Public Information Arrivals and Stock Price Changes

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Abstract:

This paper investigates the impact of public information arrivals on the mean and variance of stock price changes via order submission and execution. The Australian Securities Exchange, with a continuous disclosure regime that releases centrally time-stamped company announcements, provides us with a unique proxy for public information for our analysis. With the mean effect, we document that the order flows are informative on short-term stock returns, especially that the slope of the demand curve over the supply curve of the order book could predict short-term stock returns, and that public information arrivals increase the informativeness of the order flows. With the variance effect, we find that the relation between price volatility and trading volume and that between price volatility and the slope of the order book are strengthened as the intensity of public information arrivals increase. Overall, our findings contribute to the literature by providing new evidence that the order book conveys information about both direction and magnitude of stock price changes, and that public information arrivals induce heterogeneous revision of beliefs among market participants.

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1. Introduction

The impact of information on security prices is a fundamental building block for the modern finance theory. Literature has well established that public information arrivals may cause volatility of stock prices,[1] and that private information about asset values may be conveyed by signed trading volume or net order flows.[2] However, how public and private information are eventually impounded into stock prices remains a subject of considerable debate in any types of financial markets.

The focus of this study is on how public and private information are incorporated in stock prices via order submissions and executions in a pure order-driven market. Specifically, we address three research questions: Firstly, are order flows informative on stock returns? Secondly, do public information arrivals increase or decrease the informativeness of order flows on stock returns? Thirdly, how does the intensity of public information arrivals affect the relation between price volatility, trading volume and the shape of the order book?

The Australian Securities Exchanges (ASX) provides us a unique proxy for public information arrivals in our analysis. Previous studies often use news headlines from commercial news outlets as a proxy for public information,[3] and thus may suffer from three constraints: the first is that the information is not centrally released, so prior trading on the information might exist; the second is that the information does not have

[1] This strand of literature originates from the work of Clark (1973) under the mixture distribution hypothesis. The work is then extended extensively by a number of studies including Epps and Epps (1976), Copeland (1976), Tauchen and Pitts (1983), Harris (1986, 1987), Andersen (1996).

[2] This strand of literature originates from the work of Kyle (1985) under the theory of price formation.

[3] Mitchell and Mulherin (1994) proxy public information flows by the daily number of announcements released by the Dow Jones & Company. Berry and Howe (1994) use the number of news items released by Reuter's News Service per unit of time as a measure of public information. Vega (2006) measures public information as the number of days a firm is mentioned in the news from Dow Jones publications library. Tecklock (2009) uses new stories from the Dow Jones news archive.

a time-stamped feature for intraday analysis; and the third one is that the information may not originate from the company. The ASX, with the continuous disclosure regime that releases centrally time-stamped announcements related to specific companies, enable us to overcome these limitations by providing a more timely and accurate measure of public information arrivals.

The process of incorporating public and private information in stock prices via order submission and execution can be studied in two settings. The first one examines the direction of stock price changes (the mean effect), and its relation to order flows, where both are signed variables. If informed traders use both market orders and limit orders to exploit their private information about asset values, we should expect order flows, which are measured by trade imbalance and order book imbalance, are informative on stock returns. This analysis provides insight into the debate over which orders (market orders or limit orders) are used by informed traders to exploit their information advantages. If informed traders are more likely to use market orders as proposed in Glosten (1994) and Seppi (1997), we should find that trade imbalance is more informative on price changes than order book imbalance. On the other hand, if informed traders are more likely to use limit orders as proposed in Chakravarty and Holden (1995), Bloomfield et al. (2005), Anand et al. (2005), Wald and Horrigan (2005), and Kaniel and Liu (2006), we should find that order book imbalance is more informative on stock price changes than trade imbalance.

In our study, trade imbalance is measured basing on the difference between buyer-initiated trades and seller-initiated trades[4]. The order book imbalance is measured basing on information from the slope of the order book at a given interval. In a related

[4] The ASX provides an accurate identification of these trades. A buyer-initiated trade occurs when a market buy order is executed against a limit sell order, while a seller-initiated trade occurs when a market sell order is executed against a limit buy order.

study, Cao et al. (2009) provide evidence that imbalances in order quantities and order prices are significantly related to short-term returns in the ASX. We differ from Cao et al. (2009) by arguing that traders take into account the dynamic interaction between quantities and prices when submitting their orders. We thus rely on order-book slopes, which combine both order quantities and order prices. The order book slope is presumably better to convey information about the state of the order book because the submitted order quantities are mutually contingent or dependent on the submitted order prices. We then use the relative or absolute differences between the slope of the demand curve and that of the supply curve of the order book as a proxy for the order book imbalance.

When examining the informativeness of order flows, our central point of investigation is whether public information arrivals dilute or trigger the information advantages of informed traders. We further test whether public information increase or decrease the informativeness of order flows over stock returns. Specifically, if a public information release resolves the information asymmetry among market participants as suggested by the traditional signalling theory by Spence (1973)[5], we should expect that public information arrivals may dilute the information advantages of the informed traders, and hence, reduce the informativeness of order flows on stock returns. In contrast, if the public information is heterogeneously interpreted by traders, then public information arrivals may trigger diverse views on the price formation as suggested by Harris and Raviv (1993), and Shalen (1993). Additionally, Kim and Verrecchica (1994, 1997)

[5] The theory is a policy implication to the classic paper of Akerlof (1970) "The Market for Lemons: Quality Uncertainty and the Market Mechanism". The paper implicitly shows that the information asymmetry between sellers (or firms) and buyers (or investors) generates costs by introducing adverse selection into transactions between interested parties. Spence (1973) proposed that these agents could get around the problem of asymmetric information by having one agent (firm) send a signal or information disclosure to the other agent. Akerlof, Michael Spence, and Joseph Stiglitz jointly received the Nobel Memorial Prize in Economic Sciences in 2001 for their research related to asymmetric information.

argue that if informed traders possess superior skills and experiences to extract information, their private information may be triggered by public information arrivals that are not easily interpreted. These alternative set of arguments imply that public information arrivals may trigger the information advantages of informed traders, which in turn can increase informativeness of order flows on stock returns.

The second setting considers the magnitude of stock price changes (variance effect), in which price volatility is related to trading volume as well as the slope of the order book. The positive relation between price volatility and trading volume has been explained by arrivals of new information, and by the dispersion of beliefs in the extensive literature[6]. However, the relation between price volatility and the slope of the order book has drawn little attention. In a theoretical model, Foucault et al. (2007) argue that order book should contain information about the price volatility[7]. Empirically, Naes and Skjeltorp (2006) document that the order book slope is negatively correlated with price volatility and trading volume. They suggest that this relation is driven by heterogeneous beliefs of traders. We differ from them by focusing on the impact of pubic information arrivals on the volatility-order book slope relation, thus providing evidence of the relative roles of both public information arrivals and heterogeneous beliefs of investors. We also re-examine the volatility-volume relation, incorporating the additional impact of the order book slope. We expect that public information arrivals result in a stronger relation between price volatility and trading volume, even after controlling the informativeness of the order book slope about price volatility.

[6] The survey of the relation between volatility and trading volume is in Karpoff (1987).

[7] The authors suggest that that the limit order book is a conduit for volatility information because of the options features of limit orders. Limit order traders implicitly issue a call or a put option. A buy limit order at price P is also issuing a short put option with the exercise price P. A sell limit order at price P is also issuing a short call option with the exercise price P.

Using a sample of 100 firms which are actively traded in the ASX for the 2003-2007 periods, we show that order flows, measured by both trade imbalance and order book imbalance are positively correlated with short-term stock returns. These findings are consistent with Chan (2000), Bias et al. (2005), Harris and Panchapagesan (2005), and Cao et al. (2009) in that trade imbalance and order book imbalance could predict the direction of stock price changes. We also provide new evidence that the order book slope of the demand curve over the supply curve is more informative on stock returns than the trade imbalance measure. Another new finding is that public information arrivals increase the informativeness of order flows on stock returns. Consistent with the recent stream of literature Wald and Horrigan (2005), Harris (1998), Bloomfield et al. (2005), Kaniel and Liu (2006), Rajan et al. (2007), these findings suggest that informed traders appear to employ limit orders more often than market orders in their trades, and that public information arrivals may trigger the information advantages of informed traders.

With regard to the variance effect, we document that the positive relation between price volatility and trading volume arises both from arrivals of new information, and from the dispersion of beliefs of investors. We further find that public information arrivals increases the relation between price volatility and trading volume, even after controlling for the informativeness of the order book slope. Our findings also support the theoretical prediction of Foucault et al. (2007) that the order book should convey information about price volatility and are consistent with empirical evidence documented by Naes and Skjeltorp (2006) and Duong and Kalev (2009). Moreover, we provide new evidence that the volatility-slope of the order book relation is derived from two sources: public information arrivals and heterogeneous beliefs of traders. Additionally, public information arrivals increase the relation between price volatility

and the slope of the order book. In summary, our results provide evidence that the order book is informative on both direction and magnitude of stock price changes, and that company announcements induce heterogeneous revision of beliefs among market participants.

The remainder of the paper is organized as follows. Section 2 is the literature review. Section 3 describes our data and methodology. Section 4 reports results and discussions. Section 5 is the robustness check. Section 6 provides concluding remarks.

2. Literature Review and Hypothesis Development

2.1. Return order flow relation in an order-driven market

The well-known theory of price formation by Kyle (1985) has laid the groundwork for the literature on the relation between stock price changes and informed trading in auction or quote-driven markets. In the Kyle's model, an informed trader attempts to maximize profits by trading on his private information about the liquidation value of the asset. As a result, the private information is incorporated in his order submissions. At the next step when market maker sets a market-clearing price, he can observe only aggregate orders but cannot distinguish between orders submitted by informed traders or other traders. Price changes or stock returns should therefore be positively correlated with order flows. The correlation thus may measure the informativeness of order flows on stock price changes. Many studies Stoll (2000); Chordia et al. (2002), Chordia and Subrahmanyam (2004); Locke and Onnayev (2007); Evans and Lyons (2008) have documented a significant and positive relation between stock returns and order flows

using signed trade volume or trade imbalance between buyer-initiated and seller-initiated trades.

