news event can occur between the close of the stock market on day i and the opening of the stock market on day $i + 1$. We describe this news event as the news event that occurs on day i .

2.3. Assumption 3: roles in the stock market

It is widely acknowledged that insiders can make a profit using their private information; however, there is no agreed definition of an insider. In Kyle's (1985) model, an insider is defined as a person who knows the liquidation value of a risky asset. In Wang's (1993) model, insiders have different information concerning the future growth rate of dividends and they rationally extract information from prices and dividends to maximize their expected profit. In this study, we define an insider as a person who has private information about a future news event and wants to use this information to earn a profit. Thus: (i) the insider knows the type of future news event, the specified date for the first type of news event, and the range of the dates for the second type of news event; (ii) the insider has private information about the effects of the news event, Δe ; and (iii) the insider is not necessarily certain about the occurrence of the news event (i.e., he/she only knows of the occurrence of the news event with a certain probability. We use this probability as a measure of the accuracy of the inside information in our model); (iv) after trading hours, the insider knows the quantity of stock that the information follower has bought or sold that day.

Aware of information asymmetry, some traders are likely to gather information based on their own research and expertise (e.g., by analyzing company announcements and news reports, and observing stock price changes and trading), or via intermediaries (e.g., financial analysts and investment advisors) (Admati and Pfleiderer, 1988; Barth

et al., 2001; Grégoire and Huang, 2012). We define the information follower as someone who has the ability to analyze the stock market and observe the actions (i.e., the purchase or sale of shares) of insiders. Thus: (i) the information follower knows the type of the future news event, as well as the specified date for the first type of news event, and the range of the dates for the second type of news event; (ii) the information follower does NOT have private information about the effects of the future news event; (iii) after the trading hours, the information follower knows the quantity of stock that the insider has bought or sold that day; and (iv) after a news event occurs, the information follower knows the effects of the news event.

A price-sensitive trader is defined as a person who does not have inside information, or any expertise or incentive to collect and analyze information about the stock market. In our model, this role provides liquidity to the market. The price-sensitive trader follows a trading strategy whereby he/she buys shares when stock price drops and sells shares when stock price increases. We express the relation between the quantity of the stock the price-sensitive trader has traded till time t and the price change of the stock till time t on a trading day as: $q_{3ti}/q_{total} = -\gamma^*((p_{ti} - p_{oi})/p_{oi})$, where $\gamma > 0$, p_{ti} and p_{oi} are the price at time t and the opening price of the stock on trading day i , respectively, q_{3ti} is the quantity of stock that the price-sensitive trader has traded by time t on trading day i , and q_{total} is the total number of shares of the stock. We note that $q_{total} = 1$ and q_{3ti} is the proportion of the total number of shares the price-sensitive investor trades, thus q_{3ti} is a rational number between -1 and 1 ($q_{3ti} > 0$ means the price-sensitive trader buys shares and $q_{3ti} < 0$ means the price-sensitive trader sells shares). Given that q_{total} equals 1, the relation between the quantity of stock that the price-sensitive trader has traded by time t on trading day i and the price change of the stock is simplified to: $q_{3ti} = -\gamma^*((p_{ti} - p_{oi})/p_{oi})$. If t is the closing time on trading day i , the equation becomes $q_{3i} = -\gamma^*((p_{ci} - p_{oi})/p_{oi})$, where q_{3i} is the proportion of the total number of shares the price-sensitive investor has traded by closing time on trading day i , and p_{ci} is the closing price on trading day i .

Additionally, we assume that if there are two roles buying (or selling) stock on a trading day, the average price of shares purchased (or sold) is the same for both roles. With Assumptions 1–3, we can obtain a corollary about the relation between stock prices and the economic state.

Corollary 1. If the insider and the information follower buy or sell stock on limited days, and limited news events occur during a period from day 0 to day n , the limitation of the expected stock price equals the economic state e_n (proof: see the Appendix).

$$\lim_{n \rightarrow \infty} E(p_{on}(= p_{cn})) = e_n \quad (2)$$

This corollary shows that the price of the stock is determined by the economic state. The three roles are able to estimate the economic state based on the current price of the stock.

3. Stock price movements and the premiums of the three roles

3.1. The challenges faced by the insider and the information follower

Investors' profits are normally measured by changes in stock prices, while stock prices are affected by the sale or purchase of shares. This poses a challenge in calculating market participants' expected profits. In this paper, to allow for measuring the impact of market participants' trading strategies on their subsequent expected profits, we propose a new variable economic state e , which determines stock price (see Corollary 1). We then define a new index to measure a role's premium:

$$\pi = (e - p)^*q \quad (3)$$

where e is the current economic state, and q and p are the quantity and

the average price of the shares bought by a role, respectively. The index shows that the profit of a role depends on the difference between the current economic state and the average price that he/she has paid for the shares.

Thus, the challenge for the insider and the information follower is to maximize their premiums for the two types of news events, one that occurs on a specified date, and the other that occurs over a range of days.

3.1.1. Case 1: the news event occurs on a specified date

After the trading hours on day j , the insider has inside information that on day $j + n$ a news event will occur with probability of P ($P > 0$). The change of the economic state caused by the news event is Δe . The insider has to decide how much he/she should buy on days $j + 1, j + 2, j + 3, \dots, j + n, j + n + 1$ to maximize his/her premium. Thus:

$$\pi_1 = E(e_{j+n+1} * (\sum_{i=1}^{n+1} q_{1(j+i)}) - \sum_{i=1}^{n+1} (p_{1(j+i)} * q_{1(j+i)})) \tag{4}$$

where e_{j+n+1} is the economic state on day $j + n + 1$, $q_{1(j+i)}$ is the quantity the insider buys on day $j + i$, and $p_{1(j+i)}$ is the average price of the stock that the insider buys on day $j + i$.

After trading hours, the information follower knows the quantity that the insider bought on this day and has to decide how much he/she should buy on days $j + 2, j + 3, \dots, j + n, j + n + 1$ to maximize his/her premium. Thus:

$$\pi_2 = E(e_{j+n+1} * (\sum_{i=2}^{n+1} q_{2(j+i)}) - \sum_{i=2}^{n+1} (p_{2(j+i)} * q_{2(j+i)})) \tag{5}$$

where $q_{2(j+i)}$ is the quantity that the information follower buys on day $j + i$, and $p_{2(j+i)}$ is the average price of the stock that the information follower buys on day $j + i$.