In order-driven markets, the market setting is different from the auction market[8]. Traders can submit market orders at available quotes with immediate executions. Traders can also submit limit orders at better prices but with delayed or non-execution, and with the risk of being adversely picked off in case of new information arrivals. Informed traders thus face a trade-off between market orders and limit orders while exploiting his information advantages. Further, trade or executed order is only one part which results from matching orders up to that time. The state of the order book is the other part which provides all share volume of all standing orders submitted by traders at different prices up to that time. Order flows should therefore be measured by not only signed trade volume but also but also state of the order book or the order book imbalance. The issue, therefore, is that whether the order flow, measured by both trades and standing orders in the order book, is informative on the direction and magnitude of stock price changes?

This issue is first linked to the question of which orders, market orders or limit orders, informed traders use to exploit their information advantages. The current literature remains inconclusive with regard to this question. In the traditional limit order models Glosten (1994), Rock (1996), Seppi (1997), informed traders are always assumed to use

[8] Foucault (2004) suggests three main differences in the interaction between liquidity traders (uninformed) and informed traders in these two markets, which in turn could affect the order flow-return relation. In a quote-driven market: (1) There is an exogenous dichotomy between liquidity suppliers and liquidity demanders where traders cannot choose between posting quotes or hitting quotes, (2) Uniform pricing rule, and (3) Signalling: Liquidity suppliers observe the size of the orders submitted by liquidity demanders before posting quotes. In a order driven market: (1) There is an endogenous dichotomy between liquidity suppliers and liquidity demanders where traders can choose between market or limit orders, (2) Discriminatory pricing rule, and (3) Screening: Liquidity suppliers post quotes before observing orders submitted by liquidity demanders.

market orders to exploit their information advantages. The common belief is that with short-lived private information, informed traders will be impatient and prefer market orders because these orders guarantee immediate execution.

The second stream of literature both theoretically and empirically document the use limit orders by informed traders. Wald and Horrigan (2005) develop a model for the optimal limit or market order choice from the perspective of a risk-averse investor. They suggest that informed investors who expect returns to be positive should place a slightly discounted limit order, often inside the bid-ask spread, because the probability of fill for such orders is high. Harris (1998) models the order submission strategies of liquidity traders and informed traders. The author argues that if the private information is material and if it will soon become public, informed traders will use market orders to trade quickly. Otherwise, if bid-ask spreads are wide and trading deadlines are distant, they submit limit orders to minimize their transaction costs. Similarly, Bloomfield et al. (2005), using an experimental market setting, emphasize limit orders as important components of informed traders' order submission strategies. Informed traders start more likely to employ market orders to profit from their information advantages. As the trading day progresses and prices converge to their true values, informed traders swift to trading mostly with limit orders to earn profits based on the bid-ask spread.

Kaniel and Liu (2006) develop an extension of the Glosten-Milgrom (1985) model, which support the use of limit orders by informed traders. The authors posit the expected time horizon of the private information as a key determinant of choice between limit orders versus market orders. On average, the higher the expected time horizon for their private information, or the higher the probability that the private information is long-lived, the more likely informed traders are to submit limit orders

instead of market orders. Further, Rajan et al. (2007) numerically show the first dynamic model of limit orders with asymmetric information. They assume that the asset has a common value and each trader additionally has a private value for it. Traders randomly arrive at the market, after choosing whether to purchase information about the common value. Traders may either post prices or accept posted prices. If the order has not been executed, they randomly re-enter the market, and may change their previous orders. Their simulation results show that agents with no intrinsic benefits from trade have the highest willingness to pay for information and tend to supply liquidity in equilibrium. The intuition based on Rajan et al. (2007) is that limit orders are submitted by informed traders, on average.

As to the question of whether traders can learn about the informativeness of order flows, i.e., whether order flows in an order-driven market could predict the direction of stock price changes, the initial evidence is mixed.

Bias et al. (1995) provide evidence that quotes adjust in the direction of previous trades in the Paris Bourse. For example, after a large sale, which is regarded as a negative information signal, the bid quote is adjusted downward because the large trade consumed the liquidity at the bid, whereas the ask quote is frequently lowered next as the market adjusts its expectations downward. Intuitively, investors learn about the information content of trades in the limit order market. On the other hand, Griffiths et al. (2000), when analysing costs and determinants of order aggressiveness on the Toronto Stock Exchange, find that aggressive orders (market orders) require a significant premium for immediacy of execution and has a positive price impact on stock returns, whereas more passive (limit) orders have a negative price impact, and that large passive orders do not have a higher price impact than do smaller passive orders.

The intuition from their findings is that market orders are informative while limit orders are not with regard to the direction of stock price movements.

The more recent evidence supports the hypothesis that limit order books are informative on future price movements. When studying the price impact of trading on the stock exchange of Hong Kong, Chan (2000) finds that signed trading volume has a positive effect on future stock returns. Harris and Panchapagesan (2005) provide evidence that the order imbalances between demand and supply sides in terms of order quantities as well as option value from the standing limit orders could help to predict future stock return. Cao et al. (2009) provide evidence that imbalances between demand and supply schedules along the books of S&P/ASX 20 are significantly related to future short-term returns. In their paper, the authors employ imbalances in order quantities and order prices behind the best quotes as two separate measures in predicting short-term stock returns.

In examining the return-order flow relation, we analyse not only the informativeness of standing limit orders in the book but also the executed orders or trades. Furthermore, we extend Cao et al. (2009) by simultaneously examining the informativeness of order quantities and order prices in the order book. Because traders take into account the dynamic interaction between order quantities and prices when submitting their orders, we combine both imbalances in quantities and prices as one independent variable, which is measured by the sensitivity of order quantities to order prices or simply the slope of the bid and ask sides of the order book. The slope of the order book is presumably better to convey information about the state of the order book because the submitted order quantities are mutually contingent or dependent on the submitted order prices. The relative or absolute differences between the slope of the demand curve and

that of the supply curve of the order book are assumed as better proxies for the order book imbalance because it takes into account the mutual dependence of order prices and order quantities while still captures the information content of imbalances in order quantities and order prices of limit orders.

Based on the insight from the above literature, we form the following hypothesis:

Hypothesis (1): Order flows, which are measured by order book imbalance (the order book slope of the bid over the ask sides) and trade imbalance, should be informative on short-term stock returns.

2.2. Public Information Arrivals and the Return Order Flow Relation

The above section summarizes the literature and form a testable hypothesis that order flows should be informative on short-term stock returns. On the basis of this, this section develops the hypothesis that public information arrivals could affect the order flow return relation.

Under the assumptions of rational expectations of investors and the efficient market, it is commonly understood in the market microstructure literature that public information, rather than affecting order flows, is directly incorporated into stock prices. For example, in Kyle (1985, 1989), the informed trader has the information advantage and order flow is a channel to convey his private information. However, one weakness[9] in this setting is that the informed trader faces no competition from public information arrivals. Price fluctuations are, therefore, from order flow effects rather than from public information effects.

To support the above argument, Hasbrouck (1991), when studying the information content of signed trade volume, concludes that trades convey information and cause a

[9] From Kyle's lecture series while he lectured at the FIRN Master Class in Australia, 2008.

positive impact on the stock price changes or quote revisions. He argues that public information arrives before the associated quote revision and after the trade. In the first place when the public information arrives, quotes adjust according to the information and then trades occur based on the quote level. Public information thus has no effects on trades. Evan (2002) argues in another way. He assumes that if information arrives in the form of common knowledge news, then it has no relation to the return-order flow relation. Common knowledge news is characterized by a simultaneous arrival of information to all market participants, and a homogenous interpretation across these participants. This news could be in the form of public news announcements that might affect the stock price but are not likely to cause much of a divergence of opinions among traders. The common-knowledge news causes an immediate effect on all transaction prices because all traders update their beliefs about the fair value of the asset simultaneously, and thus have no relation to the order flows. However, Evans and Lyons (2008) challenge the previous literature on the currency market with the finding that while the order flow contributes significantly to changing currency prices at all times, it contributes more to changing prices immediately after macro-news announcements. Macro-news, which previously is viewed as being common knowledge and having no impact on order flows, affects prices indirectly via its impacts on the volatility of order imbalance.

Arguably, public information arrivals could affect the return order flows if those assumptions do not hold. Under the theory of asymmetric information, public information arrivals could intuitively affect the information advantages of the informed traders in two ways. The signalling theory by Spence (1973) suggests that corporate disclosure to the market is to reduce information asymmetry among firms and market participants e.g. informed investors or uninformed investors. This is the traditional view

of the effect of public announcements that information advantage of the informed trades is reduced because the uninformed traders can interpret the public information as well as informed traders do. In another way, Kim and Verrecchica (1994, 1997) argue that the private signals the informed traders receive may be triggered by public information that is not easily interpreted. These informed traders possess their superior skills and experiences in analysing public news, and are able to better predict the future price movements. In that sense, public information arrivals increase the information advantages of the informed traders. In both cases, as the information advantage of the informed traders is more or less due to public information arrivals, their next task is again the choice of limit or market orders to utilize it.

Under the models of heterogeneous beliefs and differences in opinions by Harris and Ravis (1993), Shalen (1993), public information arrivals would intuitively affect the order strategies of informed traders because of the differences in their opinions about the value of assets. Differences in opinion or heterogeneous beliefs among traders, which results from public information arrivals, can affect their order strategies. Orders placed along the bid and ask schedules could reflect different valuations of the stock value among traders or the private information of the informed traders. If there is a greater consensus among traders about a certain piece of information arriving regarding the stock value, orders would be more likely to be concentrated at a certain price level along the bid and ask price schedules. On the other hand, if there is a divergence of beliefs resulting from public information arrivals about the value of assets, traders would submit orders spanning along the bid and the ask schedules. Intuitively, public information arrivals would affect the order strategies of informed traders because of the generation of diverse beliefs about the value of assets.

Foucault (1999) provides a game theoretic model of price formation and order placement. Trading occurs in Foucault's setting because of differences in valuations and asset value evolves as public information arrives. In equilibrium, order placement strategies of traders are characterized as a function of differences in asset valuation and the best order in the order book. Handa et al. (2003) extend Foucault (1999) by modelling quote setting and price formation where trading occurs because investors differ in their share valuations, and the advent of private information.

Drawing insights from above theoretical models, given that the order flow is informative on stock returns, we argue that the public information releases may affect the return-order flow relation because of the interactions between public and private information, and differences in the revision of beliefs among traders about asset values. If a public information release is more homogenously interpreted by the informed traders, then public information resolves the information asymmetry among market participants as suggested by Spence (1973). We should expect that public information arrivals may dilute the information advantages of the informed traders. This diluted effect is expected to reduce the informativeness of order flows over stock returns.

In contrast, if the public information is more heterogeneously interpreted by informed traders, then public information arrivals may trigger diverse views on the price formation as suggested by Harris and Raviv (1993), Shalen (1993). Additionally, informed traders may possess superior skills and experiences in interpreting public news as suggested by Kim and Verrecchica (1994, 1997). In this sense, we argue that public information arrivals may trigger the information advantages of informed traders. In turn, this triggered effect is expected to increase informativeness of order flows over stock returns.

Regarding to how the public information could affect choice of market orders versus limit orders. Harris (1998) models the order submission strategies and argues that if the private information is material and if it will soon become public, informed traders use market orders to trade quickly. Otherwise, they submit limit orders to minimize their transaction costs. In the same vein, Kaniel and Liu (2006) provide a theoretical model suggesting that the choice of limit orders versus market orders faced by informed trader depends critically on the expected time horizon of his private information. If the expected time horizon of private information increases, the probability that a limit order would be hit becomes greater, thereby decreasing the disadvantages of having uncertain execution. As a result, the informed traders prefer limit orders to market orders. In other words, the higher the probability that the private information is long-lived, the more likely the informed traders place limit orders rather than market orders.

Drawing insight from models by Harris (1998), Kaniel and Liu (2006), we argue that in the presence of public information arrivals, if informed traders prefer market orders to limit orders, then trade imbalance is more informative on short-term stock returns compared to order book imbalance. Otherwise, if informed traders prefer limit orders to market orders, then order book imbalance is more informative on short-term stock returns compared to trade imbalance.

Empirical studies with regard to the choice of market order versus limit orders around the information events; Kavajecz (1999) provides evidence that limit order traders in NYSE reduce depth around information events, thereby reducing their exposure to adverse selection costs. One implication is that informed traders prefer market orders to limit orders around the information events. Caglio and Berber (2005) investigate the order submissions around the earning announcements events, and finds that informed

traders are likely to use non-aggressive strategies (limit orders). More specifically, informed traders submit buy limit orders well below the bid price in order to hide their information before a positive earning announcement event, and that limit orders induce a stronger impact on stock price changes. Yang (2009) shows that informed traders act strategically during the quarterly earning announcements. Prior the announcements when the time is still enough for order executions, informed traders use small orders and limit orders to trade stealthily and reduce price risk. Right before the announcements, informed traders trade more aggressively by using large market orders to ensure the execution and high profits.

Based on the discussion above, to examine how the public information could affect the informativeness of the order flows, we form the following hypothesis:

Hypothesis (2a): If public information arrivals trigger (dilute) the information advantages of informed traders, then order flows including both trade imbalance and order book imbalance are more (less) informative on short-term stock returns.

To examine how public information could affect the choice of market orders versus limit orders of the informed traders, we form the following hypothesis:

Hypothesis (2b): In the presence of public information arrivals, if informed traders prefer limit orders (market orders) to market orders (limit orders), then order book imbalance (trade imbalance) is more informative on short-term stock returns than trade imbalance (order book imbalance).

2.3. Public Information Arrivals and the Volatility- Trading Relation

Researchers are familiar with the well-known "stylized fact" of a positive relation between the stock price volatility and trading volume. There are two complementary theoretical hypotheses for the volatility-volume relation.

The mixture of distribution hypothesis (MDH) by Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983), Harris (1986, 1987) posits that both volatility and volume are jointly driven by the same time-varying underlying information arrivals, and thus there exists a positive correlation between volume and volatility. Under the MDH, underlying information may arrive either simultaneously or sequentially to the market. The market equilibriums from an initial position to the final position can result from a gradual dissemination of a single piece of information, known as the sequential information arrival model by Copeland (1976), or from a process in which investors receive information simultaneously. Andersen (1996) modifies the MDH by decomposing trading volume into informed volume and noise volume, and argues that only the informed volume and volatility are related to the information flows.

The other explanation is that prices do not change merely because of new information about asset values but also because of investors having dispersed beliefs about the assets. Shalen (1993) argues that strategic behaviours of uninformed traders may be an important contribution to the volume-volatility relation. Harris and Raviv (1993) develop a model of trading based on announcements of public information and differences in opinions. The model assumes that traders share the common prior beliefs and receive common information but their interpretations and reactions to the information differ. Traders may agree that the information is favourable or not favourable. However, they disagree on the extent to which the information is important and therefore excess volatility and volume should be correlated.

Among empirical studies on the effects of public information on the volume volatility relation, the earlier one is Mitchell and Mulherin (1994), who proxied for the rate of public information flows with the daily number of announcements released by the Dow

Jones & Company. They found that this rate of information arrivals is positively related to aggregate trading volume but not significantly so with aggregate price volatility. Their analysis reveals difficulties of linking volume and volatility to observed measures of information. Another study by Berry and Howe (1994) uses the number of news items released by Reuter's News Service per unit of time as a measure of public information. Their results show a positive, moderate relationship between public information and trading volume, but an insignificant relationship with price volatility. Vega (2006) measure public information or media coverage as the number of days a particular firm is mentioned in the news prior to its earnings announcement from Dow Jones interactive publications library[10]. The author shows that whether information is public or private is irrelevant with regards to stock price changes, and what matters is whether information is associated with the arrival rate of informed or uninformed traders.

Drawing insight from discussion above, we argue that although theoretical and empirical studies suggest that both volatility and volume are jointly driven by information arrivals and differences in opinions of traders about asset values, empirical analysis often reveal difficulties in testing the theoretical framework with a good proxy for public information.

In an order-driven market, trading volume is only one part which results from matching orders up to that time. The state of the order book, which is measured by the order book slope, is the other part which provides all share volume of all standing orders submitted by traders at different prices up to that time. The state of the order book may originate

[10] The publication sources are: the Wall Street Journal, Associated Press Newswire, the Chicago Tribune, the Globe and Mail, Gannett News Service, the Los Angeles Times, the New York Times, the Washington Post, USA Today, and all Dow Jones newswires.

from asymmetric information, and/or heterogeneous beliefs about the asset value or any other sources. The volatility-volume relation is also explained by the information-based trading or heterogeneous interpretations by traders about the public information release. These connections thus induce an interesting question about the relation between volatility, trading volume and the state of the order books.

Foucault et al. (2007) develop a theoretical model in which limit order traders possess volatility information. According to the authors, the limit order book is a conduit for volatility information because of the options features of limit orders. As option prices depend on volatility, limit order traders should incorporate volatility information in their limit order submissions. Put differently, given the risk of being adversely picked off and of costly non-execution of limit orders, limit order books should impound forward-looking information about future price volatility, the intensity of adverse selection, and future order flows. The limit order book therefore should contain information beyond what is publicly available.

Drawing insight from the discussion above, we argue that there should be a link between public information arrivals, price volatility, and the slope of the order book. Because the order book at any point in time results from the aggregation of all available information in the market. On the other hand, the order book should also contain forward looking information about the future price volatility, asymmetric information, and the order flows as suggested by Foucault et al. (2007)

With regard to empirical studies on the informativeness of the state of the order book related to the stock price volatility, Ahn et al. (2001), Pauscaual and Veredas (2006) show a negative relation between market depth and the volatility of stock prices. Naes and Skjeltorp (2006) find that the order book slope is negatively correlated with price

volatility in the Oslo Stock Exchange in Norway. Similarly, Duong and Kalev (2009) show that the order book slope is informative on future short-term price volatility in the ASX. Naes and Skjeltorp (2006) provide further evidence that the order book slope is negatively correlated with price volatility and trading volume. The authors suggest that heterogeneous beliefs of traders could underlie the relation.

We differ from Naes and Skjeltorp (2006) by focusing on the impact of pubic information arrivals on the volatility-slope relation, thus providing evidence of the relative roles of both public information arrivals and heterogeneous beliefs of investors. We expect both public information arrivals and heterogeneous beliefs of investors could explain the relation between price volatility and the slope of the order book. Regarding volatility-volume relation, we also re-examine the volatility-volume relation with and without public information arrivals, incorporating the additional impact of the order book slope. We expect that public information arrivals result in a stronger relation between price volatility and trading volume, even after controlling the informativeness of the order book slope about price volatility.

Based on the discussion above, we form the following hypothesis.

Hypothesis (3): Public information arrivals should increase the relation between price volatility and trading volume, even after controlling for the informativeness of the slope of the order book.

Hypothesis (4): Public information arrivals should increase the relation between price volatility and the slope of the order book, even after controlling for the effect of trading volume.