As the news event occurs with certain probability, the quantity of shares that the insider and the information follower buy on day $j + n + 1$ is conditional on the occurrence of the news event. Accordingly, it is noted as:

$$q_{m(j+n+1)} = \begin{cases} q_{m(j+n+1)}^h & \text{when the news event occurs} \\ q_{m(j+n+1)}^n & \text{when the news event does not occur} \end{cases}$$

where $m = 1$ denotes the insider, and $m = 2$ denotes the information follower.

3.1.2. Case 2: the news event occurs over a range of days

On day j , the insider obtains the inside information that, before day $j + n + 1$, a news event will occur with probability of P_{j+l} on day $j + l$, $1 \leq l \leq n$. $P_{j+1} + P_{j+2} + \dots + P_{j+n} \leq 1$. If this news event does not occur before day $j + n + 1$, it will never occur. The changing of the economic state caused by this news event is Δe . Thus, the insider has to decide the quantity of stock he/she should buy on days $j + 1, j + 2, j + 3, \dots, j + k, j + k + 1$ to maximize his/her premium:

$$\pi_1 = E(e_{j+k+1} * (\sum_{i=1}^{k+1} q_{1(j+i)}) - \sum_{i=1}^{k+1} (p_{1(j+i)} * q_{1(j+i)})) \tag{6}$$

$$k = \begin{cases} k & \text{the news event occurs on day } j+k \\ n & \text{the news event does not occur as expected} \end{cases}$$

where e_{j+k+1} is the economic state on day $j + k + 1$, and $q_{1(j+i)}$ and $p_{1(j+i)}$ are as defined in Section 3.1.1.

After trading hours, the information follower knows the quantity of stock that the insider has bought on the day. The information follower then has to decide what quantity of stock to buy on days $j + 2, j + 3, \dots, j + k + 1$ to maximize his/her premium. Thus:

$$\pi_2 = E(e_{j+k+1} * (\sum_{i=2}^{k+1} q_{2(j+i)}) - \sum_{i=2}^{k+1} (p_{2(j+i)} * q_{2(j+i)})) \tag{7}$$

where $q_{2(j+i)}$ and $p_{2(j+i)}$ are as defined in Section 3.1.1.

Given that the news event occurs with certain probability, the quantity of the stock that the insider and the information follower buy on day $j + i$ depends on whether the news event occurs. It is noted as:

$$q_{m(j+i)} = \begin{cases} q_{m(j+i)}^n & \text{the news event does not occur before day } j + i \\ q_{m(j+i)}^h & \text{the news event occurs on day } j + i - 1 \end{cases}$$

where $m = 1$ denotes the insider, and $m = 2$ denotes the information follower.

The gain (or loss) to the insider and the information follower is exactly balanced by the loss (or gain) to the price-sensitive trader. The premium of the price-sensitive trader is defined as:

$$\pi_3 = -(\pi_1 + \pi_2) \tag{8}$$

In our model, the information follower can only know the quantity of stock purchased/sold by the insider after the trading hours and then has to decide the quantity of stock to buy/sell the next day. Thus, the insider can set a trap for the information follower; for example, on one day, if the insider buys q_{1i} shares of stock, on the next trading day the information follower will buy $q_{2(j+1)}$ shares (i.e., a quantity larger than $2q_{1i}$). However, if the insider is aware of the information follower's strategy, he/she can use the following strategy: on day 1, he/she buys q_{1i} shares of the stock and sells q_{1i} shares of the stock on day 2. Using this strategy, the insider can earn a profit without any risk. Vila (1989) discusses a similar real-life example whereby agents spread false rumors about a company and make profits by "shorting" the stock. Our model shows that an insider could earn a profit by giving a wrong signal to an information follower. This wrong signal is similar to the false rumors in Vila's (1989) example.

In the following sections, we do not allow the insider to set a trap for the information follower. Thus, we assume that:

Assumption 4. If the insider knows that a good (bad) news event will occur in the future with certain probability, in the following days, he/she cannot sell (buy) the stock until the news event occurs or until it is certain that the news event will never occur.

Thus, if the insider knows that a good news event will occur in Case 1, he/she cannot sell the stock before or on day $j + n$; in Case 2, he/she cannot sell the stock before or on day $j + k$.

3.2. The insider and the information follower's best strategies and the stock price movements

In our model, the insider's actions (i.e., the purchases or sales) affect the premium of the information follower and vice versa. Thus, the insider (or the information follower) has to analyze the strategy of the information follower (or the insider) and choose his/her response accordingly. The insider and the information follower adjust their responses until they are mutually consistent.

3.2.1. Case 1: the news event occurs on a specified date

In Case 1, on day j , the insider knows that a good news event will occur with probability of P . On day $j+2$, the information follower knows that a good news event will occur by observing the insider's purchase of shares on day $j + 1$. He/she is then able to buy any quantity of shares of the stock, which the insider knows. With $q_{1(j+i)} + q_{2(j+i)} + q_{3(j+i)} = 0$, $q_{3(j+i)} = -\gamma * ((p_{c(j+i)} - p_{o(j+i)}) / p_{o(j+i)})$, where $q_{1(j+i)}$, $q_{2(j+i)}$ and $q_{3(j+i)}$ are the proportions of the total number of shares traded by the insider, the information follower, and the price-sensitive trader on trading day $j + i$, respectively, we have $p_{c(j+i)} = p_{o(j+i)} + \frac{1}{\gamma} q_{1(j+i)} p_{o(j+i)}$. The average price of the stock the insider bought on day $j + i$ can be calculated based on $p_{1(j+i)} = p_{o(j+i)} + \frac{1}{\gamma} q_{1(j+i)} p_{o(j+i)}$:

$$p_{1(j+i)} = \frac{\int_0^{q_{1(j+i)}} (p_{o(j+i)} + \frac{1}{\gamma} q p_{o(j+i)}) d(q)}{q_{1(j+i)}} = p_{o(j+i)} \left(1 + \frac{1}{2\gamma} q_{1(j+i)} \right) \quad (9)$$