3. Data and Empirical Methodology

3.1. Institutional Setting of the Australian Securities Exchange

The Australian Securities Exchanges (ASX) commenced its business on April 1, 1987. The ASX operates under the fully computerized Stock Exchange Automated Trading System (SEATS) with trading rules of an electronic limit order market. The pre-opening period takes place between 7:30am to 10:00am, during which orders can enter the system but cannot be matched at this time. The market opening period is from 10:00am to 10:09am with a call auction. Normal trading takes place continuously on all stocks between 10:09am to 4:00pm from Monday to Friday as a purely limit order market. Orders entered during the normal trading hours will be matched, resulting in trades for market orders, or stored in the order book automatically for limit orders. We also aggregate all multiple trade records generated by a single market order into a single trade. The pre-closing period begins at 4:00pm to 4:05pm and then is followed by an official single price closing auction. The closing period is between 4:05pm to 5:00pm, during which orders can be entered, deleted and amended but no matching can occur. The market closed from 5:00pm to 7:00pm during which orders can be deleted only.

3.2. The Sample

Our data set is provided by the Securities Industry Research Centre of Australasia (SIRCA), with a sample of 100 companies listed on the ASX over the five year period from January 2, 2003 to December 31, 2007. The sample consists of intraday data, bid and ask prices, traded price, and number of shares traded, number of shares standing at bid and ask quote in the order book, and total number of news announcements released by ASX for all trading days. We first have all the companies in the constituent list of S&P/ASX 300 at the January 2, 2003. We exclude all mining companies from our sample because these companies belong to a special category, whose stock prices depend heavily on world fuel prices and the exploration process, and the stock price

may result from the luck brought by the nature, and therefore company disclosures may be biased. We require that the company has at least one announcement to the market during the study period. We further require that the company has at least 500 trading days, from January 2nd, 2003 to December 31st, 2007, having the records of trades, quotes, and order quantities. This fitter rule requires the life time of each company in our sample of at least two years, which aims to reduce bias in the information content of company announcements.

3.3. Variable Definitions

3.3.1. Public Information

On the disclosure policy, the ASX listing rules ensure that it is the first place, rather than any public media, to release all corporate announcements. Companies are required to submit all announcements to the ASX before public releases. Each announcement is centrally released by ASX to the public with a time stamp[11].

We employ the company announcements released by the ASX as a measure of public information arrivals. The ASX has classified company announcements into 19 categories. A list of types of company's announcements is provided in the Appendix 1. The unique features of company announcements in the ASX are time-stamped, continuously and centrally released, which makes it different from all other prior proxies for public information used in the literature. First, the time-stamped feature, which is normally a constraint of prior proxies for public information, allows us to study effects of public information arrivals on the intra-day basis, and thus better understand the market microstructure setting. Second, company announcements are released

[11] The comparable U.S. intraday dataset, New York Stock Exchange Trade and Quote (TAQ), does not provide a time stamp for public news releases. Moreover, it is not guaranteed that the NYSE is the first place to receive public news announcements.

continuously and centrally by the ASX, rather than any other public media. Third, the announcement is company-specific, which originates from the company rather than any other sources.

As the company announcements are continuously released. We consider this public information as a flow of information arrivals to the market, rather than an event analysis. We index one news announcements as one count, and then aggregate all announcements for each half-hour trading interval. Because ASX also releases company announcements outside the normal trading hour (10.00 am-4.00pm), we follow Brock and Kleidon (1992) by accumulating all overnight news arrivals from the closing time (4:00 pm) of the previous trading day to news arrivals of the opening time of the next trading day (10:00 am).

3.3.2. Order Flows

We employ two variables, trade imbalance and order book imbalance, as measures of order flows.

With regard to the trade imbalance, we first aggregate all multiple trades at the same price and at the same time as one trade. Literature often follows the algorithm by Lee and Ready (1991)[12] to classify trades. In the ASX, each trade is recorded directly as a buyer-initiated or seller-initiated trade. Buyer-initiated trades occur when a market buy order is executed against a limit sell order, while a seller-initiated trade occurs when a market sell order is executed against a limit buy order. Therefore, for a short trading interval, trades can be proxies for all market orders submitted and matched during that trading interval.

[12] Lee and Ready (1991) propose the algorithm to classify each trade as either buyer-initiated or seller-initiated. If a trade is transacted above the mid point price, then it is classified as a buyer-initiated trade. If a trade is transacted below the mid point price, then it is classified as seller-initiated trade.

For each stock for each thirty minutes, trade imbalance (TIB) equals the difference between the buyer-initiated trading volume and the seller-initiated trading volume, which is then scaled by total trading volume of the trading period. Trading volume is calculated by three alternative measures: total number of trades or total number of shares traded, or total dollar trading volume[13]. Following Chordia and Subrahmanyam (2004), trade imbalance is scaled by the total trading volume in order to obtain the standardized measure which is not affected by the total trading activity. Trading volume is also logarithm transformed to achieve standardization.

$$TIB_{i,t} = \frac{\sum P_b V_b - \sum P_s V_s}{\sum P_b V_b + \sum P_s V_s}$$

where P is the traded price, V is total number of share trades, the subscript *b* is for a buy and *s* is for a sale.

Order book imbalance is calculated based on standing orders in the order book. Cao et al. (2009) measure the order imbalances as the width (price imbalance) and the length (volume imbalance). We take both order volume at different order prices into account while measuring order imbalances. Order book imbalances for stock *i* in interval *t* is the slope of demand curve over the supply curve. This measure of the order book imbalances could capture the whole characteristics of the order book imbalances in terms of different order volume and order prices at one point in time.

The slope of the order book is calculated following Naes and Skeltorp (2006). The order book slope for the buy side for each stock *i* in each half-hour trading interval *t* is calculated as:

[13] Our results are similar to all three measures, so we report only total dollar trading volume.

$$DE_{i,t} = \frac{1}{N_B}\left(\frac{v_1^B}{\left| p_1^B / p_0 - 1 \right|} + \sum_{\tau=1}^{N_B - 1} \frac{v_{\tau+1}^B / v_\tau^B - 1}{\left| p_{\tau+1}^B / p_\tau^B - 1 \right|} \right)$$

Similarly, the order book slope for the sell side can be calculated as:

$$SE_{i,t} = \frac{1}{N_A}\left(\frac{v_1^A}{p_1^A / p_0 - 1} + \sum_{\tau=1}^{N_A - 1} \frac{v_{\tau+1}^A / v_\tau^A - 1}{p_{\tau+1}^A / p_\tau^A - 1} \right)$$

where N_A and N_B is the total number of bid and ask prices at tick levels containing limit orders, respectively. τ is the tick level for the best bid-ask mid-point, τ =0 for the best ask (bid) mid-point. τ =1 represents the best bid (ask) quote with positive share volume. p_0 is. v_τ^A and v_τ^B is the logarithm transformation of cumulative total share volume at all ask and bid orders each tick price levels p_τ^A and p_τ^B.

At the end of each half-hour interval, we use ten tick levels or ten best bid and ten best ask quotes, and the cumulative share volume of all limit orders at each of these quotes for calculating the order book slope. We do not include hidden orders in our calculation of the order book slope.

The order book slope for stock *i*, in interval *t*, is the average of the order book slopes of the buy side and sell side:

$$SLOPE_{i,t} = \frac{DE_{i,t} + SE_{i,t}}{2}$$

The order book imbalance for stock *i*, in interval *t* is the aggregate of sign order book slopes or the difference between order book slopes of the bid side minus that of the ask side.

$$OIB_{i,t} = DE_{i,t} - SE_{i,t}$$

Another measure for the order book imbalances for stock *i* in interval *t* is the relative slope of demand curve over the supply curve.

$$OIB_{i,t} = \frac{DE_{i,t}}{SE_{i,t} + DE_{i,t}}$$

3.3.3. Stock Return and Volatility

Stock return is calculated based on the difference of logarithm of the mid-quote prices at the end of every half-hour interval. As the short-term stock returns are serially correlated, following Cao et al. (2009) we want to focus on the innovation in returns. The innovation return is used as a proxy for stock returns in our analysis of the return-order flows relation, because the innovation return captures the unpredicted component of return. Specifically, we obtain the innovation in returns by using AR(12) model for each firm in our sample.

$$R_t = a + \sum_{i=1}^{12} b_i R_{t-i} + \varepsilon_t \qquad (1)$$

where $R_{,t}$ is the half-hour return for each stock at the trading interval t, the innovation $\hat{\varepsilon}_t$ from (1) is the stock return (r_t) for our analysis of the return order-flows relation.

The volatility of stock prices calculated as the absolute value of the residual series $|\varepsilon|$ from (1) is used for our analysis.

As the intraday volatility and trading volume based on one-half hour segments over the trading day is specifically characterized by a U-shaped curve (Berry and Howe (1994)), we also remove this intraday effect by including a dummy variable for time intervals in the related regressions.

3.4. Empirical Methodology

3.4.1. Return order flow relation in an order-driven market

To test our hypothesis (1), we run the following regression:

$$r_t = \lambda TIB_{t-1} + \gamma OIB_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + u_t \quad (2)$$

where $r_{i,t}$ is the innovation return for stock i, at interval t obtained from regression (1). TIB_{t-1} is the trade imbalance and OIB_{t-1} is the order book imbalance or the relative order book slope of the demand curve over the supply curve. T_t is the time dummy for twelve trading intervals of one trading day.

If order flows or the order book imbalance and trade imbalance are informative on short-term stock returns, we expect both λ and γ to be positive and statistically significant. Furthermore, if limit orders are more informative on short-term stock returns compared to market orders, we expect that γ is bigger than λ.

3.4.2. Public Information and the Return Order Flow Relation

To test our hypothesis (2a)(2b), we run the following regression:

$$r_t = (\lambda_1 + \lambda_2 D_{news}) TIB_{t-1} + (\gamma_1 + \gamma_2 D_{news}) OIB_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + e_t \quad (3)$$

where D_{news} is a dummy variable equal to 1 if there are public information arrivals during the previous trading interval or 0 otherwise.

The interaction between trade imbalance and the dummy news captures the incremental return predictability of trade imbalance between periods having news and periods having no news. Similarly, the interaction between the order book imbalance and the dummy news captures the incremental return predictability of order book slope between periods having news and periods having no news.

To support our hypothesis (2a) that public information arrivals affect the return order flows relation, we expect that both the coefficients on the news dummy, λ_2 and γ_2, are statistically significant. If public information arrivals dilute the information advantage of the informed traders, then we expect λ_2 and γ_2 to be negative and statistically significant. Otherwise, if public information arrivals trigger the information advantage of the informed traders, we expect λ_2, γ_2 to be positive and statistically significant.

To support our hypothesis (2b) that public information arrivals may affect the choice of market orders versus limit orders, if both λ_2 and γ_2 are positive, and γ_2 is larger than λ_2 then the hypothesis that limit orders are more preferable by informed traders is supported. Otherwise, if both λ_2 and γ_2 are positive, and λ_2 is larger than γ_2 then the hypothesis that market orders are more preferable by informed traders is supported.

3.4.3. Public Information and the Volume-Trading Relation

Since the volatility-volume relation may stem from two sources: news as well as not news (differences in opinions, heterogeneous beliefs). To test our hypothesis (3), we follow two-step procedures. We first decompose trading volume into news-related component and no-news related component by regressing the number of share volume on concurrent and lagged news as in the regression (4). The predicted value *(V_{news})* is regarded as news-related trading volume. The residual *(V_{nonews})* is regarded as no-news trading volume. We add twelve lags of news to allow for trading on stale news because of market frictions (Ajinkya and Jain, 1989).

$$V_t = \phi_{i0} News_t + \sum_{k=1}^{12} \phi_k News_{t-k} + \iota_t \qquad (4)$$

In the next step, where we run the following two regressions:

$$|\varepsilon_t| = \alpha_1 V_{news,t} + \alpha_2 V_{nonews,t} + \alpha_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} n_j |\varepsilon_{t-j}| + \zeta_t \quad (5a)$$

$$|\varepsilon_t| = \alpha_1 V_{news,t} + \alpha_2 V_{nonews,t} + \alpha_3 Slope_{t-1} + \alpha_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} n_j |\varepsilon_{t-j}| + \zeta_t \quad (5b)$$

where V is the trading volume measured by the logarithm transformation of the total number of share volume, $|\varepsilon|$ is the price volatility estimated from the regression (1), V_{news} is the news-related component of trading volume, V_{nonews} is the no-news component of trading volume, and *Slope* is the slope of the order book measured by the average of the order book slopes of the demand and supply curve. We include average trade size *AV*, and the lag of price volatility as the control variables for price volatility following Jones et al. (1994). T is the dummy for trading intervals.

Regression (5a) is to see whether the volatility-volume relation is stronger for the news component of trading volume than the no-news component of volume or not. If both α_1 and α_2 to be positive and statistically significant, and if α_1 is greater than α_2, then our hypothesis that the volatility-volume relation in the period having public information arrivals is stronger than the period having no news arrivals is supported.

Regression (5b) is to see whether the stronger relation between volatility and news components of trading volume still holds after controlling for informativeness of the order book slope. Since the order book slope is also one source of public information that might causes price volatility as suggested by Foucault et al. (2007). If we control for the order book slope in (5b), then there may be possibility that the alternative hypothesis holds. In other words, the informativeness of the order book slope reduces the correlation between volatility and news-related trading volume so that this

correlation become smaller compared to the correlation between volatility and no-news trading volume. However, if α_1 is still greater than α_2, then our hypothesis is supported.

To test our hypothesis (4), we follow procedures similarly to the above section. We first decompose the order book slope into news and no-new components by regressing the order book slope on concurrent and lagged news in the regression (6).

$$Slope_t = \phi_{i0} News_t + \sum_{k=1}^{12} \phi_{i,k} News_{t-k} + \xi_t \qquad (6)$$

In the next step, where we run the following two regressions:

$$|\varepsilon_t| = \beta_1 Slope_{news,t} + \beta_2 Slope_{nonews,t} + \beta_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} l_j |\varepsilon_{t-j}| + \xi_{i,t} \qquad (7a)$$

$$|\varepsilon_t| = \beta_1 Slope_{news,t} + \beta_2 Slope_{nonews,t} + \beta_3 V_{t-1} + \beta_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} l_j |\varepsilon_{t-j}| + \xi_{i,t} \qquad (7b)$$

where $Slope_{news}$ is the news-related component of the slope of the order book, which is the predicted value from regression (6), $Slope_{nonews}$ is the no-news component of the slope of the order book, which is the residual value from regression (6), V is the trading volume measured by the logarithm transformation of the total number of share volume, and AV is the average trade size. T is a dummy for time intervals.

Regression (7a) is to see whether the relation between price volatility and the slope of the order book relation is stronger for the news component of the slope compared to the no-news component of the slope. If both β_1 and β_2 to be positive and statistically significant, and if β_1 is more negative than β_2, then the relation between volatility and slope of the order book is stronger in the period having public information arrivals compared to the period having no news arrivals.

Regression (7b) is to see whether the stronger relation between volatility and slope of the order book still holds after controlling for trading volume. Since the trading volume is also one source of public information that might causes price volatility. If we control trading volume in (7b), then there may be possibility that the alternative hypothesis holds. In other words, the informativeness of trading volume reduces the correlation between volatility and news-related slope. However, if β_1 is still more negative than β_2, then our hypothesis is still supported.

4. Results and Discussion

4.1. Descriptive Statistics

The summary statistics are reported in Table 1. Our final sample includes 100 companies with the mean of market capitalisation of AUD 2,429 million, where the first twenty companies dominate the market with the market capitalisation of AUD 11,047 million. The next twenty companies have market capitalisation of AUD 846 million and the smallest group has the mean of AUD 13 million. Our sample thus spans all three categories: large, medium and small firms. Public information has a sample mean of 0.05 with a standard deviation of 0.15 for each trading interval. We find that public information is positively correlated with firm size. The larger the firm is, the more announcements the firm releases. This is consistent with the literature that firm size can be a proxy for information asymmetry. Information asymmetry among market participants is narrower than that for a smaller firm because the information about bigger firms is more frequently released. The number of trades and number of share trading volume has a mean of 22 trades and 106,992 shares for each trading interval, respectively. The pattern of number of trades and share trading volume for five groups show that both number of trades and share trading volume are positively correlated with

firm size. The larger the market capitalisation the firm has, the higher the trading volume that occurs. Trade imbalance has the mean of 0.02, which suggests that more buy market orders than sell market orders over the half-hour trading interval over the study period.

The average order book slope is 21.55 for large cap stocks and declines to 9.5 and 6.75 for medium stocks, and to 3.29 and 1.8 for small cap stocks. The patterns are the same for the slope of the bid side or ask side. The results imply that the larger the stock, the steeper the demand and supply curves in the order book and the smaller the stock, the flatter the demand and supply curves. Intuitively, the order quantities of both buy and sell orders of large cap stocks are very sensitive to stock price changes. Small changes in prices of large cap stocks may result in large changes in order volume. The opposite is held for the small cap stocks, it takes larger movements in stock prices to change the order quantities. Order book imbalance, measured by the slope of the buy side over the sell side of the limit order book, has a mean of 0.49, which suggests that the demand curve has a smaller slope than the supply curve in the order book on average. The statistics also show that the order book of the sell side is 11.84m, which is slightly larger than that of the buy side of 10.64.

We also find that stock price changes and trading activities differ between periods having public information arrivals and those having no arrivals. Share trading volume in news periods has 268,144 shares while in no-news periods has 103,445 shares, which is more than twice as high. The volatility of stock prices stands at 0.0004 and 0.0001 for news and no-new periods, respectively. Furthermore, stock returns, and the slope of the order book and trading imbalance are all larger for news periods compared to no-news periods.

This descriptive statistics provides us preliminary evidence that supports our hypothesis that public information arrivals may affect both direction and magnitude of stock price changes in relation to trading and the state of the limit order book.

4.2. The Return-Order Flow Relation in the Order-Driven Market

Table 2 presents our results of investigating informativeness of order flows over stock returns. The hypothesis is that the order flow, which is measured by the relative order book slope of the bid over the ask sides and trade imbalance, should be informative on the direction of stock price changes or short-term stock returns. Panel A is the result for the entire sample and Panel B is the result for the sample sorted by firm size.

From the Panel A of Table 2, we document strong support for the predictability of the order flows for stock returns over the half-hour trading interval. Specifically, the coefficients for both trade imbalance and order book imbalance that are positive and statistically significant at the 5% level[14] are 70% and 81% of the sample, with mean value of 0.0012 and 0.0354, respectively. This result provides strong evidence that the order flows, measured by both trade imbalance and order book imbalance, convey information about the direction of stock price changes or stock returns. The result implies that informed traders use both market orders and limit orders to exploit their information advantage. This finding is consistent with the evidence documented by Bias et al. (1995), Chan (2000) that signed trade volume conveys information about stock returns. The finding is also similar to the evidence documented by Harris and Panchapagesan (2005), Cao et al. (2009) that order book imbalances in term of order quantities and order prices could predict short-term stock returns.

[14] The discussions of results in this paper are all based on 5% level of significance.

Our result thus offers new evidence that the relative order book slope[15], which is measured either by the slope of the demand curve over the supply curve, or the difference between slopes of the demand curve over the supply curve conveys the information about short-term stock returns. The relative order book slope is a good measure for the order book imbalance because it takes into account the mutual dependence of order prices and order quantities while still captures the information content of imbalances in order quantities and order prices of limit orders.

When comparing both coefficients and percentages of significant coefficients of the order book imbalance and trade imbalance, those of the order book imbalance (0.0354, 81%) are larger than those of the trade imbalance (0.0012, 70%). The result indicates that the order book imbalance is more informative compared to the trade imbalance on short-term stock return. This result suggests not only that informed traders use both market orders and limit orders, but also that informed traders on average use more limit orders than market orders while exploiting their information advantages. This finding supports the later stream of literature Wald and Horrigan (2005), Harris (1998), Bloomfield et al. (2005), Kaniel and Liu (2006), and Rajan et al. (2007) that the limit order book is informative or informed traders submit limit orders more than market orders.