Thus, for the insider, the best strategy on day $j+1$ is to maximize his/her premium on day $j+1$:

$$\begin{aligned} \max : \pi_{1(j+1)} &= E(e_{j+n+1} * q_{1(j+1)} - (p_{1(j+1)} * q_{1(j+1)})) \\ &= ((e_j + \Delta e) * q_{1(j+1)} - (p_{1(j+1)} * q_{1(j+1)}))P \\ &\quad + ((e_j) * q_{1(j+1)} - (p_{1(j+1)} * q_{1(j+1)}))(1-P) \end{aligned}$$

$$s.t. \quad p_{1(j+1)} = p_{o(j+i)} \left(1 + \frac{1}{2\gamma} q_{1(j+1)} \right)$$

The solution to this problem is:

$$q_{1(j+1)} = \gamma \left(\frac{\Delta e P + e_j}{p_{o(j+1)}} - 1 \right) \quad (10)$$

We can then get $p_{c(j+1)} = \Delta e P + e_j$. From Corollary 1, the insider can use $p_{o(j+1)}$ to estimate e_j , then $q_{1(j+1)} = \gamma \Delta e P$. The best strategy is to buy $\gamma \Delta e P$ shares of the stock and increase the stock price by Δp , where $\Delta p = \Delta e P$. Thus, if he/she buys shares at a price higher than $\Delta e P + e_j$, the expected premium will be negative.

On day $j+2$, the information follower knows that the insider wants to maximize his/her premium on day $j+1$. He/she can then use $p_{c(j+1)} = \Delta e P + e_j$ to estimate the break-even point, $\Delta e P + e_j$. Thus, the information follower knows that his/her expected premium will be positive (or negative) if he/she buys the stock with a price lower (or higher) than $\Delta e P + e_j$. The insider wants to maximize his/her premium on day $j+2$. Similarly, the information follower also wants to maximize his/her premium on day $j+2$:

$$\max : \pi_{1(j+2)} = ((e_j + \Delta e) * q_{1(j+2)} - (p_{1(j+2)} * q_{1(j+2)}))P + (e_j * q_{1(j+2)} - (p_{1(j+2)} * q_{1(j+2)}))(1-P)$$

$$\max : \pi_{2(j+2)} = ((e_j + \Delta e) * q_{2(j+2)} - (p_{2(j+2)} * q_{2(j+2)}))P + (e_j * q_{2(j+2)} - (p_{2(j+2)} * q_{2(j+2)}))(1-P)$$

With Assumption 3, we know the insider and the information follower have the same average purchase price of the shares on day $j+2$; we note $p_{(j+2)}$ as the average trading price of the shares on day $j+2$, then $p_{(j+2)} = p_{1(j+2)} = p_{2(j+2)}$. Thus:

$$p_{(j+2)} = p_{o(j+2)} \left(1 + \frac{1}{2\gamma} (q_{1(j+2)} + q_{2(j+2)}) \right)$$

The solution to this problem is:

$$q_{1(j+2)} = q_{2(j+2)} = 0.5 * \gamma \left(\frac{\Delta e P + e_j}{p_{o(j+2)}} - 1 \right) \quad (11)$$

$$p_{c(j+2)} = \Delta e P + e_j \quad (12)$$

We know that the information follower and the insider use $p_{c(j+1)}$ to estimate $\Delta e P + e_j$. Thus:

$$q_{1(j+2)} = q_{2(j+2)} = 0.5 * \gamma \left(\frac{p_{c(j+1)}}{p_{o(j+2)}} - 1 \right) \quad (13)$$

On days $j+3, \dots, j+n$, we get:

$$q_{1(j+i)} = q_{2(j+i)} = 0.5 * \gamma \left(\frac{p_{c(j+1)}}{p_{o(j+i)}} - 1 \right)$$

If the news event occurs on day n , the insider and the information follower expect the closing price of the stock to be $p_{o(j+1)} + \Delta e$ on day $j+n+1$. Thus:

$$q_{1(j+n+1)} = q_{2(j+n+1)} = 0.5 * \gamma \left(\frac{p_{o(j+1)} + \Delta e}{p_{o(j+n+1)}} - 1 \right) \quad (14)$$

If the news event does not occur, the insider and the information follower expect the closing price of the stock to be $p_{o(j+1)}$ on day $j+n+1$. Thus:

$$q_{1(j+n+1)} = q_{2(j+n+1)} = 0.5 * \gamma \left(\frac{p_{o(j+1)}}{p_{o(j+n+1)}} - 1 \right) \quad (15)$$

The best strategy for the insider and the information follower is as follows. The insider buys $\gamma \Delta e P$ on the first day. Then, from day 2 to day $j+n$, the insider and the information follower should buy $0.5 * \gamma \left(\frac{p_{c(j+1)}}{p_{o(j+i)}} - 1 \right)$ respectively. On day $j+n+1$, they should buy $0.5 * \gamma \left(\frac{p_{o(j+1)} + \Delta e}{p_{o(j+n+1)}} - 1 \right)$ respectively if the news event occurs, and $0.5 * \gamma \left(\frac{p_{o(j+1)}}{p_{o(j+n+1)}} - 1 \right)$ respectively if the news event does not occur on day $j+n$.

In Case 1, with Eq. (1), the stock price moves as follows: the opening price of the stock on day $j+i (i \leq n)$ is $p_{(j+i)} = a p_{o(j+1)} + (1-\alpha) e_j + e_{j+i+1}$, and the closing price of the stock on day $j+i (i \leq n)$ is $p_{o(j+1)}$. If the news event occurs as expected, the opening price and the closing price of the stock on day $j+n+1$ are $a p_{o(j+1)} + (1-\alpha)(e_j + \Delta e) + e_{j+n+1}$ and $p_{o(j+1)} + \Delta e$, respectively. If the news event does not occur, the opening price and the closing price of the stock on day $j+n+1$ are $a p_{o(j+1)} + (1-\alpha) e_j + e_{j+n+1}$ and $p_{o(j+1)}$, respectively.