From the Panel B of Table 2, we find that the return-order flow relation differs between large-cap stocks and small-cap stocks, which are shown by differences in coefficients and percentages of significance among five groups. With regard to trade imbalance, the percentage of significant coefficients for the largest firm group is 90%, and decreases gradually to 65% and 40% for the smallest group. It means that the return trade

[15] The result is similarly to both measures: relative order book slope and absolute order book slope of the demand curve over the supply curve; we present only one measure that is the relative slope of the order demand curve over the supply curve.

imbalance relation depends on firm size. The larger the firm is, the stronger the relation between trade imbalance and stock return is, or the better the return predictability of trade imbalance. Because trade imbalance is already standardized, it is supposedly less affected by the total trading activity or the intensity of trading. One explanation for the result is the possibility that informed traders use more market orders in their trades for large-cap stocks than small-cap stocks. Interestingly, the coefficient for trade imbalance for the large-cap stock is 0.0005 while that of the small-cap stock is 0.0031. Thus, coefficients increase as firm size becomes smaller. It shows that the price impact of trade imbalance is larger for smaller firms.

With regard to order book imbalance, we find that the medium stocks have the highest percentage of significant coefficients. The coefficients for group two and group three that are significant are 100% and 95% while those for group one and group four are both 75%, and for group five is 60%. The pattern of significant coefficients of order book imbalance looks the same as trade imbalance, excepting for the largest group. The result suggests that the slope of the order book is more informative on stock return for medium cap stocks. Again, one possible explanation is that informed traders use more limit orders in their trades for medium-cap stocks.

Overall, the results presented in Table 2 support our first hypothesis that the order flows, which are measured by trade imbalance and the relative order book slope of the demand over the supply sides, are informative on the direction of stock price changes or short-term stock returns. The finding also suggest that informed traders use both market orders and limit orders to exploit their information advantages, and that on average, informed traders use more limit orders than market orders. Moreover, we provide new evidence that the limit order book, particularly the relative slope of the demand curve

and the supply curve of the limit order book, conveys the information about the direction of stock price changes or short-term stock returns.

4.3. Public Information Arrivals and the Return-Order Flow Relation

Table 3a and Table 3b present our results of investigating the effects of public information arrivals on the return-order flow relation. Table 3a reports the coefficients of trade imbalance and order book imbalance in the absence of news arrivals. Table 3b reports the coefficients of the interaction between trade imbalance, order imbalance and the dummy news variable. The result in Panel A is for the whole sample and Panel B is for the sample sorted by firm size.

From Panels A and B of Table 3a, we find that the patterns of coefficients of trade imbalance and order book imbalance are similar to the previous section. Specifically, the coefficients of trade imbalance and order book imbalance that are positive and significant are 68% and 80% of our total sample. The results suggest that with or without public information arrivals, trade imbalance and order book imbalance are informative on short-term stock returns. This result provides additional evidence supporting the hypothesis (1) that the order flows is informative on stock returns.

From Panel A and B of Table 3b, we document that in the presence of public information arrivals, order flows or trade imbalance and order book imbalance are more informative on short-term stock returns, and this informativeness of order flows also depend on firm sizes. Specifically, the coefficients of the interaction between trade imbalance, order book imbalance and dummy news that are positive and statistically significant are 72% and 60% of the sample. The implication is that public information arrivals trigger the information advantages of informed traders, and therefore the order flow is more informative on stock returns. This result is consistent with the insights

from the heterogenous beliefs models by Harris and Ravis (1993), Sharen (1993), and superior skills and experiences in extracting public news of informed traders by Kim and Verrecchica (1994, 1997).

We also find that the coefficients of the interactions between trade imbalance, order book imbalance and dummy news that are negative and statistically significant are 9% and 9% of the sample. This result indicates that public information arrivals also dilute the information advantage of informed traders. This result is consistent with the traditional expectation under signalling theory by Spence (1973) that public information arrivals reduce the information asymmetry among traders. Public information arrivals thus induce a homogenous interpretation among traders, and erode the information advantage of the informed trader. However, the proportion of negative and significant coefficients is smaller than that of positive coefficients. It means that the triggered effects outweigh the diluted effects. Public information arrivals are heterogeneously interpreted thus leading to more dispersed views on price formation, which results in higher informativeness of order flows over stock returns. These findings support the hypothesis that public information arrivals trigger the information advantages of informed traders, which results in the more informativeness of order flows over short-term stock returns

From Panel A of Table 3b, when comparing the coefficients of the interactions between news and order imbalance and trade imbalance, the figure offers an interesting interpretation. The percentage of significant coefficients for trade imbalance is 72%, which is higher than that of order imbalance (60%). The coefficient on trade imbalance is 0.0086, which is smaller than that of order imbalance – which is 0.0135. These results suggest that informed traders are more likely to use market orders than limit orders if

that trading period has public information arrivals, which then results in a higher percentage of significant coefficients for trade imbalance than that of order imbalance. However, the price impact of order book imbalance on stock returns is still stronger than that of trade imbalance as evidenced by the higher coefficient of order book imbalance. The result is consistent with the insights from the theoretical models by Harris (1998), Kaniel and Liu (2006) that if the private information soon becomes public (or in the presence of public information arrivals), informed traders are more likely to use market orders to profit on the short-lived private information. The result is also consistent with empirical evidences documented by Yang (2009) with regard to the preference of market orders by informed traders during earning announcement events.

Generally, results presented in table 3a, 3b support the hypothesis that public information arrivals trigger the information advantage of informed traders, and thus order flow becomes more informative on short-term stock returns. Moreover, in the presence of public information arrivals and over a short-term trading interval, informed traders on average are less likely to use market orders to exploit their information advantages.

4.4. The Volatility-Volume, Volatility-Order Book Slope Relations and Public Information

This section presents the results of investigating the effects of public information on the relation between trading volume, price volatility and the slope of the order book. The result in Table 4 is for the volatility-volume relation. The result in Table 5 is for the volatility-slope of the order book relation.

From Panel A of Table 4, we find strong evidence that volatility-volume relation arises from both two sources: public information arrivals and heterogenous beliefs of traders about asset values. Specifically, the number of positive and significant coefficients on

news-related trading volume and no-news trading volume account for 93% and 92% of the sample, respectively. These results support both theoretical hypotheses that the positive relation between trading volume and volatility of stock arises from the arrival of new information under the MDH by Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983), Harris (1986, 1987), and from the dispersion of beliefs by Shalen (1993), Harris and Ravis (1993).

Moreover, when comparing the mean values of these coefficients both with and without controlling for the order book slope, the coefficient of news-related trading volume is 0.0005, which is higher that of no-news trading volume (0.0001). It means that the sensitivity of price volatility to trading volume is higher for news-induced components than no-news components, suggesting that volatility-volume relation is stronger in presence of public information arrivals, even after controlling for additional information of the order book slope.

We also document strong evidence that the slope of the order book is informative on short-term price volatility. Specifically, the coefficient of the order book slope that is negative and statistically significant is 85% of the sample, and having a mean value of -0.0001. The finding supports the theoretical prediction of Foucault et al. (2007) that the order book should contain forward looking information about the price volatility. The result is also consistent with empirical evidence documented by Naes and Skjeltorp (2006), Duong and Kalev (2009) about the negative relation of the order book slope with regard to price volatility.

From Panel B of Table 4, we find that the relationship between trading volume and price volatility becomes stronger as firm size increases. Interestingly, the informativeness of the slope of the order book with regard to price volatility moves

inversely with firm size. The smaller the firm is, the more the information content that the slope of the order book conveys about the price volatility.

Table 5 presents the results in investigating the relation between price volatility and two components of slope of the order book, which are news-induced slope and no-news slope. From Panel A of Table 5, we document new evidence supporting our hypothesis that the correlation between price volatility and the order book slope is negative and statistically significant, and stronger for the news component of the order book slope. Specifically, the coefficient of news-related slope is -0.00115, which is more negative than that of no-news slope which is -0.0008. The results suggest that public information arrivals induce price volatility and reshape the order book. Panel A also shows that the number of the coefficients of no-news components of the slope of the order book that are significant represents around 84% of the whole sample. The results suggest that the shape of the order book arises from both public information arrivals and heterogeneous interpretations and difference in opinions of investors about the asset value. From the Panel B of Table 5, we also find that the correlation between price volatility and the slope of the order book is stronger for smaller firms compared to that of larger firms.

On the whole, the results in Table 4 and Table 5 support our hypothesis that in the presence of public information arrivals, the volatility-volume relation is stronger. The result is consistent with theoretical explanation of the information-based trading hypothesis by the MDH Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983), Harris (1986, 1987) and heterogeneous beliefs by Shalen (1993), Harris and Ravis (1993). Our finding also show consistent evidence with prior studies that the order book slope is negatively correlated with the price volatility in the next trading periods Naes and Skjeltorp (2006), Duong and Kalev (2009). The result also supports that the limit

order book conveys more information about stock price and trading activities than what is publicly available. Particularly, these results further document new evidence that the volatility-slope of the order book relation also arises from two sources public information arrivals and heterogeneous beliefs similarly to volatility-volume relation. Further, the results also evidence that public information increases the volatility-slope of the order book relation.

5. Robustness Check - Causality Relation

A potential problem with our analysis is the causality relation between stock returns, price volatility with the corresponding explanatory variables. This section shows a summary result of these causality tests. With regard to stock returns, table 6 provides the Granger Causality Test for stock returns, trade imbalance and order book imbalance. We mainly find a one-way causality from trade imbalance and order book imbalance to stock returns for three largest groups. The result is consistent with our evidence that both trade imbalance and order book imbalance conveys information about stock returns, especially for large-cap stocks. With regard to price volatility, table 7 provides the Granger Causality Test for price volatility, trading volume, and the slope of the order book. We only find one-way Granger causality from the order book slope to price volatility. However, we find two-way Granger causality for price volatility and trading volume. Overall, our findings and discussion are robust the causality relation between dependent and independent variables.