3.2.2. Case 2: the news event happens over a range of days

In Case 2, on day $j+1$, the insider faces the same challenge as in Case 1 with the probability $P'_1 = P_1 + P_2 + \dots + P_n$. The insider should buy $q_{1(j+1)} = \gamma \left(\frac{\Delta e P'_1 + e_j}{p_{o(j+1)}} - 1 \right)$ on day $j+1$. The insider can use $p_{o(j+1)}$ to estimate e_j . The best strategy is to buy $\gamma \Delta e (P_1 + P_2 + \dots + P_n)$ shares of stock on day $j+1$ while the stock price is increased by $\Delta p = \Delta e P'_1$. Thus: $p_{c(j+1)} = \Delta e P'_1 + e_j$.

If the news event does not occur on day $j+1$, the insider knows on day $j+2$ that his/her action and the information follower's action should only increase the stock price to $\Delta e P + e_j = \Delta e P'_2 + p_{o(j+1)}$ (noted as $p_{c(j+2)}^*$), where $P'_2 = \frac{P_{j+2} + P_{j+3} + \dots + P_{j+n}}{1 - P_{j+1}}$. If $a = P_{j+1}, b = P_{j+2} + \dots + P_{j+n}$, from $b < b + a(1-a-b) = (1-a)(a+b)$ when $a > 0, b > 0, a + b < 1$, then: $\frac{b}{1-a} < a + b$, or $\frac{P_{j+2} + P_{j+3} + \dots + P_{j+n}}{1 - P_{j+1}} < P_{j+1} + P_{j+2} + \dots + P_{j+n}$, and thus $p_{c(j+2)}^* < p_{c(j+1)}$. If the news event does not occur on days $j+2, j+3, \dots, j+n$, then: $p_{c(j+n)}^* < \dots < p_{c(j+2)}^* < p_{c(j+1)}$. Given that there is a disturbance term e_{j+i+1} in Eq. (1), two situations arise: (i) $p_{o(j+i)} \leq p_{c(j+i)}^*$; and (ii) $p_{o(j+i)} > p_{c(j+i)}^*$. If $p_{o(j+i)} > p_{c(j+i)}^*$, with Assumption 4, the insider cannot sell shares, thus his/her best strategy is to take "No Action."

In relation to the information follower, he/she will know on day $j+2$ that the insider has bought some shares of the stock on day $j+1$ and:

- (1) He/she knows $\Delta p = \Delta e (P_1 + P_2 + \dots + P_n)$;
- (2) He/she does not know P_2 , so he/she does not know $p_{c(j+2)}^*$; and
- (3) He/she knows $p_{o(j+i)} > p_{c(j+i)}^*$ sometimes.

In this case, the information follower does not know when the news event will occur in the period. If he/she buys some shares when $p_{o(j+i)} > p_{c(j+i)}^*$, he/she will lose money. It is impossible for the information follower to earn a premium with this limited information. Thus, his/her best strategy is to take "No Action."

The insider's best strategy can be described as:

- (1) when $p_{o(j+i)} < p_{c(j+i)}^*$ and the news event does not occur before day $j+i$;

$$q_{1(j+i)} = \gamma \left(\frac{P_{c(j+i)}^*}{P_{o(j+i)}} - 1 \right) \tag{16}$$

(2) when $P_{o(j+i)} \geq P_{c(j+i)}^*$, and the news event does not occur before day $j + i$:

$$q_{1(j+i)} = 0 \tag{17}$$

where $P_{c(j+i)}^* = \Delta e \left(\frac{P_{j+i} + P_{j+i+1} + \dots + P_{j+n}}{1 - P_{j+i-1}} \right) + P_{o(j+i)}$.

If the news event occurs on day $j + k + 1$, the insider and the information follower expect that the closing price of the stock will be $P_{o(j+1)} + \Delta e$. Thus:

$$q_{1(j+k+1)} = q_{2(j+k+1)} = 0.5 * \gamma \left(\frac{P_{o(j+1)} + \Delta e}{P_{o(j+k+1)}} - 1 \right) \tag{18}$$

If the news event does not occur on day $n + 1$, the insider and the information follower expect that the closing price of the stock will be $P_{o(j+1)} + \Delta e$. Thus:

$$q_{1(j+n+1)} = q_{2(j+n+1)} = 0.5 * \gamma \left(\frac{P_{o(j+1)}}{P_{o(j+n+1)}} - 1 \right) \tag{19}$$

The insider's best strategy is to buy $\gamma \left(\frac{P_{c(j+i)}^*}{P_{o(j+i)}} - 1 \right)$ when $P_{o(j+i)} < P_{c(j+i)}^*$, and 0 when $P_{o(j+i)} \geq P_{c(j+i)}^*$ until the news event occurs or the news event never occurs. After the news event has occurred, on the following day, he/she buys $0.5 * \gamma \left(\frac{P_{o(j+1)} + \Delta e}{P_{o(j+k+1)}} - 1 \right)$. If the news event does not occur, he/she buys $0.5 * \gamma \left(\frac{P_{o(j+1)}}{P_{o(j+n+1)}} - 1 \right)$ on day $j + n + 1$. The best strategy for the information follower is to only buy $0.5 * \gamma \left(\frac{P_{o(j+1)} + \Delta e}{P_{o(j+k+1)}} - 1 \right)$ on the day following the day on which the news event occurs, and to only buy $0.5 * \gamma \left(\frac{P_{o(j+1)}}{P_{o(j+n+1)}} - 1 \right)$ on the last day in the range of days if the news event has not occurred.

In Case 2, the stock price depends on whether or not the news event occurs. Before the news event occurs, the closing price of the stock on day $j + i (i \leq n)$ is $\max(p_{o(j+i)}, \Delta e P'_{j+i} + P_{o(j+1)})$, where $P'_{j+i} = \frac{P_{j+i} + P_{j+i+1} + \dots + P_{j+n}}{1 - P_{j+i-1}}$, $P_{o(j+i)} = \alpha P_{o(j+1)} + (1 - \alpha) \epsilon_j + \epsilon_{j+i+1}$. If the news event occurs, the closing price of the stock on the following day is $P_{o(j+1)} + \Delta e$.

4. Monte Carlo simulation

In the previous section, we discussed the best strategies for the insider and the information follower. In this section, we design a Monte Carlo simulation to discuss premiums and stock price movements. To examine how the information follower affects the premiums of the insider and the price-sensitive trader, in addition to Cases 1 and 2 (referred to as Situations ii and iv respectively in this section), two other situations are considered in the Monte Carlo stimulation: the news event occurs on a specified date and the information follower does not take any action (i.e., Situation i), and the news event occurs over a range of days and the information follower does not take any action (i.e., Situation iii). In Situations i and iii, since the information follower does not take any action, there is no information follower and thus there are only two roles in the model: the insider and the price-sensitive trader.

We assume that:

(1) $e_0 = P_{o0} = 10,000$; with $q_{total} = 1$, the initial stock market value is

10,000;

(2) $\alpha = 0.5$ in Eq. (1);

(3) $\gamma = 1/7.5$ in $q_{3i} = -\gamma * ((P_{ci} - P_{oi})/P_{oi})$. This is based on Levin and Wright's (2002) suggestion that downward-sloping demand curves would decrease the price by approximately 7.5 percent for a one percent increase in the number of outstanding shares; and

(4) On the first day of a cycle of 20 days during which only one news event can occur, the insider knows that a news event will occur on day n with probability of P (i.e., Situations i and ii), or that a news event will occur on a day before day $n+1$ with probability of $[P_1, P_2 \dots P_n]$ (i.e., Situations iii and iv). This news event changes the economic state by +500 or -500. Let $n=2, 3, \text{ and } 6$, respectively, let $P=0.2, 0.4, 0.6, 0.8, \text{ and } 1$, respectively in Situations i and ii, and $[P_1, P_2 \dots P_n] = [\frac{1}{n} * P, \frac{1}{n} * P, \dots, \frac{1}{n} * P]$, respectively (where $P=0.2, 0.4, 0.6, 0.8, \text{ and } 1$) in Situations iii and iv.

We define a cycle with 20 days and simulate 200,000 days (i.e., 10,000 cycles). In every cycle, we use Matlab functions to simulate the situations in which the news event occurs, and situations in which the news event does not occur for the given probabilities. We calculate the average premiums of all three roles in these cycles.

Table 1 reports the average premiums of the insider, the information follower, and the price-sensitive trader in a cycle. It shows that the premiums earned by the three roles are affected by the accuracy (P) of the insider's inside information, and the number of days (n) that the insider obtains the information in advance. Specifically, the premiums of the insider and the information follower increase with increases in the values of n and P . Thus, the earlier an insider obtains the inside information (i.e., the larger the n is), or the more accurate the inside information is (i.e., the larger the P is), the greater the premium the insider and the information follower earn. For example, in Situation ii, when $P=1$ (i.e., the insider knows for certain that the event will occur), and $n=6$ (i.e., the insider obtains the inside information six days before the event occurs), the insider and the information follower earn a premium of 2.64 and 1.02, respectively, if the initial stock market value is 10,000. In contrast, if the insider knows six days in advance that the event will occur with a probability of 0.2, the insider and the information follower only earn a premium of 0.14 and 0.07, respectively. In the long run, the insider can earn high premiums even he/she only knows of the occurrence of the event with certain levels of probability.

We use some stocks in the US stock market to illustrate the effects of the insider's information advantages, and the competition between the insider and the information follower on the premiums that traders can earn in the real market. For example, for Apple Inc, whose market capitalization was US\$569 billion on January 5, 2016, if the insider knows that a future news event occurring (with probability of 0.2) six days later will increase/decrease Apple stock price by five percent, our results indicate that the insider can earn a premium of US\$7.97 million, and the information follower can earn US\$3.98 million. This example demonstrates that insiders and information followers of large firms can earn large premiums even when the accuracy of the inside information is relatively low. We also consider an example of a small firm to examine whether the effects of asymmetric information, and the competition between the insider and the information follower differ for small firms. Previous studies (e.g., Seyhun, 1986; Lakonishok and Lee, 2001) show that insiders have better information advantages in small firms than in large firms. If we use the accuracy of private information as a proxy for insiders' information advantage, and assume that the insider of a small firm, Violin Memory (with a market capitalization of US\$84.6 million on January 5, 2016), is certain (with probability of 1) that a future news event occurring six days later will increase/decrease the stock price by five percent, he/she can earn a US\$22.3 thousand premium, and the information follower can earn a US\$8.6 thousand premium. In this example, while the insider of Violin Memory has a

Table 1
The average premiums of the three roles in a cycle.

Probability	Situation	Insider			Information follower			Price-sensitive trader		
		Insider	Information follower	Price-sensitive trader	Insider	Information follower	Price-sensitive trader	Insider	Information follower	Price-sensitive trader
P=0.2	i	0.16	0	-0.16	0.18	0	-0.18	0.25	0	-0.25
	ii	0.11	0.03	-0.14	0.11	0.05	-0.16	0.14	0.07	-0.21
ΣP _t =0.2	iii	0.13	0	-0.13	0.14	0	-0.14	0.15	0	-0.15
	iv	0.07	0.03	-0.10	0.10	0.03	-0.13	0.11	0.03	-0.14
P=0.4	i	0.43	0	-0.43	0.52	0	-0.52	0.78	0	-0.78
	ii	0.34	0.08	-0.42	0.38	0.12	-0.50	0.45	0.20	-0.65
ΣP _t =0.4	iii	0.35	0	-0.35	0.38	0	-0.38	0.46	0	-0.46
	iv	0.19	0.05	-0.24	0.31	0.05	-0.36	0.34	0.05	-0.39
P=0.6	i	0.84	0	-0.84	1.07	0	-1.07	1.61	0	-1.61
	ii	0.71	0.12	-0.83	0.77	0.19	-0.96	1.00	0.42	-1.42
ΣP _t =0.6	iii	0.69	0	-0.69	0.77	0	-0.77	0.96	0	-0.96
	iv	0.38	0.07	-0.45	0.66	0.05	-0.71	0.76	0.06	-0.82
P=0.8	i	1.47	0	-1.47	1.80	0	-1.80	2.81	0	-2.81
	ii	1.22	0.17	-1.39	1.32	0.29	-1.61	1.79	0.72	-2.51
ΣP _t =0.8	iii	1.15	0	-1.15	1.30	0	-1.30	1.71	0	-1.71
	iv	0.62	0.06	-0.68	1.18	0.04	-1.22	1.36	0.06	-1.42
P=1	i	2.17	0	-2.17	2.72	0	-2.72	4.34	0	-4.34
	ii	1.83	0.20	-2.03	2.04	0.41	-2.45	2.64	1.02	-3.66
ΣP _t =1	iii	1.83	0	-1.83	2.08	0	-2.08	2.84	0	-2.84
	iv	0.97	0.04	-1.01	1.85	0.03	-1.88	2.19	0.06	-2.25