6. Conclusion

Investigating the informativeness of the public limit order book and the impacts of public information flows on stock price changes is important because it provides insights about how public and private information are incorporated in stock prices. This

paper contributes to the market efficiency research by examining the impacts of public information on the mean and variance of stock price changes via order submission and execution in the ASX. With the mean effect, we examine whether order flows are informative about stock returns and how the public information arrivals affect the informativeness of order flows. Order flows are measured by trade imbalance and the relative slope of the demand curve over that of supply curve of the limit order book. With the variance effect, we examine how public information arrivals affect the relation between price volatility, trading volume and the slope of the limit order book.

We employ company announcements of listed firms released to the ASX as a proxy for public information, and study a sample of 100 firms actively traded on the ASX for the period 2003-2007. Our results show that order flows are informative on short-term stock returns, especially the relative or absolute difference between slope of the demand curve and the supply curve of the order book could predict the direction of stock price changes. We also find public information arrivals increase the informative of order flows. Public information arrivals also result in a stronger relation between price volatility and trading volume, and a stronger relation between price volatility and the order book slope. Overall, our findings are consistent with the literature that the order book is informative on the magnitude of stock price changes or the price volatility. We further contribute to the literature by showing that the order book slope is also informative on the direction of stock price changes or stock returns. Furthermore, our findings suggest that company announcements induce heterogeneous revision of beliefs about the asset values among market participants.

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Appendix 1: Types of News Announcements

Primary Code	Descriptions
01	Takeover announcements
02	Shareholder Details
03	Periodic Reports
04	Quarterly Activity Reports
05	Quarterly Cash flow Reports
06	Issued Capital
07	Asset Acquisition and Disposals
08	Notice of Meeting
09	Stock Exchange Announcements
10	Dividend Announcements
11	Progress Reports
12	Company Admistrations
13	Notice of Call
14	Others
15	Chairman's Address
16	Letter to Shareholders
17	ASX Queries
18	Warrants

Table 1: Descriptive Statistics

This table presents summary statistics of the 100 stocks in this study for each half-hour trading frequency. The sample period is from January 2, 2003 to December 31, 2007. Number of news is the total number of company announcements released to the market. Return is the stock return which is calculated based the difference of logarithm of the mid-quote prices at the end of every half-hour interval. Trading volume is the total number of share volume. Slope is the limit order book slope based on ten best quotes. Relative Slope is the order book imbalance, which is measured by the relative slope of demand side over supply side. Trade Imbalance equals the difference between the buyer-initiated trading volume and the seller-initiated trading volume, which is then scaled by total trading volume of the trading period.

Panel A: Sample Means by Market Capitalisation

Group	1	2	3	4	5
No of obs.	295496	271371	241552	136364	82946
Market Cap.	11047.58	846.12	192.78	45.17	12.63
Total news	0.04	0.02	0.01	0.01	0.01
No of trades	49.63	17.69	10.33	3.82	2.49
Share trading volume	196530.06	64397.66	55934.81	81385.86	118152.06
return	0.00107	0.00068	0.00040	0.00010	0.00004
volatility	0.00005	0.00005	0.00007	0.00025	0.00041
ask slope	21.55	9.50	6.75	3.39	1.86
bid slope	21.37	9.30	6.48	2.98	1.51
order book slope	21.48	9.47	6.69	3.29	1.80
relative slope	0.50	0.49	0.49	0.47	0.45
trade imbalance	0.02	0.03	0.02	0.00	0.03
Spread	0.01	0.02	0.02	0.02	0.01

Panel B: Sample Means by Periods having news and no-news arrivals.

Variable	Sample	No-news Period	News Period
Market cap.	2428.86		
total news	0.02	0.00	1.05
Number of trades	22.08	21.43	51.49
Share Volume	106992.22	103445.94	268144.52
return	0.0006	0.0005	0.0030
volatility	0.0001	0.0001	0.0004
ask slope	11.84	11.69	18.28
bid slope	10.64	10.50	17.03
order book slope	11.78	11.63	18.19
Relative Slope	0.49	0.47	0.48
Trade imbalance	0.02	0.02	0.01
spread	0.01	0.02	0.01

Table 2: Return order flow relation in an order-driven market

This table presents the results of investigating the return order flow relation. The results are obtained from the following empirical regressions:

$$r_t = \lambda TIB_{t-1} + \gamma OIB_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + u_t \quad (2)$$

where r_t is the stock return for stock *i*, at interval *t* after adjusting for the autocorrelation up to 12 steps. TIB_{t-1} is the trade imbalance and OIB_{t-1} is the order book imbalance or the relative order book slope of the demand curve over the supply curve. T_t is the time dummy for twelve trading intervals of one trading day. The model is estimated for stock by stock. Significance is the percentage of stocks in the sample offering the significant coefficient with less than 5% level of significance. The mean coefficients and its *t* statistic, *p* value for trade imbalance and the order book imbalance are then reported. Panel A is for the total sample. Panel B is sorted by market capitalization.

Panel A: Total Sample

Variables	Significance	Coef.	t-stat.	P-value.
TIB_{t-1}	70%	0.0012	3.21	0.02
OIB_{t-1}	81%	0.0354	5.31	0.01

Panel B: Sample by Firm Size

TIB_{t-1}				
Market Cap.				
1 (largest)	90%	0.0005	3.61	0.01
2	85%	0.0005	3.01	0.02
3	70%	0.0009	3.97	0.01
4	65%	0.0021	2.69	0.02
5 (smallest)	40%	0.0031	2.28	0.05
OIB_{t-1}				
Market Cap.				
1 (largest)	75%	0.0073	4.06	0.01
2	100%	0.0138	6.63	0.00
3	95%	0.0281	8.10	0.00
4	75%	0.0617	4.07	0.01
5 (smallest)	60%	0.0822	2.40	0.02

Table 3a: Public Information and the Return Order Flow Relation

This table represents the effects of public information arrivals on the return order flows relation. The results are obtained from the following regression:

$$r_t = (\lambda_1 + \lambda_2 D_{news})TIB_{t-1} + (\gamma_1 + \gamma_2 D_{news})OIB_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + e_t \quad (3)$$

where D_{news} is a dummy variable which is equal to 1 if there are public information arrivals during the previous trading frequency or otherwise 0. TIB_{t-1} is the trade imbalance and OIB_{t-1} is the order book imbalance or the relative order book slope of the demand curve over the supply curve. T_t is the time dummy for twelve trading intervals of one trading day. The model is estimated for stock by stock. Significance is the percentage of stocks in the sample offering the significant coefficient with less than 5% level of significance. The mean coefficients and its *t* statistic, *p* value for trade imbalance and the order book imbalance are then reported. Panel A is for the total sample. Panel B is sorted by market capitalization.

Panel A: Total Sample				
Variables	**Significance**	**Coef.**	**t-stat.**	**P-value.**
TIB_{t-1}	68%	0.0011	3.17	0.02
OIB_{t-1}	80%	0.0361	5.20	0.01
Panel B: Sample by Firm Size				
TIB_{t-1}				
Market Cap.				
1 (largest)	85%	0.0005	3.48	0.01
2	85%	0.0005	2.98	0.02
3	75%	0.0009	3.87	0.01
4	60%	0.0022	2.64	0.02
5 (smallest)	35%	0.0028	2.40	0.03
OIB_{t-1}				
Market Cap.				
1 (largest)	75%	0.0074	4.14	0.00
2	95%	0.0137	6.61	0.00
3	85%	0.0277	8.08	0.00
4	80%	0.0586	3.87	0.01
5 (smallest)	65%	0.0852	2.26	0.02

Table 3b: Public Information and the Return Order Flow Relation

Panel A: Total Sample				
Variables	**Significance**	**Coef.**	**t-stat.**	**P-value.**
TIB_{t-1}*D_{news}				
Positive	72%	0.0086	2.69	0.02
Negative	9%	-0.097	-3.85	0.00
OIB_{t-1}*D_{news}				
Positive	60%	0.0135	2.74	0.03
Negative	9%	-0.0405	-3.59	0.03
Panel B: Sample by Firm Size				
TIB_{t-1}*D_{news} (Positive)				
1 (largest)	80%	0.0023	2.55	0.02
2	90%	0.0030	2.26	0.03
3	70%	0.0082	2.87	0.02
4	75%	0.0213	3.11	0.01
5 (smallest)	45%	0.0116	4.21	0.00
TIB_{t-1}*D_{news} (Negative)				
1 (largest)	0%	-	-	-
2	0%	-	-	-
3	10%	-0.0038	-3.70	0.00
4	10%	-0.0198	-3.72	0.00
5 (smallest)	25%	-0.1538	-3.95	0.01
OIB_{t-1}*D_{news} (Positive)				
1 (largest)	60%	0.0020	2.99	0.03
2	70%	0.0031	2.27	0.03
3	70%	0.0105	2.95	0.03
4	60%	0.0227	2.64	0.04
5 (smallest)	40%	0.0283	2.75	0.02
OIB_{t-1}*D_{news} (Negative)				
1 (largest)	10%	-0.002	-3.00	0.02
2	5%	-0.002	-2.21	0.03
3	5%	-0.004	-3.76	0.00
4	10%	-0.011	-1.69	0.09
5 (smallest)	15%	-0.114	-5.21	0.02

Table 4: The Volatility-Volume Relation and Public Information Arrivals

This table represents the effects of public information arrivals on the relation between trading volume, volatility and the state of the limit order book. The results are obtained from the regressions (4)(5a)(5b). Regression (4) decomposes trading volume into news-related volume by regressing the number of share volume on concurrent and lagged news. The predicted value (V_{news}) is regarded as news-related trading volume and the residuals (V_{nonews}) is regarded as no-news trading volume is used in the regression (5a) and (5b).

$$V_t = \phi_{i0} News_t + \sum_{k=1}^{12} \phi_k News_{t-k} + \iota_t \qquad (4)$$

$$|\varepsilon_t| = \alpha_1 V_{news,t} + \alpha_2 V_{nonews,t} + \alpha_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} n_j |\varepsilon_{t-j}| + \zeta_t \qquad (5a)$$

$$|\varepsilon_t| = \alpha_1 V_{news,t} + \alpha_2 V_{nonews,t} + \alpha_3 Slope_{t-1} + \alpha_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} n_j |\varepsilon_{t-j}| + \zeta_t \qquad (5b)$$

where Slope is the slope of the order book, AV is average trade size AV, T is time dummy for trading intervals. The model is estimated for stock by stock. Significance is the percentage of stocks in the sample offering the significant coefficient with less than 5% level of significance. The mean coefficients and its *t* statistic, *p* value for trade imbalance and the order book imbalance are then reported. Panel A is for the total sample. Panel B is sorted by market capitalization.