This table reports the premiums of the three roles (i.e., the insider, the information follower, and the price-sensitive trader) under different situations. Situation (i): the news event occurs on a specified date with certain probability, and the information follower does not take any action. Situation (ii): the news event occurs on a specified date with certain probability, and the information follower takes action. Situation (iii): the news event has the possibility of occurring over a range of days, and the information follower does not take any action. Situation (iv): the news event has the possibility of occurring over a range of days, and the information follower takes action. We assume $e_0 = \rho_0 = 10,000$. In Situations (iii) and (iv),

better information advantage than the Apple insider, the premium of US\$22.3 thousand he/she can earn is much less than the US\$7.97 million premium the Apple insider can earn. The two examples show that insider trading in large firms has a more profound effect on the stock market than insider trading in small firms.

In our model, the price-sensitive trader is at a disadvantaged position, but the loss to the price-sensitive trader can be alleviated by competition between the insider and the information follower. For example, when $P=1$ and $n=6$ in Situation ii, the price-sensitive trader's loss is 3.66, less than his/her loss of 4.34 in Situation i in which the information follower does not take action (i.e., when there is no information follower).

We use a simple situation to illustrate the stock price movements in our model. When calculating how the stock price moves in Cases 1 and 2, we assume that both the initial economic state and stock price are 10,000, the random item ε_{t+1} is zero in Eq. (1), and the news event is a good news event. In Fig. 1, the solid line shows the opening prices and the closing prices when the news event has not occurred while the longdash line shows the prices after the news event occurs. In Case 1, the closing price is 10,400 on days 1, 2, and 3; the closing price on day 4 is 10,500 if the news event occurs, and 10,000 if the news event does not occur. In Case 2, the closing price is 10,400, 10,364, 10,286, and 10,000 on days 1, 2, 3, and 4, respectively if the news event does not occur before each of these days, while the closing price is 10,500 if the news event occurs.

Table 2 shows the stock price movements and the trading volumes. The stock price change is calculated as the change in closing prices, and the trading volume is measured as the daily number of shares traded as a proportion of the total number of shares outstanding. In Case 1, if the investor only observes the closing price, the stock price only changes on the day after the insider obtains the information, or on the day after the news event occurs. When the probability of the occurrence of the news event is small, the stock price jumps occurs after the news event occurs. For example, when $P=0.2$ and $n=2$, the change is four percent on day 3 if the news event occurs. When the probability of the occurrence of the news event is large, the dramatic change in stock price occurs after the

insider has obtained the inside information; for example, when $P=0.8$ and $n=2$, the change is four percent on day 1.

5. Conclusion

A fundamental issue that has been examined by a large body of literature is the influence of insider trading on asset pricing, and the profits made by insiders and other market participants. This paper develops a model characterized by an insider, an information follower, and a price-sensitive trader who each has asymmetric information about future news events. We examine their trading strategies and the stock price movements in relation to news events within a game theoretical framework. Unlike previous studies, our model explicitly considers the insider's level of information advantage using the level of accuracy of the inside information and the length of the timing advantage of the inside information, and links insider trading profits with the insider's information advantage and the information environment in the market. The model does not require the insider to have accurate inside information. Further, in relation to outsiders, the model distinguishes between more sophisticated investors and less sophisticated investors to account for varying levels of investor sophistication.

The model can be applied to explain some phenomena in stock markets; for example, sometimes when good news is released, the stock market (or a stock) only increases slightly, or even drops. In our model, if the insider's private information is accurate, the stock price jumps after the insider receives the inside information; however, the stock price changes little when the news event occurs. This result explains why in some circumstances the market does not respond as positively as expected when good news is released.

This paper also addresses important issues about traders' trading strategies and the findings have practical implications for different types of investors in stock markets. These findings are important to policy makers and market participants concerned with insiders' strategic trading and interested in limiting insiders' trading advantages. Our model shows that the price-sensitive trader's trading strategy of buying losers and selling winners incurs losses, highlighting the

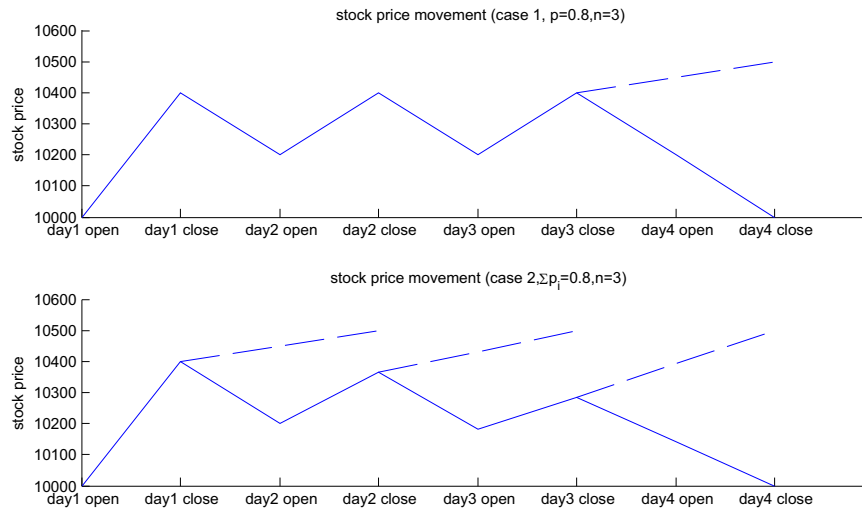


Fig. 1. Stock price movements after the insider has obtained the inside information. This figure shows the stock price movements in Case 1 (the news event occurs on a specified date with certain probability) and Case 2 (the news event has the possibility of occurring over a range of days). The solid line shows the stock prices before the news event occurs, and the longdash line shows the stock prices after the news event occurs.

disadvantaged position of less sophisticated investors in the real world. It also shows that the information follower can earn profits by analyzing the stock market and competing with the insider in the presence of information asymmetry, and that competition between the insider and the information follower can reduce the losses of the price-sensitive trader and thus alleviates the disadvantaged position of the price-sensitive trader. The findings suggest that competition between sophisticated investors and insiders could benefit less sophisticated investors by allowing faster diffusion of private information across market participants, and thus reducing the adverse selection problem faced by uninformed investors, if they realize that enough informed trading occurs such that the prevailing prices reflect most material

information. The findings also emphasize the importance of information transparency, and the role of sophisticated investors in mitigating the expropriation of investors by insiders. The intention of sophisticated investors may not be to monitor insiders to maximize firm value; however, less sophisticated investors still benefit when sophisticated investors and insiders compete to maximize their own profits.

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Table 2
The stock price movements after the insider has obtained the inside information.

Probability	Case	Stock	$n = 2$	$n = 3$	$n = 6$
$P=0.2$	Case 1	Change (%)	1.0,0,4.0 ^h /-1.0 ⁿ	1.0,0,0,4.0 ^h /-1.0 ⁿ	1.0,0,0,0,0,0, 4.0 ^h /-1.0 ⁿ
		Volume (%)	0.13,0.07,0.26 ^h /0.07 ⁿ	0.13,0.07,0.07,0.26 ^h /0.07 ⁿ	0.13,0.07,0.07,0.07,0.07, 0.07,0.26 ^h /0.07 ⁿ
$\Sigma P_i=0.2$	Case 2	Change (%)	1.0,-0.4 ⁿ /4.0 ^h , -0.6 ⁿ /4.4 ^h	1.0,-0.3 ⁿ /4.0 ^h , -0.3 ⁿ /4.3 ^h , -0.4 ⁿ /4.6 ^h	1.0,-0.1 ⁿ /4.0 ^h , -0.2 ⁿ /4.1 ^h , -0.2 ⁿ /4.3 ^h , -0.2 ⁿ /4.4 ^h , -0.2 ⁿ /4.6 ^h , -0.2 ⁿ /4.8 ^h
		Volume (%)	0.13,0.01 ⁿ /0.26 ^h ,0.04 ⁿ /0.29 ^h	0.13,0.03 ⁿ /0.26 ^h ,0.028 ⁿ /0.30 ^h	0.13,0.05 ⁿ /0.26 ^h ,0.04 ⁿ /0.27 ^h ,0.03 ⁿ /0.28 ^h ,0.01 ⁿ /0.29 ^h ,0 ⁿ /0.30 ^h ,0.001 ⁿ /0.31 ^h
$P=0.4$	Case 1	Change (%)	2.0,0,2.9 ^h /-2.0 ⁿ	2.0,0,0,2.9 ^h /-2.0 ⁿ	2.0,0,0,0,0, 2.9 ^h /-2.0 ⁿ
		Volume (%)	0.27,0.13,0.19 ^h /0.13 ⁿ	0.27,0.13,0.13,0.19 ^h /0.13 ⁿ	0.27,0.13,0.13,0.13,0.13, 0.13,0.19 ^h /0.13 ⁿ
$\Sigma P_i=0.4$	Case 2	Change (%)	2.0,-0.7 ⁿ /2.9 ^h , -1.2 ⁿ /3.7 ^h	2.0,-0.5 ⁿ /2.9 ^h , -0.6 ⁿ /3.4 ^h , -0.9 ⁿ /4.1 ^h	2.0,-0.2 ⁿ /2.9 ^h , -0.2 ⁿ /3.2 ^h , -0.3 ⁿ /3.4 ^h , -0.3 ⁿ /3.7 ^h , -0.4 ⁿ /4.1 ^h , -0.5 ⁿ /4.5 ^h
		Volume (%)	0.27,0.03 ⁿ /0.19 ^h ,0.08 ⁿ /0.24 ^h	0.27,0.07 ⁿ /0.19 ^h ,0.02 ⁿ /0.22 ^h ,0.06 ⁿ /0.26 ^h	0.27,0.1 ⁿ /0.19 ^h ,0.09 ⁿ /0.21 ^h ,0.06 ⁿ /0.22 ^h ,0.04 ⁿ /0.24 ^h ,0.01 ⁿ /0.26 ^h ,0.03 ⁿ /0.29 ^h
$P=0.6$	Case 1	Change (%)	3.0,0,1.9 ^h /-2.9 ⁿ	3.0,0,0,1.9 ^h /-2.9 ⁿ	3.0,0,0,0,0, 1.9 ^h /-2.9 ⁿ
		Volume (%)	0.40,0.20,0.13 ^h /0.20 ⁿ	0.40,0.20,0.20,0.13 ^h /0.20 ⁿ	0.40,0.20,0.20,0.20,0.20, 0.20,0.13 ^h /0.20 ⁿ
$\Sigma P_i=0.6$	Case 2	Change (%)	3.0,-0.8 ⁿ /1.9 ^h , -2.1 ⁿ /2.8 ^h	3.0,-0.5 ⁿ /1.9 ^h , -0.8 ⁿ /2.4 ^h , -1.6 ⁿ /3.3 ^h	3.0,-0.2 ⁿ /1.9 ^h , -0.3 ⁿ /2.2 ^h , -0.4 ⁿ /2.4 ^h , -0.5 ⁿ /2.8 ^h , -0.7 ⁿ /3.3 ^h , -1.0 ⁿ /4.0 ^h
		Volume (%)	0.40,0.08 ⁿ /0.13 ^h ,0.14 ⁿ /0.18 ^h	0.40,0.13 ⁿ /0.13 ^h ,0.05 ⁿ /0.16 ^h ,0.11 ⁿ /0.22 ^h	0.40,0.17 ⁿ /0.13 ^h ,0.15 ⁿ /0.14 ^h ,0.12 ⁿ /0.16 ^h ,0.08 ⁿ /0.18 ^h ,0.02 ⁿ /0.22 ^h ,0.07 ⁿ /0.26 ^h
$P=0.8$	Case 1	Change (%)	4.0,0,1.0 ^h /-3.9 ⁿ	4.0,0,0,1.0 ^h /-3.9 ⁿ	4.0,0,0,0,0, 1.0 ^h /-3.9 ⁿ
		Volume (%)	0.53,0.26,0.06 ^h /0.26 ⁿ	0.53,0.26,0.26,0.06 ^h /0.26 ⁿ	0.53,0.26,0.26,0.26,0.26, 0.26,0.06 ^h /0.26 ⁿ
$\Sigma P_i=0.8$	Case 2	Change (%)	4.0,-0.6 ⁿ /1.0 ^h , -3.2 ⁿ /1.6 ^h	4.0,-0.4 ⁿ /1.0 ^h , -0.8 ⁿ /1.3 ^h , -2.8 ⁿ /2.1 ^h	4.0,-0.2 ⁿ /1.0 ^h , -0.2 ⁿ /1.1 ^h , -0.3 ⁿ /1.3 ^h , -0.5 ⁿ /1.6 ^h , -0.8 ⁿ /2.1 ^h , -2.0 ⁿ /2.9 ^h
		Volume (%)	0.53,0.17 ⁿ /0.06 ^h ,0.22 ⁿ /0.11 ^h	0.53,0.21 ⁿ /0.06 ^h ,0.14 ⁿ /0.09 ^h ,0.19 ⁿ /0.14 ^h	0.53,0.24 ⁿ /0.06 ^h ,0.22 ⁿ /0.07 ^h ,0.20 ⁿ /0.09 ^h ,0.16 ⁿ /0.11 ^h ,0.08 ⁿ /0.14 ^h ,0.13 ⁿ /0.19 ^h
$P=1.0$	Case 1	Change (%)	5.0,0,0 ^h /-4.8 ⁿ	5.0,0,0,0 ^h /-4.8 ⁿ	5.0,0,0,0,0, 0 ^h /-4.8 ⁿ
		Volume (%)	0.67,0.33,0 ^h /0.33 ⁿ	0.67,0.33,0.33,0 ^h /0.33 ⁿ	0.67,0.33,0.33,0.33,0.33, 0.33,0 ^h /0.33 ⁿ
$\Sigma P_i=1.0$	Case 2	Change (%)	5.0,0 ⁿ /0 ^h ,0 ^h	5.0,0 ⁿ /0 ^h ,0 ⁿ /0 ^h ,0 ^h	5.0,0 ⁿ /0 ^h ,0 ⁿ /0 ^h ,0 ⁿ /0 ^h ,0 ⁿ /0 ^h ,0 ^h ,0 ^h
		Volume (%)	0.67,0.33 ⁿ /0 ^h ,0 ^h	0.67,0.33 ⁿ /0 ^h ,0.33 ⁿ /0 ^h ,0 ^h	0.67,0.33 ⁿ /0 ^h ,0.33 ⁿ /0 ^h ,0.33 ⁿ /0 ^h ,0.33 ⁿ /0 ^h ,0.33 ⁿ /0 ^h ,0