Panel A: Total Sample								
	(5a)				**(5b)**			
Variables	**Significance**	**Coef.**	**t-stat.**	**P-value**	**Significance**	**Coef.**	**t-stat.**	**P-value.**
$V_{news,t}$	93%	0.0005	5.38	0.01	90%	0.0005	5.00	0.01
$V_{nonews,t}$	92%	0.0001	8.90	0.00	87%	0.0001	6.89	0.00
$Slope_{t-1}$	-	-	-	-	85%	-0.0001	-4.50	0.01
Panel B: By Firm Size								
$V_{news,t}$								
1 (largest)	100%	0.0023	6.68	0.01	95%	0.0023	6.60	0.01
2	100%	0.0028	5.67	0.01	100%	0.0027	5.03	0.01
3	95%	0.0044	6.46	0.01	95%	0.0038	5.50	0.02
4	95%	0.0082	4.58	0.01	95%	0.0040	3.21	0.03
5 (smallest)	75%	0.0076	2.77	0.00	85%	0.0085	4.14	0.01
$V_{nonews,t}$								
1 (largest)	100%	0.0003	8.25	0.00	95%	0.0003	8.67	0.00
2	100%	0.0003	8.07	0.00	95%	0.0004	8.98	0.00
3	90%	0.0004	9.05	0.00	85%	0.0005	9.79	0.00
4	90%	0.0014	9.63	0.00	85%	0.0014	8.70	0.00
5 (smallest)	80%	0.0025	9.48	0.00	75%	0.0021	7.77	0.00
$Slope_{t-1}$								
1 (largest)	-	-	-	-	75%	-0.0037	-4.20	0.01
2	-	-	-	-	85%	-0.0068	-4.65	0.00
3	-	-	-	-	80%	-0.0594	-5.50	0.00
4	-	-	-	-	95%	-0.1712	-4.19	0.01
5 (smallest)	-	-	-	-	90%	-0.2617	-3.96	0.01

Table 5: The Volatility -Oder Book Slope Relation and Public Information Arrivals

This table represents the effects of public information arrivals on the relation between trading volume, volatility and the state of the limit order book. The results are obtained from the regressions (6)(7a)(7b). Regression (6) decomposes the order book slope into news and no-news components by regressing the slope of the order book on concurrent and lagged news. The predicted value *($Slope_{news}$)* is regarded as news-component of the slope and the residuals *($Slope_{nonews}$)* is regarded as no-news component that are used in the regression (7a) and (7b).

$$Slope_t = \phi_{i0} News_t + \sum_{k=1}^{12} \phi_{i,k} News_{t-k} + \xi_t \quad (6)$$

$$|\varepsilon_t| = \beta_1 Slope_{news,t} + \beta_2 Slope_{nonews,t} + \beta_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} l_j |\varepsilon_{t-j}| + \xi_{i,t} \quad (7a)$$

$$|\varepsilon_t| = \beta_1 Slope_{news,t} + \beta_2 Slope_{nonews,t} + \beta_3 V_{t-1} + \beta_4 AV_{t-1} + \sum_{k=1}^{12} a_k T_{kt} + \sum_{j=1}^{12} l_j |\varepsilon_{t-j}| + \xi_{i,t} \quad (7b)$$

where V is the trading volume measured by the logarithm transformation of the total number of share volume, and AV is the average trade size. T is a dummy for time intervals. The models are estimated for stock by stock. Significance is the percentage of stocks in the sample offering the significant coefficient with less than 5% level of significance. The mean coefficients and its *t* statistic, *p* value for trade imbalance and the order book imbalance are then reported. Panel A is for the total sample. Panel B is sorted by market capitalization.

Panel A: Total Sample								
	(7a)				**(7b)**			
Variables	**Significance**	**Coef.**	**t-stat.**	**P-value**	**Significance**	**Coef.**	**t-stat.**	**P-value.**
$Slope_{news,t}$	74%	-0.0115	-4.31	0.01	73%	-0.0113	-4.11	0.01
$Slope_{nonews,t}$	84%	-0.0008	-4.34	0.01	86%	-0.0007	-4.98	0.00
NTt-1	-	-	-	-	86%	0.0473	7.98	0.00
Panel B: By Firm Size								
$Slope_{news,t}$								
1 (largest)	85%	-0.0120	-8.02	0.01	85%	-0.0112	-7.06	0.00
2	80%	-0.0112	-4.14	0.01	80%	-0.0150	-4.12	0.02
3	85%	-0.2327	-4.96	0.01	85%	-0.2216	-4.79	0.01
4	55%	-0.0961	-1.68	0.02	50%	-0.1281	-1.99	0.01
5 (smallest)	65%	-0.2189	-1.05	0.01	65%	-0.2156	-1.00	0.02
$Slope_{nonews,t}$								
1 (largest)	90%	-0.0033	-4.43	0.01	95%	-0.0040	-5.36	0.01
2	80%	-0.0045	-4.64	0.01	90%	-0.0076	-5.78	0.00
3	80%	-0.0329	-5.13	0.00	80%	-0.0393	-5.92	0.00
4	90%	-0.1123	-3.47	0.01	90%	-0.1071	-3.57	0.01
5 (smallest)	80%	-0.1883	-4.14	0.01	75%	-0.1996	-4.25	0.00
V_{t-1}								
1 (largest)	-	-	-	-	100%	0.0418	12.20	0.00
2	-	-	-	-	100%	0.0333	9.54	0.00
3	-	-	-	-	90%	0.0246	7.57	0.00
4	-	-	-	-	65%	0.0793	4.15	0.00
5 (smallest)	-	-	-	-	75%	0.0727	4.10	0.00

Table 6: Granger Causality Test for return, trade imbalance and order book imbalance

This table provides the results of Granger Causality Test for price volatility, trading volume, and the slope of the order book for the whole sample. The null hypothesis of Test 1 is that return is not Granger-caused by trade imbalance. The null hypothesis of Test 2 is that return is not Granger-caused by the order book imbalance. The null hypothesis of Test 3 is that the order book imbalance is not Granger-caused by return. The null hypothesis of Test 4 is that trading imbalance is not Granger-caused by the return. The null hypothesis of Test 5 is that trading imbalance is not Granger-caused by the order book imbalance. The null hypothesis of Test 6 is that the order book imbalance is not Granger-caused by trading imbalance. Significance is the percentage of stocks in each quintile that rejects the null hypothesis.

Firm size	Tests	Significance	DF	Chi-Sq	P-value.
1 (largest)	1	90%	12	71.14	0.00
1	2	80%	12	45.89	0.02
1	3	20%	12	26.49	0.02
1	4	40%	12	24.17	0.02
1	5	95%	12	60.59	0.00
1	6	85%	12	39.17	0.01
2	1	75%	12	31.56	0.02
2	2	90%	12	50.17	0.00
2	3	10%	12	30.49	0.02
2	4	40%	12	30.51	0.02
2	5	65%	12	48.38	0.01
2	6	60%	12	31.14	0.02
3	1	55%	12	33.45	0.01
3	2	85%	12	65.58	0.00
3	3	30%	12	22.74	0.04
3	4	20%	12	23.79	0.04
3	5	45%	12	41.38	0.02
3	6	20%	12	31.22	0.01
4	1	45%	12	20.59	0.06
4	2	25%	12	64.07	0.00
4	3	10%	12	29.22	0.01
4	4	5%	12	21.94	0.05
4	5	25%	12	26.67	0.04
4	6	20%	12	26.67	0.04
5 (smallest)	1	45%	12	19.45	0.08
5	2	10%	12	40.46	0.00
5	3	10%	12	40.46	0.00
5	4	20%	12	29.81	0.05
5	5	10%	12	23.75	0.02
5	6	30%	12	20.73	0.06

Table 7: Granger Causality Test for Volatility, Trading Volume, Slope of the Order Book.

This table provides the results of Granger Causality Test for price volatility, trading volume, and the slope of the order book for the whole sample. The null hypothesis of Test 1 is that volatility is not Granger-caused by trading volume. The null hypothesis of Test 2 is that volatility is not Granger-caused by the slope of the order book. The null hypothesis of Test 3 is that the slope of the order book is not Granger-caused by the volatility. The null hypothesis of Test 4 is that trading volume is not Granger-caused by the volatility. The null hypothesis of Test 5 is that trading volume is not Granger-caused by the slope of the order book. The null hypothesis of Test 6 is that the slope of the order book is not Granger-caused by trading volume. Significance is the percentage of stocks of the whole sample that rejects the null hypothesis.

Sample

Test	Significance	DF.	Chi-Sq.	P-value.
1	76%	12	148.68	0.01
2	60%	12	31.37	0.03
3	50%	12	36.65	0.01
4	80%	12	93.17	0.01
5	70%	12	134.04	0.00
6	68%	12	87.37	0.01