This table reports the stock price movements after the insider has obtained the inside information. The change is calculated as: (closing price in day $n+1$ /closing price in day n)-1. The trading volume is measured as the daily number of shares traded as a proportion of the total number of shares outstanding. a^n indicates that the news event does not occur; a^h indicates the news event occurs on the day before day n .

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Appendix A. proof of corollary 1

As the insider and the information follower buy/sell the stock on limited days, and there are limited news events occurring from day 0–day n , we can find the day m on and after which there is no news event occurs, and the insider (and the information follower) does not buy/sell after day m :

On days $m + 1, m + 2, m + 3, \dots, m + i$

$$p_{o(m+i)} = p_{c(m+i)}, \text{ where } i = 1, 2, 3, \dots$$

$$e_{m+1} = e_{m+2} = e_{m+3} = \dots = e_{m+i}$$

Defining a sequence $\{x_{m+i}\}$, where $x_{m+i} = E(p_{o(m+i)})$, with Eq. (1) we obtain:

$$x_{m+i+1} = E(p_{o(m+i+1)}) = E(\alpha p_{c(m+i)} + (1-\alpha)e_{m+i+1} + \varepsilon_{m+i}) = E(\alpha p_{o(m+i)} + (1-\alpha)e_{m+i+1}) = \alpha E(p_{o(m+i)}) + (1-\alpha)e_m = \alpha x_{m+i} + (1-\alpha)e_n$$

$$x_{m+i+1} - x_{m+i} = \alpha x_{m+i} + (1-\alpha)e_n - x_{m+i} = (1-\alpha)(e_n - x_{m+i})$$

Case 1: $p_{cm} > e_m$

With $p_{o(m+1)} = \alpha p_{cm} + (1-\alpha)e_m + \varepsilon_{m+1}$, we can get $E(p_{c(m+1)}) = E(p_{o(m+1)}) > e_m$

For any $i \in \mathbb{N}^+$, we can get $x_{m+i} = E(p_{o(m+i)}) > e_m$

With $x_{m+i+1} - x_{m+i} = (1-\alpha)(e_n - x_{m+i})$, we can get $x_{m+i+1} < x_{m+i}$.

We know every increasing (or decreasing) real sequence that is bounded from above (below) converges (Ok, 2007).

Thus, $\lim_{n \rightarrow \infty} x_n$ exists.

Let $y = \lim_{n \rightarrow \infty} x_n$.

With $x_{m+i+1} = \alpha x_{m+i} + (1-\alpha)e_n$ and $\lim_{n \rightarrow \infty} (x_{m+i+1}) = \lim_{n \rightarrow \infty} (\alpha x_{m+i}) + (1-\alpha)e_n$, we have $y = \alpha y + (1-\alpha)e_n$. Thus:

$$y = e_m = e_n$$

$$\lim_{n \rightarrow \infty} E(p_{on} (= p_{cn})) = e_n$$

Case 2: $p_{cm} < e_m$

Using a similar process of the proof of Case 1, we can get: $\lim_{n \rightarrow \infty} E(p_{on} (= p_{cn})) = e_n$

Case 3: $p_{cm} = e_m$

$$p_{o(m+1)} = \alpha p_{cm} + (1-\alpha)e_m + \varepsilon_{m+1} = e_m + \varepsilon_{m+1},$$

then:

$$\lim_{n \rightarrow \infty} E(p_{on} (= p_{cn})) = e_n$$

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